LogForum

> Scientific Journal of Logistics <

http://www.logforum.net

e-ISSN 1734-459X

Scientific journal, issued quarterly
since 2005

The papers are published in English only, in four issues yearly. The journal is edited in the paper form and also presented on-line (www.logforum.net). Each publication is evaluated (double blind) by at least two independent Reviewers.

The ethical policy of LogForum journal follows the Committee on Publication Ethics (COPE) recommendations.

AIMS AND SCOPE

LogForum is a scientific journal created to be a global forum for an exchange of scientific achievements and implementations in the field of logistics.

The journal publishes reviewed papers, which paid special attention to the most important aspects of logistics, e.g.:

Logistics and Supply Chain Management

1. Sustainable, safe, secure supply chain and logistics processes organization,
2. Technologies, information systems and standards for interconnected logistics,
3. Corridors, hubs and logistics equipment in supply chain management,
4. Packaging, warehousing and transport problems.

Management science - theory and practice

1. Modeling, simulation and optimization of management processes,
2. Specific management solutions in various branches,
3. Logistics and management education.

The journal is tracked by: Web of Science Core Collection - Emerging Sources Citation Index, DOAJ, Business Source Premier (ebsco), Academic Search Complete/Business Source Complete (ebsco) Ulrichs WEB, Primo Central Index, HINARI, J-Gate, Electronic Journals Library (EZB), Scirus, BazEkon, EconBiz , Erih Plus, Socolar (China), ROAD Directory of Open Access scholarly Resources, University of California Libraries, Swiss University Library Network (RERO), Arianta, Baztech, CEJSH, Harvard Libraries, Index Copernicus, Bielefeld Academic Search Engine, Baidu, TRIS (Transportation Research Information Services), Cabell's International.

Contents
Volume 16 2020

Issue 1

January - March 2020

Issue 2

April - June 2020

Issue 3

July - September 2020

Issue 4

October - December 2020

LogForum

> Scientific Journal of Logistics <

2020, 16 (1), 7-13

http://doi.org/10.17270/J.LOG.2020.382

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

ARTIFICIAL NEURAL PSEUDO-NETWORK FOR PRODUCTION CONTROL PURPOSES

Marek Fertsch

Poznań University of Technology, Poznań, **Poland**

ABSTRACT. **Background:** Experience from the implementation of the industry 4.0 concept has proved that the key success factor is the use of techniques and methods of artificial intelligence. One of these techniques is artificial neural networks. The development of artificial neural networks has been taking placefor a long time and has led to a number of important applications of this technique in industrial practice. Along with the development of practical applications, a wide theoretical base has also been created regarding the concepts, tools and principles of using this technique.
Methods: This paper contains an attempt to use the theoretical basis of artificial neural networks to build a specialized tool. This tool is called a pseudo-network. It is based not on the whole of the theory of artificial neural networks but only on the targeted elements selected for it. The selection criterion is the use of an artificial neural pseudo-network to control production.
Results: The paper presents the assumptions of an artificial neural pseudo - network, the architecture of the developed solution and initial experience of using it.
Conclusions: These initial results proved the assumptions made by an author. The architecture of the pseudo-network has been developed. Work to build a system demonstrator representing the artificial neural pseudo - network have been initiated and is still in progress.

Key words: artificial intelligence, neural networks, production control, industry 4.0.

A part of this study was presented as oral presentation at the „8th International Logistics Scientific Conference WSL FORUM 2019" in Poznan (Poland), 18th-19th of November 2019.

INTRODUCTION

Experience from the implementation of the industry 4.0 concept has proved that the key success factor is the use of artificial intelligence tools [Lee et.al 2018]. When considering these artificial intelligence tools, the analogy method seems to be the most common approach. Solutions are developed on the basis of available knowledge and of understanding how a particular system functions. Observing the natural environment is another source of inspiration when searching for new solutions [Bouffanais 2016, Key 2016]. The third source of inspiration in thinking about artificial intelligence tools are abstract concepts in the field of mathematics, sociology or psychology, such as the concept of belonging to a set (group). These have inspired tools based on fuzzy set theory or grey set theory.

Artificial neural networks are one of the groups of artificial intelligence tools. These are information systems that imitate the operation of the human brain. The development of artificial neural networks has been going on for a long time. Networks consist of a number of typical elements, such as: processing elements (neuron analogs), inputs and outputs information, transfer functions,

Citation: *Fertsch M., 2020. Artificial neural pseudo-network for production control purposes. LogForum 16 (1), 7-13, http://doi.org/10.17270/J.LOG.2020.382*

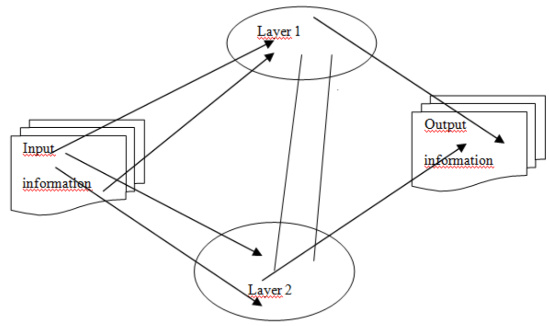
Received: 23.08.2019, Accepted: 04.11.2019, on-line: 30.12.2019.

interconnections of processing elements, network learning principles.

It was quickly noted that artificial neural networks could be used to control processes [Willis et al. 1995]. This research trend still continues [Bouzenad K. and Ramdani M., 2017]. The usefulness of artificial neural networks in production scheduling as well as in tracking and adjusting the production process was also identified quickly [Guillot et al. 1994, Burduk 2017.]. This trend in research also continues and is present in many publications [Zhang et al. 2016]. The experience gained during attempts to use artificial neural networks for production control has modified the general approach to this problem. A mixed approach has appeared, based on combining artificial neural networks with other artificial intelligence techniques (hybrid approach), [Sittisathanchai, Dagli 1993, Lee, Dagli 1997, Massaro et al. 2019] or models of operational research [Foo, Takefuji, 1988]. Research based on this approach is also on-going [Singh et. al. 2019].

The paper presents the concept of an IT system developed for production control in an industrial enterprise that produces complex products under discrete production conditions. The system is part of the production planning and control system. It cooperates with the production planning system from which it periodically downloads the data on production tasks covering the assortment of manufactured products, production programs of individual assortment items, production start and end dates, as well as production updates. In turn, it reports to the production planning subsystem about the progress in implementing the current production tasks. The production planning and control system is a part of the cyber-physical system architecture for Industry 4.0 manufacturing system. It belongs to the cognition level, where it participates in collaborative diagnostics and decision-making functions [Lee et al. 1915, Wong et al. 2018, Rojek 2017].

An essential part of the proposed system is an artificial neural network. Its structure, however, does not correspond to any of the typical artificial neural network architectures presented in the literature. Elements of the system and relations between them have been selected to enable the system to perform production control. The author calls this solution a neural pseudo-network. The architecture of this neural pseudo-network is shown in Figure 1.



Source: own work

Fig. 1. Architecture of artificial neural pseudo–network

Processing elements in both layers of the neural pseudo-network are interconnected:
- via an infrafield connection in the same layer,
- via an interfield connection between processing element in both layers. Processing elements in the first layer are connected with processing elements in the second layer. This type of connection is unidirectional.

The proposed pseudo-network operates on the basis of the self-organizing map model. Cheung [Cheung 1994] suggested the possibility of using this model to solve production control problems. The self - organizing map includes an array of inputs with numerous connections to the processing layer. Every input element is connected to the processing layer through a localization function represented by the lateral connection weights.

The pseudo–network developed here consists of two layers of processing elements. The first one maps the production task, monitors the progress of its execution, and determines the order for performing all the technological operations comprising the production task. The second layer assigns technological operations to the work stations in the production system, and tracks and analyses the state of the production system.

The IT system based on the proposed architecture builds a schedule of produced elements that constitute a production task on an ongoing basis. It also has the feature of a smart system - the ability to create a virtual copy (digital twin) of physical reality and the ability to act autonomously until the situation requires no intervention from a higher level of management. Adding to this interoperability (the ability of machines, devices, products and services and people to communicate with each other) results in defining a system capable of operating in the architecture of cyber-physical systems for Industry 4.0 manufacturing systems.

This paper presents the architecture of the first network, its elements and operating principles. It also presents the results obtained when testing the network prototype.

INPUT INFORMATION TO THE FIRST LAYER

The first Layer 1 maps the production task, monitors the progress of its execution, and determines the order for performing all the technological operations comprising the production task.

The matrix describing technological processes

The matrix will contain descriptions of the technological processes of elements manufactured in the production system. The matrix is presented below in the form of a table.

Table 1. The matrix describing technological processes

Nr	Element ID	Operation number O	Σt_j	β
		Workstation ID		
		t_j operating time		

Source: own work

The elements in the table are ordered:

- by number of operations - from max to min
- if these are identical - by Σt_j value i.e. from max to min
- if the previous two criteria are identical - according to the value of the identifier - from max to min.

In the matrix of the description of technological processes there is also β - identifier of the possibility of starting a given operation, which takes either the value β = 1, when the operation is possible within the time limit or β = 0 in the opposite case.

The purpose of the matrix describing the technological processes of the elements produced in the production system is to provide data for calculations carried out by the processing layer, which calculates (dynamically modifies) the localization function and the lateral connection weights.

The matrix describing a production task to be carried out in the planning horizon

The matrix will present a description of the production task to be carried out in the given planning horizon. On the lines there are individual elements planned for execution in the given planning horizon, and in the columns, individual planning orders (parts of elements) are presented. Elements in the matrix will be ordered corresponding to the modified order in the matrix describing technological processes.

The elements in the table 2 are ordered:

- by number of operations - from max to min
- if these are identical - by Σt_j value i.e. from max to min
- if the previous two criteria are identical, according to the size of the production program, which is the sum of the size of individual orders, from max to min.

The matrix is presented below in Table 2.

Table 2. Matrix presenting a description of the production task planned to be carried out in the given planning horizon

Nr	Element ID	order number N		$P_{p.}$
			n_o	
			t_r	
			t_z	

Source: own work

The data in the matrix describing the production task in the columns concerning individual production orders are taken from the MRP module of the ERP system:

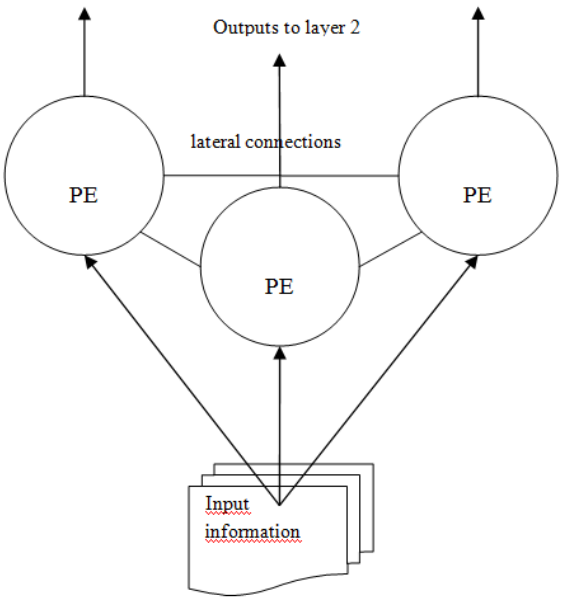
- n_o - size of the production order
- t_r - start date, the moment when task is launched
- t_z - end date., the moment when task is finished

The order numbers are assigned consecutively, according to the start date - from the earliest to the most recent.

The size of the production program given in the last column of the matrix for a given element is the sum of the individual sizes of the production tasks: $P_p = \Sigma n_o$.

OPERATION OF THE FIRST LAYER

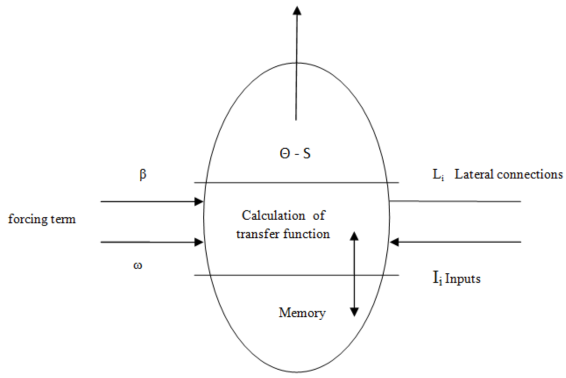
Architecture of the first layer is shown in figure 2. The first layer consists of processing elements (analogs of biological neurons). The number of processing elements in this layer corresponds to the number of orders numbers.



Source: own work

Fig. 2. Architecture of the first layer of the neural pseudo–network

The processing element in layer 1 is shown in Figure 3.



Source: own work

Fig. 3. Processing element in layer 1

Each processing element in the first layer has two extra inputs (forcing term):

- β = 1 when the realization of the technological operation is possible at the given moment or β = 0 in the opposite case
- ω = 1 when the processing element has been selected or ω = 0 in the opposite case.

Inputs to processing elements in the first layer are:

- $I_{1-\tau}$ = te-ts for each order number,
- I_2 –operation number O,
- I_3 - lateral connection - infrafield connection in the same layer. These have a value of 1 or 0,
- I_4 - memory value of processing elements,
- $I_5 = \beta$.

The transfer function is the mechanism of translating inputs signals to an output signal. In a pseudo-network it is a linear function calculated according to the formula [1].

$$S = \sum Ii \qquad [1]$$

where i Є <1;5>.

The first layer of the pseudo-network works according to "the winner takes everything" principle, which means that at each step of the network's operation only one neuron with the highest value of transfer function is active.

The output value is calculated according to the following rules:

– in the case when S > θ and β = 1 and ω = 0, then for the maximum value of S - Θ output the value is {N, O}- two-element set of information,
  L - lateral connection value = 1, the value of memory for all remaining processing elements is increased by 0.5 (competitive learning).
– in the case when S > θ and β = 0 and ω = 0, then the processing element is not active,
– in the case when S < θ and β = 1 and ω = 0, then the processing element is not active,
– in the case when S > θ and β = 0 or 1 and ω = 1, then for the maximum value of S - Θ output is {N, O}, lateral connection value = 1, the value of memory for all other processing elements is increased by 0.5 (competitive learning).
– threshold value θ is calculated from formula 2.

$$\Theta = \tau + N \qquad [2]$$

For each activity of a given neuron, this value is calculated according to formula 3.

$$\Theta = \Theta + 1 \qquad [3].$$

EXAMPLE OF THE FIRST LAYER OPERATION

The operation of the first layer of the network was tested on data from technological processes of eight randomly selected elements. The test results are presented in Table 3.

Table 3. Ranges of parameters used in computational experiments

N	1	2	3	4	5	6	7	8	F	KR	
O	4	4	4	3	3	3	2	1	-		
τ	5	6	5	4	6	6	7	3			
θ	6	8	8	8	11	12	14	11			
S	7	8	7	6	8	8	9	5			
S- θ	1	-	-	-	-	-	-	-	1	N 1	S- θ max
L/M	-/-	1/ 0	1/0	1/0	1/ 0	1/0	1/ 0	1/ 0			
θ	7	8	8	8	11	12	14	11			
S	8	9	8	7	9	9	10	6			
S- θ	1	1	-	-	-	-	-	-	2	N 2	ω = 1
L/M	1/-	-/ .5	1/.5	1/.5	1/ .5	1/.5	1/ .5	1/ .5			
θ	7	9	8	8	11	12	14	11			
S	9	9.5	8.5	7.5	9.5	9.5	10.5	6.5			
S- θ	2	.5	.5	-	-	-	-	-	3	N 1	S- θ max
L/M	-/ .5	1/ 1	1/ 1	1 / 1	1 / 1	1 / 1	1/ 1	1/ 1			
θ	8	9	8	8	11	12	14	11			
S	9.5	11	9	8	10	10	11	7			
S- θ	1.5	2	1	-	-	-	-	-	4	N 2	S- θ max
L/M	1/ .5	- / 1.5	1/ 1.5	1/ 1.5	1/ 1.5	1/ 1.5	1/ 1.5	1/ 1.5			

Source: own work

CONCLUSIONS

The preliminary results confirm the assumptions made by the author and presented in this paper. A concept for a production control IT system has been developed with a new approach by combining selected elements of the theory of artificial neural networks with other components. The fundamental component of the system developed is an artificial neural pseudo-network. The architecture of the pseudo-network has been developed. It consists of two cooperating layers of processing elements (artificial pseudo-neurons). The operating principles of the first layer of the pseudo-network have already been developed and tested. The results obtained confirmed the assumptions made. Work on building a system demonstrator representing the new concept has been initiated. This demonstrator is to be based on IT systems required by the concept of Industry 4.0 and to simulate the work of a production planner, and moreover, if necessary, support problem-solving in the production control area. The functional features of such an IT system combining elements of artificial intelligence tools with knowledge of the principles of production control are currently difficult to determine. This work is still in progress.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The research was financed from the statutory research on topic no. 11/140/DSPB/4163 of the Faculty of Engineering Management at the Poznań University of Technology.

REFERENCES

Bouzenad K., Ramdani M., 2017. Multivariate Statistical Process Control Using Enhanced Bottleneck Neural Network, Algorithms, 2017, 10(2), 49; http://doi.org/10.3390/a10020049

Bouffanais R.,2016. Design and Control of Swarm Dynamics, Springer Briefs in Complexity. Springer Singapore, 2016.

Burduk A., 2017. Artificial Neural Networks as Tools for Controlling Production Systems and EnsuringTheir Stability. 12th International Conference on Information Systems and Industrial Management (CISIM), Sep 2013, Krakow, Poland. 487-498, HAL Id: hal-01496094, https://hal.inria.fr/hal-01496094 Submitted on 27 Mar 2017.

Cheung J.Y., Scheduling, [in:] Dagli C.H. (ed.) Artificial Neural Networks for Intelligent Manufacturing, Chapman & Hall, London, 1994.

Foo S.Y, Takefuji T, 1988. Integer Linear Programming Neural Networks for Job-Shop Scheduling, IEEE International Conference on Neural Networks.

Guillot M., Azouzi R., Cote M., 1944. Process Monitoring and Control, [in:] Dagli C.H. (ed.) Artificial Neural Networks for Intelligent Manufacturing, Chapman & Hall, London, 1994.

Key J.W., 2016. Neural networks in process control: Neural network architecture, controls , February 26, 2016, Control Engineering, https://www.controleng.com/articles/neural-networks-in-process-control-neural-network-architecture-controls/

Lee J., Bagheri B., Kao H., 2015. A Cyber – Physical Systems architecture for Industry 4.0 – based Manufacturing Systems., Manufacturing Letters, 3, 18-23.

Lee Y., Davari H., Singh J., Pandhare V., 2018. Industrial Artificial Intelligence for Industry 4.0 Based Manufacturing Systems, Manufacturing Letters, Volume 18, 20-23.

Lee H.C., Dagli C.H., 1997. A Parallel Genetic-neuro Scheduler for Job Shop Scheduling Problems, International Journal for Production Economics, 51 (1-2), 115–122.

Massaro A., Manfredonia I., Galiano A., Xhahysa B., 2019. Advanced Process Defect Monitoring Model and Prediction Improvement by Artificial Neural Network in Kitchen Manufacturing Industry: a Case of Study, 2019 II Workshop on Metrology for Industry 4.0 and IoT (MetroInd4.0&IoT), 12 August 2019, http://doi.org/10.1109/METROI4.2019.8792872

Rojek I., 2017. Technological process planning by the use of neural networks, AI EDAM, 31, 1. http://doi.org/10.1017/S0890060416000147

Singh P., Dwivedi P., Kant V., 2019. A hybrid method based on neural network and improved environmental adaptation method using Controlled Gaussian Mutation with real parameter for short-term load forecasting, Energy, Volume 174, 2019, 460-477. http://doi.org/10.1016/j.energy.2019.02.141

Sittisathanchai S., Dagli C.H.,, 1993. Genetic Neuro-Scheduler for Job Shop Scheduling, Computers and Industrial Engineering, 25,1993, 267-270.

Willis M.J, Montague G.A., Peel C., 1995. On the Application of Artificial Neural Networks to Process Control, [in:] Murray A.F. (ed.), Application of Neural Networks, Kluwer Akademic Publishers, Boston, Dordrecht, London, 1995.

Wong W.C., Chee E., Li J., Wang X., 2018. Recurrent Neural Network-Based Model Predictive Control for Continuous Pharmaceutical Manufacturing, Mathematics 2018, 6, 242, http://doi.org/10.3390/math6110242

Zhang J., Wang J., Qin W., 2016. Artificial Neural Networks in Production Scheduling and Yield Prediction of Semiconductor Wafer Fabrication System, [in:] Garcia Rosa J., L., [ed.]. Artificial Neural Networks. Models and Applications, Intech Open, Published: October 2016, http://doi.org/10.5772/61493

SZTUCZNA PSEUDOSIEĆ NEURONOWA W STEROWANIU PRODUKCJĄ

STRESZCZENIE. **Wstęp:** Doświadczenia z wdrażania koncepcji Industrie 4.0 wskazują, że kluczowym czynniku sukcesu jest stosowanie metod i technik z zakresu sztucznej inteligencji. Jedną z tych technik są sztuczne sieci neuronowe. Rozwój sztucznych sieci neuronowych trwa od długiego czasu i doprowadził do wielu istotnych zastosowań tej techniki w praktyce przemysłowej. Równolegle z rozwojem zastosowań praktycznych stworzona została baza teoretyczna koncepcji, narzędzi i zasad stosowania tej techniki.
Metody: Artykuł ten zawiera próbę wykorzystania teoretycznej bazy sztucznych sieci neuronowych do stworzenia specjalnego narzędzia. Nosi ono nazwę sztucznej pseudo - sieci neuronowej. Opiera się ona nie na całości dorobku teorii sztucznych sieci neuronowych ale na celowo wybranych jego elementach. Kryterium doboru było zastosowanie sztucznej pseudo-sieci neuronowej do sterowania produkcji.
Wyniki: Artykuł przedstawia założenia do opracowania sztucznej pseudo-sieci neuronowej, architekturę opracowanego rozwiązania i wstępne doświadczenia z prób jego zastosowania.
Wnioski: Wstępne wyniki potwierdziły założenia przyjęte przez autora artykułu. Opracowana została architektura sztucznej pseudo - sieci neuronowej. Zapoczątkowane zostały pracy nad budową demonstratora sztucznej pseudo-sieci neuronowej. Prace trwają nadal.

Słowa kluczowe: sztuczna inteligencja, sieci neuronowe, kontrola produkcji, Industry 4.0

Marek Fertsch ORCID ID: https://orcid.org/0000-0001-8438-7975
Poznan University of Technology
Faculty of Engineering Management
Poznań, **Poland**
e-mail: marek.fertsch@put.poznan.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (1), 15-31

http://doi.org/10.17270/J.LOG.2020.375

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

THE IMPACT OF CONCENTRATED LEVERAGE AND OWNERSHIP ON FIRM PERFORMANCE: A CASE IN PAKISTAN

Marriam Rao, Ambreen Khursheed, Faisal Mustafa

UCP Business School, Lahore, **Pakistan**

ABSTRACT. **Background:** The objective of this study is to determine the impact of concentrated leverage and ownership (high levels of control and power) on firm performance in the case of Pakistan's logistics sector separately in the presence and absence of growth options available to the firm. Both leverage and ownership concentration can have a significant influence on firm performance in either a positive or a negative way.

Methods: In the data sample of this study, 141 companies in Pakistan listed on the Karachi Stock Exchange were selected with a study window from 2008 to 2018. The selection criteria for our sample study are based on firms with the highest market capitalization. Using a Panel based regression methodology, Generalized Methods of Estimating Equations are applied, which cover for 1st and 2nd order serial correlation and controls for endogeneity and autocorrelation problems.

Results: The overall results indicate that the availability and non-availability of growth options to firms are very important factors in analyzing ownership concentration and debt influence on firm performance. This paper takes growth option availability and non-availability as dummy variables and finds that in the presence of growth options, non-linear relations are found between firm performance and ownership concentration and positive significant relations of debt with firm performance. Whereas, in the absence of growth opportunities, inverse parabola relations are depicted of ownership concentration and firm performance, and negative relations between debt and firm performance.

Conclusions: Financial leverage represents a two part structure, negative in the presence of growth options and positive in the absence of growth options. The study demonstrates that high levels of power concentrated in the hands of owners leads to a convergence and entrenchment effect depicting non-linear relations with financial performance in both the availability and non-availability of growth options. Furthermore, the study also revealed that the explanatory power of results with a sales rate of growth (as a growth options measurement proxy) is higher than the Price to Earnings Ratio measurement proxy.

Key words: growth opportunities, leverage, ownership concentration, firm value, underinvestment, overinvestment, Pakistan.

INTRODUCTION

The influence of concentrated leverage and ownership on firm performance has been a common topic for both academics and practitioners. In a frictionless world, both leverage and dividend policies are irrelevant as they do not alter the set of firm investment opportunities [Miller, Modigliani 1961]. However, conversely, when imperfections are included, this irrelevance proposition does not hold for long. Nowadays, lots of important research can be found on the influence of corporate leverage policy decisions on firm value creation [Barclay, Smith 1996, Mustafa et al. 2018, Khan et al. 2018]. Similarly, power and control in higher and lower management, in contrast to owners, also contribute to firm performance levels. The availability of firm investment opportunities (growth options) is found to have a strong influence on the alteration of corporate leverage policies [Wu, 2004]. Financial leverage presents a two part impact in the presence and absence of growth opportunities available to a firm. In the

Citation: Rao M., Khursheed A., Mustafa F., 2020. Impact of Leverage and Ownership Concentration on the Firms' Performance: A Case of Pakistan. LogForum 16 (1), 15-31, http://doi.org/10.17270/J.LOG.2020.375

Received: 25.07.2019, Accepted: 02.10.2019, on-line: 30.12.2019.

presence of growth opportunities, leverage has a negative impact on firm value due to a rise in underinvestment costs [Barclay et al. 2003]. Managers of firms who have high debt ratios and positive NPV projects available are more likely to forgo positive NPV projects if project earnings move into the hands of bondholders [Li, Cui 2003]. When good investment projects are not available, that is, in the absence of growth opportunities, leverage plays a positive role in the reduction of overinvestment costs by limiting the access of managers to the misuse of free cash flows in poor net present value projects [Bougatef, Chichti 2011].

Ownership concentration represents the proportion of shareholdings held by the majority shareholders. In this study, the proportion of shares held by the top one and the top five majority shareholders was taken to analyze the direct effects on firm performance. The higher the ownership concentration, the greater the extent of the owners would be to control and monitor managers in order to increase the firm's performance [Gursoy, Aydogan 2002]. Literature supports the positive effects of ownership concentration on firm performance. However, in addition to ownership concentration as an independent variable, this study also employs squares of ownership concentration. This leads to the fact that, no matter whether ownership concentration has a positive effect on firm value, if the concentration is squared, a negative impact on the firm's value occurs because of an excessive increase in the concentration of control in the hands of the owners, which leads to an entrenchment effect [Dyck, Zingales 2004]. With respect to growth options, in the presence of growth opportunities, non-linear effects of ownership concentration are found. At first, the relationship is positive with initial levels of concentration due to an alignment of interests between managers and owners due to increased control mechanisms, but negative with the concentration square (more than a threshold) variable, which means that too much power in the hands of owners leads to an entrenchment effect [Miguel et al. 2004, Pindado et al. 2008, Filatotchev et al. 2007]. In the absence of growth opportunities, ownership concentration has an inverse non-linear effect on firm value. This is because, in Pakistani firms with poor investment growth options, concentrated owner investments are diversified. Therefore, large controlling shareholders try to extract corporate resources if they do not expect high investment returns from firms with poor investment opportunities, and try to gain from firms with positive investment projects available [Demsetz, Villalonga 2001; Joh 2003]. Therefore, concentrated owners hedge their investment returns from the poor and high investment opportunities available. Ownership concentration square has a positive effect on firm value in the absence of growth options. This is because of the poor investment projects available, and their investment in particular firms becoming too high that they try to increase the value of the firm with control mechanisms to increase their wealth. In Pakistan, work was found by Javid, Iqbal [2008] who studies the relationships between corporate governance, firm value and its ownership structure. These things provide evidence that, in Pakistan, large firms with investment opportunities have adopted better governance structures to reduce agency conflicts, whereas the presence of good investment opportunities results in more highly concentrated ownership. Similarly, Din, Javid [2011] analyzed the impact of the family ownership structure on firm performance, where the performance level of a firm is measured by ROE, ROA and Tobin's Q. A Linear regression model is used for estimation where their results revealed a positive relationship between the concentration of family ownership and firm performance up to an optimal level, after which it began to decline with a negative relation. Overall, this implies the importance of studying the relationships between all these topics together. A joint relationship effect exists between investment opportunities, firm value, and corporate leverage policies and ownership control which holds when firms face positive NPV projects that is availability of growth opportunities and when they do not.

The study contributes in multiple ways; firstly, although there is similar research for countries with developed capital markets, the evidence from underdeveloped markets is still scarce and is absent in Pakistan. Secondly, immense research can be found on the influence of corporate leverage on firm performance, but little work can be found on determining how the availability and non-availability of growth opportunities directly alters firm important corporate leverage structure decisions, especially in firms with concentrated ownership. Thirdly, the study helps management to build financial policies with objectives of the maximization of firm long-term performance differently in the presence of good investment projects (availability of growth options) and differently in the absence of investment options (non-availability of growth options). Furthermore, in order to measure growth options, this study contributes a comparison between Price Earnings Ratio and Sales Rate of Growth as the growth options measurement proxy of the firm. The comparison contributes to revealing which measurement proxy revealed the highest explanatory power of results. The objective of this study is to analyze the interrelationship between corporate leverage policies, ownership control and firm performance in the presence and absence of good investment opportunities. This study used a sample of 141 non-financial Pakistani firms listed from 2008-2018 on te Karachi Stock Exchange to examine how leverage and ownership concentration affect firm value based on the availability of growth opportunities. In order to control for heterogeneity and biased results, the firm's control variables are also included. These include asset tangibility, dividend policies, depreciation, size and profitability.

The rest of this paper is structured as follows: The second part provides a framework of theoretical background and evidence based on relationships between firm financial decisions, ownership concentration and firm performance with respect to the availability of growth opportunities. The third part documents research design and methodology, while the fourth part presents results and empirical findings. The final part consists of conclusions, recommendations and limitations.

LITERATURE REVIEW

Leverage and Growth opportunities

A theoretical background provides evidence on the importance and influence of corporate financial decisions and ownership concentration on firm performance. Therefore, to shed light on how the availability of growth opportunities can cause conflicts of interest between managers and shareholders, the role of debt, dividends and ownership concentration is reviewed via studies of research both in the absence and in the presence of growth opportunities. Ndubuisi et al., [2019] selected data form 2000-2015 for the examination of a leverage effect on firm growth in the stock market of Nigeria. They chose the panel data regression model, along with the fixed effect model, pooled regression model and the random effect model. According to their research, financial leverage shows a significant positive effect on the profit growth of firms. López-de-Foronda [2019] worked on the examination of corporate leverage on firm overinvestment along with the analysis of system liquidity. They used the data of 124,000 companies for the sample years 2003-2014. They found a significant positive relation between corporate leverage and overinvestment.

Iqbal and Usman [2018] worked on 5-year data of the Pakistan stock exchange from 2011-2015 for the examination of leverage impact on firm performance. They used descriptive analysis and correlation analysis along with regression to depict the conclusion of their selected data. The results showed a significant negative effect of financial leverage on firm ROE, whereas there is a significant positive effect of financial leverage on firm ROA. The high rate of interest, along with more debt contributes to lowering the firm's value and has a negative impact on firm performance. In addition, debt has a positive effect on firm performance and ROA when it doesn't become more than the value of equity.

Hamouri [2018] worked on Amman stock markets to determine the impact of financial leverage on firm growth opportunities. They analyzed a sample consisting of 91 firms for their research work by using the panel data regression method. The results showed an insignificance between the financial leverage and growth of assets of a firm. In contrast, growth of sales is positively correlated with the size of a firm. Farrukh et al. [2017] selected the Pakistan stock market for determining the impact of dividend policy on shareholder wealth and firm performance. Dividend policy showed a significant positive impact on shareholder wealth and firm performance with regression results in the emerging market of Pakistan. It suggested that the implementation of effective, stable and target oriented dividend policies, along with a well supervised framework would be helpful in increasing shareholder wealth and firm performance in Pakistan. Rahman [2017] selected the Bangladesh stock market for his research in order to determine the impact of financial leverage on firm market value and also to enrich his research work with an analysis of Tobin's Q ratio. He wanted to investigate the effects of financial leverage on both firm market value and on Tobin's Q ratio on the Bangladesh stock exchange with sample data of a 20-year period from 1996-2015. According to his results, MV/BV ratio showed a negative relationship with firm leverage.

Ishari and Abeyrathna [2016] did 50 observations of the selected data of ten companies on the Sri Lanka stock exchange for the sample years 2011-2015. Regression analysis, descriptive analysis and Pearson's correlation were used in this work. The results revealed a significant relation between debt equity ratio and ROA. However, according to Pearson's correlation, a weak negative relationship, and not a significant one, was found between debt equity ratio and ROA. Furthermore, this study suggested the need for more empirical studies to investigate how financial leverage might impact firm value.

De Jong and Van Dijk [2007] examined the relation between leverage and four agency problems i.e. asset substitution, wealth transfers, overinvestment and underinvestment. Using structural equations models with sample data from non-financial, listed Dutch firms for a period from 1992 to 1997, the simultaneous nature of the relationship was tested between leverage and Tobin's Q (firm performance measure). Overinvestment behavior was explicitly tested by measuring the excess investment and its determinant as leverage. The result confirmed a significant negative effect of leverage on Tobin's Q. The determinants of the investment results showed that leverage reduces investment. However, in determinants of leverage for Dutch firms, low leverage was found for overinvestment firms i.e. the firms with high free cash flows and low Tobin's Q.

Ghalandari [2013] worked on Tehran security exchanges for the examination of moderating the effects of growth opportunities on the relationship between ownership structure and financial decisions, including dividend policies and capital structure, with firm value. He selected 121 firms for investigation for the sample period of 2007 to 2011. He concluded that there is a positive relationship between leverage and dividend and firm value. This relation shows a significant and negative effect with growth opportunities. In contrast, it shows a positive and significant effect without growth opportunities. Ownership structure and the value of a firm have a non-linear significant relation when investment opportunities exhibit a significant impact on this relationship. Alonso et al. [2005] give an insight into the joint effects of leverage, dividends and ownership concentration effects on the value of a firm in the presence and absence of growth opportunities. With 101 samples of non-financial Spanish firms from 1991 to 1995, multivariate regression analysis was applied, indicating the dual role of leverage and dividends pay-outs, conditional on the absence and presence of growth opportunities. This study provides evidence for the positive effects of leverage and dividends in the absence of growth opportunities and negative effects in the presence of growth opportunities. Furthermore, it also reveals how different majority controlled shareholders (institutional, family and financial intermediaries) influence firm value with a majority ownership concentration. The results illustrate that firm value is higher if the majority shareholder is a bank or any other financial intermediary. Barclay et al. [2003] found that the underinvestment costs of debt increase with additional growth opportunities using compustat data of US companies for a period from 1950 to 1999 with 109,000 firm year observations. The results indicate that, with increased growth opportunities, not only does firm leverage decline, but its optimal debt level also decreases. It presents a negative relationship between book leverage and growth options.

Iturriaga and Crisostomo [2010] did research work on the influence of leverage, dividend pay-out and ownership concentration on firm value creation in the Brazilian market. They used the data of 213 firms with sample years 1995-2014. The results showed that leverage possesses a dual character. It shows a positive relation with firm value in the absence of growth opportunities (overinvestment). Whereas, it shows a negative relation with firm value in the presence of growth opportunities (underinvestment). Dividend exhibits a disciplinary role in firms with fewer growth opportunities as it helps in the reduction of free cash flow under managerial controls. The ownership structure showed a non-linear effect with firm value in the Brazilian market.

Lyandres and Zhdanov [2005] found that, besides underinvestment, there exists an opposite effect of overinvestment which significantly dominates underinvestment effects in their data. With application of a generalized method of moments in 52 years of Compustat data, the results indicate a non-linear relationship with firm investment policies. They illustrate that there exists an optimal point of leverage as well as a level of investment beyond which overinvestment takes place and before underinvestment takes place. Secondly, they also examine the role of debt in changes in the intensity of firm investment provided with high and low growth opportunities where they demonstrate an overinvestment role to be more severely played rather than an underinvestment one. Johnsons [2003] investigates simultaneous equations of models with leverage and debt maturity structure on growth options. Sample data includes non-financial Compustat firms from 1986 to 1995. It indicates the positive impact of use of short-term debt on growth options, implying that short-term debt reduces the negative effects of growth opportunities on leverage. The results indicate that firms that use short-term debt reduce the negative effects of growth opportunities on leverage by six times compared to firms that use long-term debt. However, short-term debt also causes a liquidity risk for firms. It provides evidence that firm trade-off between underinvestment costs and liquidity risk increases the value of the firm.

Wu [2004] analyzed the role of growth opportunities, free cash flow and ownership structure on corporate financial policy decisions. With leverage as a dependent variable, OLS regression of Japanese firms was estimated from 1992 to 2000. The results provide evidence that leverage has a positive impact on free cash flow, whereas, when considered growth opportunities is a dummy variable, leverage shows positive behavior in low growth opportunity firms and negative behavior with high growth opportunity firms. D'Mello and Miranda [2010] analyzed the effects of long-term debt behavior on the degree of firm overinvestment. They examined overinvestment patterns with new debt issues by unlevered firms. With a sample of 366 debt issues from 1968 to 2001 for unlevered firms, the results indicate that high debt issues lead to decreased overinvestment. This relation is found to be more significant for firms with low growth opportunities, indicating a positive role of debt with high agency problems and low investment firms. Dang [2011] examined the influence of the relationship between investment decisions and the presence of conflicts of interest incentive problems on corporate financing decisions. With a system-based panel approach towards UK firms from 1996 to 2003, the findings showed that a reduction of leverage in high growth firms controlled underinvestment problems. However, this study contributes more with the inclusion of debt maturity in the model. It shows a positive relationship between debt maturity and leverage due to the presence of high liquidity risk, and a positive relationship of debt maturity and firm value. It also supports the positive role of leverage on controlling the overinvestment process.

Ownership Concentration and Growth Opportunities

In determining how to increase firm performance with maximization of shareholder wealth, debt and dividends are not the only mechanisms that influence firm investment opportunities. It also highly depends on how firm control mechanisms are defined. In

Pakistan, mostly family-oriented business structures exist, as along with a poor corporate governance system and a lack of legal protection for investors. This highlights the importance of the impact of ownership concentration on firm value in the absence and presence of growth opportunities shedding light on the problem of agency costs.

Ciftci et al., [2019] analyzed the relationship between firm performance and internal corporate governance by considering firms operating in Turkey. They found that concentrated ownership in family-based firms leads to better performance and better control. Similarly, Wu [2019] examined internationalization performance by analyzing a sample of 217 firms operating in China from 2009 to 2016. By using fixed-effect regression, the study found that the performance of non-state-owned firms is positively increased by increasing short-term loans. However, Abdullah et al. [2019] provide a seminal study regarding the impact of owner concentration on a firms' performance by analyzing 36 listed firms on the Karachi stock exchange (KSE) from 2007 to 2011. They applied correlation matrix and regression models. They found significant and negative effects of family-based owner concentration on return on assets (ROA) and a negative effect of non-family-based owner concentration on ROA. Likewise, Saidat et al. [2019] have studied the relationship between the financial performance of firms (family based and non-family based) and corporate governance. They analyzed a sample of non-financial firms listed on the Amman Stock Exchange (ASE) from 2009-2015. They found ROA and Tobin's Q share a negative effect on the family firms' performance and found no relationship between non-family firms. Furthermore, Ahmad et al. (2019) explored the effect of institutional ownership on the performance of non-financial firms in Pakistan for a period from 2007 to 2011. They used the ordinary least square model for estimating the link between variables. They found negative effects of ROA on institutional ownership.

Zraiq and Fadzil [2018] researched the effect of ownership structures on the performance of firms in Jordan. Their sample data was comprised of 228 firms, including industrial and service sectors. They reported a significant positive relationship between ownership concentration and firm performance. Yasser and Mamun [2017] studied the impact of ownership concentration on firm performance in the emerging market of Pakistan. Their research analysis was linked among eight categories, Gini index, Hirschman–Herfindahl index (HHI) and firm performance in the developing stock market of Pakistan. In the results, the ownership structure exhibited a positive relationship in both economic profits and market-based performance measures. Also, the contribution of institutional shareholders and foreign shareholders shows a positive relationship with firm performance. Najjar [2016] investigated the influence of ownership concentration and leverage on firm value by adopting panel data in Jordan. His research was based on the examination of 83 non-financial firms listed on the Amman Stock Exchange for the sample years 2005-2013. The results were in favour of prior studies and indicated the existence of a relationship between leverage and corporate ownership and firm value on the Jordan stock market.

Mighuel et.al. [2004] examined how ownership concentration and insider ownership have a direct effect on firm investment cash flow sensitivity. Applying generalized methods of moments on a panel data set of 135 Spanish firms, they found that managerial entrenchment above an optimal point worsens underinvestment and overinvestment processes and this is more prominent in the presence of growth opportunities. Filatotchy et al. [2007] examined debt to investment ratio with the control of a dominant firm owner explaining how corporate resources are expropriated at the expense of minority shareholders. They found a significant, negative role of entrenched ownership concentration which leads to less efficient use of firm financial resources (measured as firm debt to investment ratio). This indicates that entrenched dominant shareholders extract the 'control premium' from fixed claim holders for their personal interests. Joh [2003] studied the relation between ownership structure and shareholder conflicts of interest on firm performance with respect to growth opportunities in a sample of 5829 Korean firms from 1993 to 1997. Their study indicates that firms that have low ownership concentration in turn have low profitability with controlled industry and firm characteristics. Their main findings revealed an expropriation of resources by majority shareholders, even with a small ownership concentration.

Javaid and Iqbal [2008] considered 60 listed nonfinancial companies of Pakistan with more than 80% capitalization from 2003 to 2008 to study the relation between corporate governance, firm valuation and ownership structure. The results confirmed the evidence that firms with better investment opportunities and a large size have adopted better governance structures to reduce agency conflicts, whereas the presence of good investment opportunities also results in more ownership concentration. Driffield et al. [2007] estimated the 3SLS model with leverage, ownership concentration and the value of a firm to analyse the effects of ownership structure on firm financial policy. The study took non-financial listed firms of Korea, Thailand, Malaysia and Indonesia where results demonstrate that, with high ownership concentration, costs of debt are reduced. This indicates the positive effects of ownership concentration on firm financial policy and value. Chen and Austin [2007] examined the reduction of underinvestment costs, poor asset utilization efficacy and agency costs of debt and equity with ownership rights in the hands of large block holders. With a sample of large public traded companies from 1996 to 2001, they demonstrated that large controlling outside block holders are more efficient and effective in the maximization of firm value and shareholder wealth. They also demonstrate that insider controlling block holders are more effective with the high efficiency of firm asset utilization ratio because only managerial ownership is able to reduce underinvestment, which is possible due to their dual roles. Based on the literature review we developed our hypothesis below.

Hypothesis to be tested:

Price Earnings Ratio: Growth Options measure proxy

Hypothesis 1a: A negative relation exists between long term debt and firm performance in presence of growth opportunities.

Hypothesis 1b: A positive relation exists between long term debt and firm performance in absence of growth opportunities.

Hypothesis 2a: A non-linear relation exists between ownership concentration and firm performance in presence of growth opportunities.

Hypothesis 2b: An inverse nonlinear relation exists between ownership concentration and firm performance in absence of growth opportunities.

METHODOLOGY

The representation of dependent and independent variables definitions, measure ratios, estimation techniques and model specification is provided in this section.

Data Sample

In the data sample of this study, 141 listed companies of Pakistan on the Karachi Stock Exchange with a study window from 2008 to 2018 were taken. The selection criterion for our sample study was based on firms with the highest market capitalization. The financial sector is not included in the sample study because these sectors require different accounting and financial treatment for study. In addition, the same statistical estimations and techniques could not be applied for both financial and manufacturing sector firms. The service sector was also not taken due to its small sample size as the ratio of total service firms represents a very small percentage of the total listed companies.

Variables Measure Explanation

The dependent variable is Market to Book Assets ratio, whereas independent variables include corporate debt, ownership concentration and ownership concentration square to check for non-linearity. The dividends paid, depreciation, asset tangibility and size and profitability are taken as control variables. For growth options availability, Price Earnings ratio and Sales Rate of Growth are taken as dummy variables.

Growth Opportunities Proxy As Dummy Variables

Price Earnings Ratio (PER)

We define PER as the ratio of the firm's Market Value per share divided by Earnings per share, where Earnings per share is measured by adding Net Income divided by total outstanding shares. The market value per share is defined as the market price outstanding per share.

PER ratio = Market Value per shares / Earnings per share,

where, Earnings per share is measured by adding Net Income divided by total outstanding shares.

Sales rate of Growth

We define SRG as:

$$SRG = \frac{P_2 - P_1}{P_1}$$

where, P2 is present annual sales and P1 is past annual sales

Independent Variable Measures

We define our independent variables as:

Total debt (DTA): Long term debt divided by total assets ratio.

Dividend Payouts (DP): Dividend payouts divided by total assets ratio.

Ownership concentration (C1): Proportion of shares held by top largest majority shareholder.

Ownership concentration square $(C1)^2$: To check non-linear relation of ownership concentration square of proportion of shares held by top largest majority shareholder.

Ownership concentration (C5): Proportion of shares held by top five majority shareholders.

Ownership concentration square $(C5)^2$: To check non-linear relation of ownership concentration square of proportion of shares held by top five majority shareholders.

Tangibility (TANG): Total fixed assets to total assets ratio.

Dividends (DIV): Total dividends paid to total assets ratio.

Depreciation (DEP): Total depreciation paid to total fixed assets ratio.

Size (control variable): Log of total assets.

Profitability (ROA): Earnings before interest and tax divided by net income.

Table 1. Variables Operationalization

Variables	Sign	Definition	Formula
Market to Book Assets Ratio (Firm Performance)	MBA	Market Value /Book value of Asset, Where Market Value of Equity is measured by adding Book Value of Debt to Market Value of Equity	(MVE+D)/BVA
Total Debt	DTA	Total Debt/Total Assets(Book Value)	TD/(TA)
Dividend Payouts	DP/TA	Dividends/Total assets	DP/TA
Ownership Concentration	CONC1	Ownership Proportion of Top One and Top Five Shareholders	C1, C5
Ownership Concentration Square	$CONC^2$	Square of Ownership Proportion of Top One and Top Five Shareholders	C1 square, C5 square
Size	SIZE	Natural Logarithm of Total Assets	Log TA
Return on Assets	ROA	Earnings before Interest and Tax/Total assets	EBIT/TA
Price Earnings Ratio (Growth Opportunity Proxy)	PER	Market Value per share/Earning per share, Where Earnings per share is measured by adding Net Income divided by total outstanding shares	(MVPS/EPS)
Sales Rate of Growth (Growth Opportunity Proxy)	SRG	Present annual sales- Past annual sales /Past Annual Sales	P2-P1/P1

Table 1 shows a summarized view of the operation of dependent and independent variables. The key valuation of this study is to measure growth opportunities according to which our growth option variables (both Price to Earnings ratio and Sales Rate of Growth ratio) are each taken separately to allow us to compare which growth options proxy ratio yields the highest explanatory power. The growth options variables are taken as dummy variables with 0 as the absence and 1 as the presence of growth opportunities. The median value of both PER and SRG growth options variables are taken to identify that the values greater than the median value indicates the presence of growth options available to the firms. The values of PER and SRG ratio below their median values would be taken as 0, indicating the absence of growth opportunities.

In the data sample, 141 listed companies of Pakistan on the Karachi Stock Exchange with a study window from 2008 to 2018 were taken, giving 1551 observations. Thus, our panel-based data is both strong and balanced. Generalized least square regression does not cover for serial 1st and 2nd order correlation. In order to cover for endogeneity and autocorrelation, the generalized method of estimating equations is used, which covers for 1st and 2nd order serial correlation. Using Panel based regression methodology; Generalized methods of Estimating Equations is applied in which total debt, ownership concentration, ownership concentration square, dividends, depreciation, tangibility, size and profitability are regressed on firm performance calculated with Market to Book Assets Ratio.

Model Specifications

A total of five regressions were applied for the analysis. In regression 1, debt and ownership concentration was regressed on firm performance. Here, the availability and non-availability of growth opportunities was not taken. Here, the combined impact was evaluated without considering growth options proxy (price to earnings ratio or sales growth ratio). In regression 2, the presence of growth options measured with (PERP) Price to Earnings ratio is included as a dummy variable (1) to find the impact of debt and ownership concentration on firm performance when positive NPV investment projects are available to the firm. In regression 3, the absence of growth option variables, (PERA) Price to Earnings ratio in the absence of growth opportunities is included as a dummy variable (0). Here, the impact of debt and ownership concentration on firm performance in absence of growth opportunities was evaluated. In robust analysis, regression 4 and 5 were regressed similar to regression 3 and 4 only with the difference that, except for Price Earnings Ratio, the Sales Rate of Growth ratio is taken as a dummy variable for growth option proxy variable. The SRGP represents the presence of growth options and SRGA represents the absence of growth options available to the firm.

Regression 1:

$$MBA_{it} = \beta_0 + \beta_1 TDTA + \beta_2 C1 + \beta_3 (\mathrm{C1})^2 + \beta_4 C5 + \beta_5 (\mathrm{C5})^2 + \beta_6 DEP + \beta_7 TANG + \beta_8 DIV + \beta_9 SIZE + \beta_{10} ROA + \varepsilon_{it}$$

Regression 2:

$$MBA_{it} = \beta_0 + \beta_1 TDTA + \beta_2 C1 + \beta_3 (\mathrm{C1})^2 + \beta_4 C5 + \beta_5 (\mathrm{C5})^2 + \beta_6 PERP + \beta_7 DEP + \beta_8 TANG + \beta_9 DIV + \beta_{10} SIZE + \beta_{11} ROA + \varepsilon_{it}$$

Regression 3:

$$MBA_{it} = \beta_0 + \beta_1 TDTA + \beta_2 C1 + \beta_3 (\mathrm{C1})^2 + \beta_4 C5 + \beta_5 (\mathrm{C5})^2 + \beta_6 PERA + \beta_7 DEP + \beta_8 TANG + \beta_9 DIV + \beta_{10} SIZE + \beta_{11} ROA + \varepsilon_{it}$$

Regression 4:

$$MBA_{it} = \beta_0 + \beta_1 TDTA + \beta_2 C1 + \beta_3 (\mathrm{C1})^2 + \beta_4 C5 + \beta_5 (\mathrm{C5})^2 + \beta_6 SRGP + \beta_7 DEP + \beta_8 TANG + \beta_9 DIV + \beta_{10} SIZE + \beta_{11} ROA + \varepsilon_{it}$$

Regression 5:

$$MBA_{it} = \beta_0 + \beta_1 TDTA + \beta_2 C1 + \beta_3 (\mathrm{C1})^2 + \beta_4 C5 + \beta_5 (\mathrm{C5})^2 + \beta_6 SRGA + \beta_7 DEP + \beta_8 TANG + \beta_9 DIV + \beta_{10} SIZE + \beta_{11} ROA + \varepsilon_{it}$$

RESULTS & DISCUSSION

Table 2 shows the descriptive statistics. The average mean value of corporate leverage is 0.252, but the deviation is a minimum of 0.229. Amongst ownership concentration variables, minimum and maximum values are depicted between C1SQ of 0 to 63.261 and of C5SQ of 0.002 TO 78.734. Deviation is the highest in C5SQ of 20.856. Amongst other variables, the highest difference in minimum and maximum values is found in the

Depreciation variable, that is from 0 to 151.271. The summary statistics demonstrate that in Pakistan non debt companies also exist with 0 debt level. Depreciation minimum and maximum values represent the highest difference in size of firms with big and small assets and the opportunities available to them.

Table 3 demonstrates correlation coefficients amongst all variables. Sales rate of growth (SRG) is negatively correlated to MBA, whereas PER has a positive correlation with MBA indicating that a high PER ratio leads to an increase in firm performance.

Table 2. Descriptive Statistics

Variable	Obs.	Mean	Std. Dev	Min	Max
MBA	1540	2.027	3.885	0.085	41.171
PER	1535	40,026	727,976	-11055	19,661
SRG	1544	5.860	161.880	-1.000	5,949
TDTA	1551	0.252	0.229	0.000	2.073
C1	1551	0.380	0.296	0.017	7.954
C5	1551	0.677	0.287	0.043	8.873
C1SQ	1551	0.232	1.616	0.000	63.261
C5SQ	1551	0.540	20..856	0.002	78.734
TANG	1551	0.424	0.224	0.001	0.981
DIV	1551	0.033	0.067	-0.041	1.685
DEP	1551	0.350	4.728	0.000	151.271
SIZE	1551	15.411	0.629	10.348	19.386
ROA	1551	0.732	0.092	-0.335	0.552

Table 3. Correlation Coefficients

	MBA	PER	SRG	TDTA	C1	C1SQ	C5	C5SQ	TANG	DIV	DEP	SIZE	ROA
MBA	1.000												
PER	0.266	1.000											
SRG	-0.008	-0.006	1.000										
TDTA	-0.025	-0.010	-0.037	1.000									
C1	0.021	0.019	-0.020	-0.168	1.000								
C1SQ	-0.003	0.001	-0.004	-0.051	0.743	1.000							
C5	0.022	0.021	0.009	-0.158	0.875	0.782	1.000						
C5SQ	-0.003	0.002	0.001	-0.055	0.724	0.994	0.813	1.000					
TANG	0.120	0.024	-0.016	0.437	-0.101	-0.006	-0.093	-0.009	1.000				
DIV	-0.006	-0.052	-0.016	-0.226	0.224	0.069	0.154	0.059	-0.153	1.000			
DEP	-0.006	-0.002	-0.002	-0.033	-0.003	-0.002	0.010	0.001	-0.042	0.006	1.000		
SIZE	-0.029	0.027	-0.053	0.064	0.208	0.084	0.119	0.069	-0.061	0.067	-0.041	1.000	
ROA	-0.036	-0.021	-0.051	-0.425	0.144	0.060	0.079	0.046	-0.321	0.468	0.035	0.046	1.000

Table 4 represents regression results. As shown in table 3, five regression results are presented. In regression 1, debt, ownership concentration and control variables are regressed on (MBA) that is on firm performance without consideration of growth options variables. Here, debt has a positive relation with firm performance. C1, largest shareholder concentration, has a 2.416 relation with firm performance, whereas in C5, the largest 5 shareholder concentration has a -1.78 coefficient with firm performance. This indicates that, when power is distributed in more hands, then, due to their self-interests, the performance level declines. However, to check this, non-linearity concentration variables square were taken. This shows the exact opposite effect, where C1 first increases but then decreases, indicating that power in the hands of the largest shareholder increases firm values to an optimal point but then decreases. In C5, the opposite happens. In control variables, SIZE is significant at 1% but has a negative relation with firm performance of -0.733.

Regression 2 represents regression results with growth options available in the form of price to earnings ratio. Here, it is represented with PERP in the presence of growth opportunities. With this factor, debt and concentration becomes more significant at 5% and 10%. It is important to note that PERP has a positive relation with firm performance, indicating the availability of high NPV investment projects leading to high firm performance. It has a beta coefficient of 1.113 at 1% significance level. Long-term debt has a significant positive effect on firm value in the absence of growth options similar to the proposed hypothesis. Issuing Debt controls and limits their excess to free cash flow available, therefore, in the absence of growth opportunities, long-term debt acts as a disciplinary mechanism to reduce agency costs and increase firm value. The negative effect of long-term debt is high and more significant in the presence of growth opportunities, demonstrating that debt has a negative impact on the presence of good investment projects (Fatma andChichti, 2011; D'Mello and Miranda, 2010; Zhang and Li, 2008; Li and Cui, 2003). Ownership concentration variables are slightly increased, that is, with more growth options available, C1 has a positive relation with firm performance. This is due to the convergence effect. In C1 square, when concentration exceeds the optimal point, then it leads to an entrenchment effect (non-linear) and when power is increased from the optimal point, then owners begin to use their power for their own self-interest. In the presence of growth options, especially in ownership concentration square, it has a more negative significant impact on firm performance. This means that the availability of growth options leads to an expropriation of resources from powerful owners.

Table 4. Regression Results

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5
Intercept	**12.771*** **	**11.250*** **	**12.363*** **	**11.902*** **	12.152
	6.51	5.83	6.43	5.92	6.13
TDTA	**0.911***	**0.980** **	**0.980** **	**0.872***	0.872
	1.74	1.9	1.90	1.67	1.67
C1	2.416	**2.908***	**2.908***	2.457	2.457
	1.40	1.71	1.71	1.42	1.42
C5	-1.780	-1.787	-1.787	-1.918	-1.918
	-0.77	-0.78	-0.78	-0.83	-0.83
C1SQ	-0.795	-0.805	-0.805	-0.857	-0.857
	-0.69	-0.71	-0.71	-0.74	-0.74
C5SQ	0.594	0.568	0.568	0.652	0.652
	0.59	0.57	0.57	0.64	0.64
PERP	-	**1.113*** **	-	-	-
		6.82			
PERA	-	-	**-1.113*** **	-	-
			-6.82		
SRGP	-	-	-	**0.250***	-
				1.75	
SRGA	-	-	-	-	**-0.250***
					-1.75
DEP	-0.006	-0.006	-0.006	-0.005	-0.005
	-0.43	-0.49	-0.49	-0.41	-0.41
TANG	1.069	**1.214***	**1.214***	1.05	1.050
	1.58	1.82	1.82	1.55	1.55
DIV	-7.480	-0.361	-0.361	-0.766	-0.766
	-0.60	-0.29	-0.29	-0.61	-0.61
SIZE	**-0.733*** **	**-0.683*** **	**-0.683*** **	**-0.683*** **	**-0.683*** **
	-6.38	-6.08	-6.08	-5.82	-5.82
ROA	0.569	-0.209	-0.209	0.629	0.629
	0.50	-0.19	-0.19	0.55	0.55
N	1540	1540	1540	1540	1540
Wald chi2	51.03	98.11	98.11	53.88	53.88
Prob > chi2	0.00	0.00	0.00	0.00	0.00
Method	GEE	GEE	GEE	GEE	GEE

Note: GEE is Generalized Estimating Equations method, ***,**,* denotes significance level at 1%, 5% and 10% levels respectively. T-statistics values are presented in parentheses

Regression 3 presents the absence of growth opportunities with the variable PERA. Here it is important to note that PERA has a -1.113 relation with firm performance at 1% significance level. This indicates that the absence of growth options reduces firm performance. In the absence of growth options, debt and concentration variables results almost remain the same as regression 1. This indicates that, without growth options, there are no resources for self-interest which managers and owners can exploit, therefore firm performance increases. Tangibility becomes significant at 10% in the presence of growth opportunities that are 1.214 in value. Depreciation and dividends pay-outs show the same pattern in overall regression models, whereas ROA reduces PER, though not with SRG growth options models. Regression 4 and 5 represent Sales rate of growth SRG taken as a dummy variable as proxy for growth opportunities available and not available. In regression 4, SRGP represents the presence of growth opportunities and, in regression 5, SRGPA represents the absence of growth opportunities. The overall results are similar to PER ratio. However, the significance level has declined, indicating the PER to be a better indicator of growth opportunities. In addition, beta values have also slightly increased compared to ownership concentration variables but declined of debt variable. There is no change in the sign of any variable between SRG method and PER ratio. The estimated results gave higher explanatory power results with PER ratio than with SRG ratio. Here in the presence of growth opportunities, a non-linear effect is demonstrated with positive and negative signs of C1 and C1 square. However, in the absence of growth opportunities, the opposite reaction occurs, where, with an initial rise in concentration, a negative effect is demonstrated on firm value and, with a high level of concentration, a positive effect is seen on firm value, giving an inverse, non-linear effect in the absence of growth opportunities. The inverse, non-linear effect takes place in the absence of growth opportunities, as firms that lack good investment opportunities are more transparent. Due to visible transparency, the entrenchment effect is reduced, and a high concentration effect becomes positive for firm value. This is also supported and consistent with other studies [Javid, Iqbal 2008].

CONCLUSION

This research analyzed the dual effects of a firm's important financial decisions, that is corporate leverage impact, on a firm's value in the presence of good investment opportunities and without the presence of good investment opportunities. Price to Earnings Ratio & Sales Rate of Growth were utilized to seek firms with division in the presence of firms with the highest and lowest growth opportunities. These ratios are shown to be the most popular firm performance indicators which take firm earnings and sales rates into account to increase firm value with increased growth of firms because This research took 141 non-financial Pakistani companies listed on the Karachi stock Exchange from 2008 to 2018. The Generalized Estimation Equations Technique was applied for panel data sets, with results indicating the positive effects of corporate debt and dividends in the absence of growth opportunities and the negative effect of corporate debt and dividends in the presence of growth opportunities. Ownership concentration demonstrates a non-linear effect in the presence of growth opportunities and an inverse non-linear effect in the absence of growth opportunities.

Long-term debt is found to have a negative impact on firm value in the presence of growth opportunities due to underinvestment costs borne by the firm with the presence of agency conflicts between managers and bondholders of the company. Managers do not find it worthwhile to fund risky investment projects if project earnings go to bondholders in the case that investment in a risky project leads to a loss. This leads managers to avail themselves of the option of not investing. Therefore long-term debt has a negative impact on firm value. In the absence of growth opportunities, short-term debt and long-term debt have positive effects on firm value due to its disciplinary mechanism in limiting access to free cash flow in the hands of managers, which can lead to overinvestment problems. Managers expand firms unnecessarily, sometimes to increase their prestige, and also make bad investments. With access to free cash flows, they even invest in poor NPV given projects, therefore, it is preferable to issue debt in the absence of growth opportunities. Pakistan firm's estimation depicts positive and significant effects of debt on firm value in the absence of growth opportunities. Total debt effect was checked with a negative term which gives negative effects of overall debt on firm value in the presence of growth opportunities at 0.01%.

Dividends relations are uncertain in Pakistan as they give out negative effects with MBA ratio, positive effects with SMBA ratio and again negative effects with MBE ratio. Ownership concentration gives non-linear relations in all scenarios and cases. However, in Pakistan, for firms with poor NPV projects, ownership concentration has an inverse non-linear effect on firm value. Size and ROA act fully as control variables with the highest significance level with SMBA as dependent variable.

Firm growth opportunities reflect a firm's high value on the market and an increased market price. The main focus of this study was to check the joint effects of corporate debt and dividends and their different roles played differently in the presence and absence of growth opportunities. This reflects how much a firm's policy on financial decisions is fully affected by good investment opportunities. Due to the presence of agency costs and conflicts of interest, a firm's management sometimes designs corporate financial policies according to their own interests. Ownership concentration sometimes becomes beneficial in removal of these conflicts of interest and increase firm value. However, sometimes high ownership concentrations also implement their force to build firm financial policies according to their own interests. This thesis provides insight with replacement models as well as with interacted models of independent variables to demonstrate how different beneficial financial policies could be designed and implemented to help reduce underinvestment and overinvestment costs and increase firm value in the presence absence of growth opportunities.

In Pakistan, mostly family-oriented businesses exist. Therefore, Pakistani companies are mostly very highly concentrated with few or one as the largest main shareholder. This thesis shows that, with concentrated ownership control, growth opportunities could be availed or exploited due to increased agency conflicts. In replacement model results, when only one ownership concentration variable is used, excluding second ownership concentration variables, there is a positive effect on firm value in all three cases. However, inclusion of high and low concentration with concentration square taken, depicts a non-linear effect on firm value. Concentration interactions revealed useful insights into different independent variables giving insights again into a firm's policy on financial decision with different levels of concentration present in the firm. Size depicts asset utilization of firms in good investment projects. With sector, adjusted MBA ratio size shows highly significant positive values in the presence of growth opportunities and highly significant negative values in absence of them. In the absence of growth opportunities, size has a negative effect because small sized firms mostly have a lower availability of good investment projects or might be too costly and expensive. Therefore, size has a negative effect on firm value in the absence of growth opportunities, whereas it is positive in the presence of growth opportunities and full sample data. Return on assets depicts the profitability generated by a firm with efficient utilization of its assets. There is a positive relation between return on assets and PER but a negative one with SRG.

IMPLICATIONS

This paper has important implications for majority shareholders, debt holders, and investors. A firm's majority shareholders are concerned with maximization of shareholder wealth. This article would benefit them to analyze the situations and alter the financial policies built by management where, with the use of more control and power, agency costs could be reduced and wealth could be maximized. Debt holders could act as intermediaries and could help to reduce the problem of adverse selection of investment projects by management with their knowledge of company debt policies and risks to be employed. Investors could trade off against their risk and return investment projects and portfolios to design and accomplish an idea of the return of a different kind of firm based on their availability and the used proportion of good and bad investment opportunities.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Abdullah M.I., Sarfraz M., Qun W., Chaudhary M., 2019. Ownership concentration impact on firm financial performance. LogForum 15 (1), 107-118. http://doi.org/10.17270/J.LOG.2019.317

Abor J., Bokpin A.G., 2010. Investment opportunities, corporate Finance and dividend Payout policy: evidence from emerging markets. Studies in Economics and Finance, 27(3), 180-194. http://doi.org/10.1108/10867371011060018

Adam T., Goyal V.K., 2008. The investment opportunity set and its proxy variables. Journal of Financial Research, 31(1), 41-63. http://doi.org/10.1111/j.1475-6803.2008.00231

Ahmad H., Javid A., 2009. Dynamics and determinants of dividend Policy in Pakistan: evidence from Karachi stock exchange non-financial listed firms. International Research Journal of Finance and Economics, 25, 148-171. https://mpra.ub.uni-muenchen.de/id/eprint/37342

Ahmad M., Baek N.W., Kim D.W., Shah B.A., 2019. The Impact of Institutional Ownership on Firms' Performance Evidence From Pakistan. Asian Studies, 22(1), 27-48.

Alonso P.D.A., Iturriaga F.J.L., Sanz J.A.R., 2005. Financial decisions and growth opportunities: a Spanish firm's panel data analysis. Applied Financial Economics, 15(6), 391-407. http://doi.org/10.1080/09603100500039201

Arellano M., 2001. Panel data econometrics. Oxford University Press.

Barclay M.J., Smith Jr C.W., 1999. The capital structure puzzle: another looks at the evidence. Journal of applied corporate finance, 12(1), 8-20. http://doi.org/10.1111/j.1745-6622.1999.tb00655.x

Barclay M.J., Marx L.M., Smith Jr C.W., 2003. The joint determination of leverage and maturity. Journal of Corporate Finance, 9(2), 149-167. http://doi.org/10.1016/S0929-1199(02)00003-2

Bougatef K., Chichti J., 2011. Timing of debt issues: evidence from a panel of Tunisian and French firms. Economics Bulletin, 31(2), 1188-1197.

Carvalhal da Silva A., Subrahmanyam A., 2007. Dual-class premium, corporate governance, and the mandatory bid rule: evidence from the Brazilian stock market. Journal of Corporate Finance, 13(1), 1-24. http://doi.org/10.1016/j.jcorpfin.2006.12.003

Chen X.C., Yur-Austin J., 2007. Re-measuring agency costs: The effectiveness of blockholders. The Quarterly Review of Economics and Finance, 47(5), 588-601. http://doi.org/10.1016/j.qref.2007.09.003

Ciftci I., Tatoglu E., Wood G., Demirbag M., Zaim S., 2019. Corporate governance and firm performance in emerging markets: Evidence from Turkey. International Business Review, 28(1), 90-103. http://doi.org/10.1016/j.ibusrev.2018.08.004

Dang V.A., 2011. Leverage, debt maturity and firm investment: An empirical analysis. Journal of Business Finance & Accounting, 38(1-2), 225-258. http://doi.org/10.1111/j.1468-5957.2010.02215.x

Demsetz H., Villalonga B., 2001. Ownership structure and corporate performance. Journal of corporate finance, 7(3), 209-233. http://doi.org/10.1016/S0929-1199(01)00020-7

Din S.U., Javid A.Y., 2011. Impact of managerial ownership on financial policies and the firm's performance: evidence Pakistani manufacturing firms. https://mpra.ub.uni-muenchen.de/id/eprint/37560

Dyck A., Zingales L., 2004. Private benefits of control: An international comparison. The journal of finance, 59(2), 537-600. http://doi.org/10.1111/j.1540-6261.2004.00642.x

D'Mello R., Miranda M., 2010. Long-term debt and overinvestment agency problem. Journal of Banking & Finance, 34(2), 324-

335. http://doi.org/10.1016/j.jbankfin.2009.07.021

De Jong A., Van Dijk R., 2007. Determinants of leverage and agency problems: A regression approach with survey data. The European Journal of Finance, 13(6), 565-593. http://doi.org/10.1080/13518470701198734

Driffield N., Mahambare V., Pal S., 2007. How does the ownership structure affect capital structure and firm value? Recent evidence from East Asia. Economics of Transition, 15(3), 535-573. http://doi.org/10.1111/j.1468-0351.2007.00291

Farrukh K., Irshad S., Shams Khakwani M., Ishaque S., Ansari N.Y., 2017. Impact of dividend policy on shareholder wealth and firm performance in Pakistan. Cogent Business & Management, 4(1), 1408208.

Filatotchev I., Isachenkova N., Mickiewicz T., 2007. Ownership structure and investment finance in transition economies: a survey of evidence from large firms in Hungary and Poland1. Economics of Transition, 15(3), 433-460. http://doi.org/10.1111/j.1468-0351.2007.00295

Fama B.M., Chichti J., 2011. Interactions between free cash flow, debt policy and structure of governance: Three stage least square simultaneous model approach. Journal of Management Research, 3(2), 1-34.

Ghalandari K., 2013. The Moderating Effects of Growth Opportunities of the Relationship between Capital Structure and Dividend Policy and Ownership Structure with Firm Value in Iran: Case Study of Tehran Securities Exchange. Research Journal of Applied Sciences, Engineering and Technology, 5(4), 1424-1431.

Gursoy G., Aydogan K., 2002. Equity ownership structure, risk taking, and performance. Emerging Markets, Finance & Trade, 38(6), 6-6.

Hamouri B., Al-Rdaydeh M., Ghazalat A., 2018. Effect of financial leverage on firm growth: Empirical evidence from listed firms in Amman stock exchange. Investment Management and Financial Innovations, 15(2), 154-164.

Holderness C.G., Kroszner R.S., Sheehan D.P., 1999. Were the good old days that good? Changes in managerial stock ownership since the great depression. The Journal of Finance, 54(2), 435-469. http://doi.org/10.1111/0022-1082.00114

Ishari M.P.S., Abeyrathna S.P.G.M., 2016. The Impact of Financial Leverage on Firms' Value (Special Reference to Listed Manufacturing Companies in Sri Lanka). International Journal of Advancement in Engineering Technology, Management and Applied Science, 3(7), 100-104. ISSN: 2349-3224

Iqbal U., Usman M., 2018. Impact of Financial Leverage on Firm Performance. SEISENSE Journal of Management, 1(2), 70-78.

Iturriaga F.J.L., Crisóstomo V.L., 2010. Do Leverage, dividend payout, and ownership concentration influence firms' value creation? An analysis of Brazilian firms. Emerging Markets Finance and Trade, 46(3), 80-94. http://doi.org/10.2753/REE1540-496X460306

Javid A.Y., Iqbal R., 2008. Ownership concentration, corporate governance and firm performance: Evidence from Pakistan. The Pakistan Development Review. 47, 643-659.

Jensen M., 1986. Agency cost of free cash flow, corporate finance, and takeovers. Corporate Finance and Takeovers. American Economic Review, 76(2), 525-573.

Joh S.W., 2003. Corporate governance and firm profitability: evidence from Korea before the economic crisis. Journal of Financial Economics, 68(2), 287-322. http://doi.org/10.1016/S0304-405X(03)00068-0

Johnson S.A., 2003. Debt maturity and the effects of growth opportunities and liquidity risk on leverage. Review of Financial Studies, 16(1), 209-236. https://doi.org/10.1093/rfs/16.1.0209

Khan A.A., Mustafa F., Khursheed A., Siddique F., 2018. Social Business Innovation: Comparison of operational efficiency of microfinance institutions in Pakistan. Pyrex Journal of Business and Finance Management Research, 4(3), 12-20.

López-de-Foronda Ó., López-de-Silanes F., López-Iturriaga F.J., Santamaría-Mariscal M., 2019. Overinvestment, leverage and financial system liquidity: A challenging approach. BRQ Business Research Quarterly, 22(2), 96-104. http://doi.org/10.1016/j.brq.2018.08.001

Lyandres E., Zhdanov A., 2005. Underinvestment or overinvestment: the effects of financial leverage on investment. Rice University working paper.

Li H., Cui L., 2003. Empirical study of capital structure on agency costs in Chinese listed firms. Nature and science, 1(1), 12-20.

Maury B., Pajuste A., 2005. Multiple large shareholders and firm value. Journal of Banking & Finance, 29(7), 1813-1834. http://doi.org/10.1016/j.jbankfin.2004.07.002

Mustafa F. Khursheed A. Fatima M., 2018. Impact of global financial crisis on financially innovative microfinance institutions in South Asia. Financial Innovation, 4(1), 1-11. http://doi.org/10.1186/s40854-018-0099-8

McConnell J.J., Servaes H., 1995. Equity ownership and the two faces of debt. Journal of Financial Economics, 39, 131–57. http://doi.org/10.1016/0304-405X(95)00824

Miguel A.d., Pindado J., Torre C.d.l., 2004. Ownership Structure and Firm Value: New Evidence from Spain. Strategic Management Journal, 25, 1199-1207. http://doi.org/10.1002/smj.430

Miller M.H., Modigliani F., 1961. Dividend policy, growth and the valuation of shares. Journal of Business, 34(4), 411–552.

Myers S.C., 1977. Determinants of corporate borrowing, Journal of Financial Economics, 5(2), 147–75. http://doi.org/10.1016/0304-405X(77)90015-0

Najjar D.M.A., 2016. Do ownership concentration and leverage influence firms' value? Evidence from panel data in Jordan. International Journal of Business and Management, 11(6), 262. ISSN 1833-3850

Ndubuisi K., Juliet I., Onyema J.I., 2019. Effect of financial leverage on profit growth of quoted non-financial firms in Nigeria. J Fin Mark. 2019; 3 (1): 9-14. J Fin Mark 2019 Volume 3 Issue 1, 10.

Pindado J., de la Torre C., 2008. Financial decisions as determinants of ownership structure: Evidence from Spanish family-controlled firms. Managerial Finance, 34(12), 868-885. http://doi.org/10.1108/03074350810915824

Rahman S.M.K., 2017. Effect of Financial Leverage on Firm's Market Value Creation in Bangladesh: A Comparison between MNCs and Domestic Firms. International Journal of Corporate Finance and Accounting (IJCFA), 4(2), 41-58. http://doi.org/10.4018/IJCFA.2017070103

Saidat Z., Silva M., Seaman C., 2019. The relationship between corporate governance and financial performance: Evidence from Jordanian family and nonfamily firms. Journal of Family Business Management, 9(1), 54-78.

Villalonga Belen, R. Amit, 2006. How do family ownership, control and management affect firm value? Journal of Financial Economics, 80(2), 385-417.

Wu L., 2004. The impact of ownership structure on debt financing of Japanese firms with the agency cost of free cash flow. In EFMA 2004 Basel Meetings Paper.

Wu S., 2019. Debt financing structure, ownership concentration and firm performance: a comparison of the listed state-owned and non-state-owned CMNEs. Journal of Chinese Economic and Business Studies, 17(2), 147-168.

Yasser Q.R., Mamun A.A., 2017. The impact of ownership concentration on firm performance: Evidence from an emerging market. Emerging Economy Studies, 3(1), 34-53. http://doi.org/10.1177/2394901517696647

Zhang H., Li S., 2008. The Impact of Capital Structure on Agency Costs: Evidence from UK Public Companies. In Proceedings of the 16th Annual Conference on Pacific Basin Finance Economics Accounting Management Conference, 1-18.

Zraiq M.A.A., Fadzil F.H.B., 2018. The impact of ownership structure on firm performance: Evidence from Jordan. International Journal of Accounting, Finance and Risk Management, 3(1), 1-4. http://doi.org/10.11648/j.ijafrm.20180301.12

WPŁYW STRUKTURY WŁASNOŚCI NA EFEKTYWNOŚĆ FIRM NA PRZYKŁADZIE PAKISTANU

STRESZCZENIE. Wstęp: Celem pracy jest określenie wpływu struktury własnościowej firmy na efekty jej działalności w obszarze sektora logistycznego w Pakistanie w przypadku opcji możliwości rozwojowych firmy oraz jej braku. Struktura własnościowa ma istotny wpływ zarówno pozytywny jak i negatywny na efekty działalności firmy.
Metody: W celu uzyskania danych do analizy, wybrano 141 firm pakistańskich, będących obecnych na giełdzie w Karachi. Dane pochodziły z okresu 2008-2018. Kryterium wyboru tych firm była najwyższa rynkowa kapitalizacja. Dane poddano analizie statystycznej za pomocą metody GEE (generalized estimating equation) stosowanej dla problemów endogeniczności i autokorelacji.
Wyniki: Uzyskane wyniki pokazują możliwości i ich brak dla różnych opcji wzrostu firm jako bardzo ważny czynnik wpływu struktury własnościowej oraz zadłużenia na efekty działalności firmy. W przypadku istnienia możliwości rozwoju dla firmy, wykryto zależność pomiędzy efektami działalności firmy and pozytywną istotną zależność pomiędzy zadłużeniem a efektami działalności firmy. W przypadku braku możliwości rozwoju zaobserwowane negatywną zależność pomiędzy strukturą własnościową a efektywnością firmy jak również negatywną zależność pomiędzy zadłużeniem a efektami działalności firmy.
Wnioski: Dźwignia finansowa ma dodatni wpływ w przypadku istnienia możliwości rozwoju i negatywny w przypadku jego braku. Uzyskane wyniki wskazują, że skupienie władzy w małym gronie właścicieli prowadzi do konwergencji i efektu „okopania się" w połączeniu z nieliniową zależnością od wyników finansowym w przypadku zarówno brak jak i występowania możliwości rozwoju firmy.

Słowa kluczowe: możliwości rozwoju, dźwignia finansowa, struktura własności, wartość firmy, niedoinwestowanie, przeinwestowanie, Pakistan

Marriam Rao
UCP Business School
Faculty of Management Studies
University of Central Punjab
1-Khayaban-e-Jinnah Road, Johar Town, Lahore, **Pakistan**
e-mail: marriam.rao@ucp.edu.pk

Ambreen Khursheed, ORCID ID: https://orcid.org/0000-0003-1497-5848
UCP Business School
Faculty of Management Studies
University of Central Punjab
1-Khayaban-e-Jinnah Road, Johar Town, Lahore, **Pakistan**
e-mail: ambreen.khursheed@ucp.edu.pk

Faisal Mustafa
UCP Business School
Faculty of Management Studies
University of Central Punjab
1-Khayaban-e-Jinnah Road, Johar Town, Lahore, **Pakistan**
e-mail: faisal.mustafa@ucp.edu.pk

LogForum

> Scientific Journal of Logistics <

2020, 16 (1), 33-46

http://doi.org/10.17270/J.LOG.2020.379

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

ANALYSIS OF THE LENGTH OF ORDER-PICKING PATHS DETERMINED USING THE S–SHAPE METHOD

Adam Redmer

Poznan University of Technology, Poznan, **Poland**

ABSTRACT. **Background:** Order-picking is a fundamental warehousing activity that accounts for in excess of 60% of total warehousing costs. Movements of pickers consume as much as half of the picking time. Thus determining picking paths is crucial. The most frequently used method is the S-shape one.

Material and methods: The average picking path length for 240 variants of the storage area (depot location, storage strategy), inventory (ABC-storage class sizes, probability of retrieving) and customer order (number of lines – 5, 10, 15) parameters was calculated. 100 simulations were carried out each time. MS Excel spreadsheet, along with macros (VBA) were used.

Results: The comparison were made of path lengths for a single block warehouse with 320 storage locations, Within-Aisle/Random storage strategies and low-level picking. Depot locations in the corner of a warehouse and in the middle of a front aisle were considered. The path lengths significantly varied with the variants that were analyzed. The shortest paths were observed for the Within-Aisle strategy, corner located depot, order sizes 5 or 10 and sizes of ABC-storage classes equal to 5/35/60% or 10/35/55% of all 320 storage locations under a retrieving probability of 90/5/5%.

Conclusions: Better and worse picking variants exist, influencing significantly the length of picking paths determined using the S-shape method. In general, the depot location is less important, even though the best variant assumed a corner location, while a location in the middle of a front aisle gives shorter paths on average. A much more important factor is the storage strategy. Lack of the strategy (randomness) substantially extends path lengths (by 50% on average).

Key words: warehousing, order picking, S-shape method, picking paths length.

INTRODUCTION

Order-picking is one of the fundamental activities carried out in warehouses. It is a sub-process of the superior warehouse process consisting in retrieving (block-stacked or racked) items from the inventory to fulfill a customer order (qualitatively and quantitatively) [Coyle et al. 2002].

The general picking strategies are [Emmett 2005, Parikh, Meller 2008, Zając 2014]:

- single-order/piece/discrete picking, the most common picking strategy, where one warehouse picker retrieves items (line by line in an order) to fulfill a single order at once,
- multi-order/batch picking, the strategy where one warehouse picker retrieves items simultaneously and sorts them afterwards to fulfill multiple orders,
- cluster picking, the strategy where one warehouse picker retrieves items simultaneously and sorts them at the same time to fulfill multiple orders; this strategy is similar to the previous one, the only difference lying in the moment of sorting the items collected,
- parallel zone/wave/consolidation picking, the strategy where many warehouse pickers retrieve items in particular storage zones

Citation: *Redmer A., 2020. Analysis of the length of order picking paths determined using the S–shape method. LogForum 16 (1), 33-46, http://doi.org/10.17270/J.LOG.2020.379*

Received: 09.08.2019, Accepted: 22.10.2019, on-line: 30.12.2019.

simultaneously and merge them afterwards to fulfill a single order,
- sequential zone picking, the strategy where many warehouse pickers retrieve items in particular storage zones consecutively and merge them simultaneously to fulfill a single order; the strategy is similar to the previous one, the only difference lying in the moment of merging collected items,

and many other strategies, which can also be generally divided into a one- and two-stage picking strategies differing in terms of the number (single or many) of orders picked at once and the number of times the retrieved items are handled, thus if sorting of them is required or not [Gudehus, Kotzab, 2009].

Particular order picking strategies can be implemented [Emmett 2005, Garbacz, Łopuszyński 2015, Kostrzewski, Kostrzewski 2014]:
- in a warehouse storage or picking areas or both,
- as picking by order or by item,
- as person-to-goods or goods-to-person picking.

The most common picking strategy is single-order/piece/discrete picking by order carried out as a low/ground-level, person-to-goods in a warehouse storage area [De Koster et al. 2007]. A picker using a picking list and a load carrier (e.g. pallet, plastic or paper box, …) goes to consecutive storage locations (according to the picking list), where inventories are kept. The picker retrieves the appropriate quantity that has been ordered (number of items) of goods and places them on or in a carrier, and in this way, visits all the storage locations on the picking list.

Order-picking, including setup, travel, search, pick and other activities is the most time- and thus labor- and cost-consuming warehouse sub-process. It is commonly recognized that it usually takes 50-60% of the total warehouse operating time, labor or costs on average [Oudijk et al. 2019, Tompkins et al. 2010], whereas travel (walking) activity separately consumes as much as a half of the picking time [De Koster et al. 2007, Dukic and Cedomir 2007, Le-Duc 2005, Tompkins et al. 2010].

METHODS FOR DETERMINING ORDER-PICKING PATHS

There are many methods for determining order-picking paths. The fundamental ones are the following [De Koster et al. 2007, Hall 1993, Le-Duc 2005]: S-shape, Midpoint, Return, Largest Gap, Combined and Optimal. Among these, one of the simplest and frequently used is the S-shape (or the Traversal) method. In this method, a warehouse picker travels (walks or rides) from a starting point (a depot/base/I/O – Input/Output/P/D – Pick-up/Drop-off point) through particular aisles in which items to be retrieved are located, traversing them only once (in one direction, with no returns – optionally with an exception for the last one aisle to be traversed) and finally coming back to the starting point. This route produces the characteristic shape of an order-picking path resembling the "S" letter. The S-shape method, like any other, has its advantages and disadvantages, which are presented in Table 1.

Table 1. Advantages and disadvantages of the S-shape picking method

Advantages	Disadvantages
Simple order picking path determining	Fixed (inelastic) when determining order picking paths
Easy to implement in practice – intuitive to pickers	Aisles containing at least one pick have to be traversed entirely – optionally with an exception for the last one aisle to be traversed
Implementable for a one- (including narrow) and a two-way aisles	Odd number of aisles to be traversed requires empty movements (adding a one aisle to be traversed with no picks or optionally with an exception for the last one aisle to be traversed in a U-turn manner)
For high numbers of order lines gives as good results as the Optimal method	Sensitive to congestion (causing blocking of pickers)
Aisles with no items to retrieve can be skipped	In case of one-way (narrow) aisles even numbers of them are required to be skipped due to no picks

Source: author's research

LITERATURE SURVEY

A low-level, picker-to-parts (also called person to goods) order-picking system employing humans and with multiple picks per route is commonly recognized to be the most frequently used in warehouses worldwide. According to De Koster et al. [2007] and also to Grosse et al. [2015], over 80% of all order-picking systems in Western Europe are like this. In this system, the travel distance is the distance a warehouse picker travels (walks or rides) from a starting point (a depot) through particular aisles in which the items to be retrieved according to customers' orders are located, before coming back to the starting point. The issue of picking distance has been extensively studied for the last decades starting from the 1970s, when one of the first methods for calculating its length was proposed by Gudehus [1973].

The travel distance (and its minimization) has become the most common objective for warehouse and picking process planning/optimization. The distance is sometimes recalculated into the travel time [Hall 1993]. The distance, or more directly, the picking time, along with the accuracy of picked orders, is crucial for the service level/quality of the whole process (the faster an order is completed, the sooner it is available for shipping). As Gajšek et al. [2017] recognized, although various activities other than travel may substantially contribute to order-picking time, travel is often the dominant component. Moreover, travel time costs labor hours but does not add value. For manual order picking systems, the travel time is an increasing function of the travel distance. Consequently, the travel distance is often considered as a primary objective in warehouse design and optimization.

The travel distance can be divided into two or three components. According to Roodbergen and Vis [2006], they are the distance traveled within the aisles and the distance traveled in the cross-aisles. According to Sadowsky and Hompel [2011], however, there are three components: the basic distance, the within-aisle distance and the across-aisle distance. The basic distance, which makes the only difference, depends on the storage area layout, and is the distance from the depot to the first (horizontal) aisle to be visited (traversed).

There are a few factors, such as warehouse operating policies, crucial for the travel distance to be covered during the picking process. Among them the most frequently pointed out and analyzed in the literature are the following: the warehouse layout and the three strategies of storage, routing/sorting and batching [Burinskienė et al. 2018, Henn 2012, Le-Duc and De Koster 2005, Petersen 1997, Petersen and Aase 2017, Petersen and Schmenner 1999, Rao and Adil 2013b]. However, there is also another factor that is not a part of operating policies, but is an independent one element, namely, the demand (customer orders) and its parameters (e.g. order sizes and the frequency of occurrence of particular SKUs in orders). This factor is studied in this research.

This factor, i.e. demand, is far more rarely addressed in the literature than the other four mentioned above. One of the examples of the research dealing with it is the study by Dijkstra and Roodbergen [2010], where the storage location assignment problem is analyzed in order to minimize the average route length traveled by the order pickers while retrieving items from locations in a warehouse. The authors developed a complex distance function that depends on the layout of a warehouse, the routing method employed, the demand frequencies of all items, and the item-to-location assignment itself. The influence of the demand patterns and order pick sizes on the picking travel distance is also studied by Le-Duc and de Koster [2005] as well as by Petersen and Schmenner [1999].

As far as the warehouse layout design is concerned, the number and relative orientation of picking aisles, the locations of the cross aisles and the position of pick-up/drop off (P/D) points (usually in the corner of a warehouse) are taken into account [De Koster et al. 2007, Rao and Adil 2013a]. When considering the routing strategy, the methods for determining the order picking paths (S-shape, Midpoint, Return, Largest Gap, Combined and Optimal one) mentioned in the previous section are usually considered [De Koster et al. 2007, Le-Duc 2005]. However, in practice, only simple routing heuristics are used, such as the S-shape and the Return [Moeller 2011]. Moreover, Burinskienė et al. [2018] indicate that the methods that are used usually involve the logic of the Largest Gap, Midpoint or S-shape one. These issues/factors influencing the length of picking paths are also addressed in this research.

Thus, the aim of this paper is to search for the quantitative influence of such specific factors as the storage strategy, the depot location, the order size, the size of ABC-storage classes, the probability of retrieving items belonging to particular ABC-storage classes and combinations of them on the length of picking paths determined using the S-shape method. The three last factors come from the demand pattern and are independent (hard to control) ones that are much more rarely addressed in the literature.

ANALYSIS

The analysis was carried out for a single block warehouse layout (with dimensions of 44.8 x 24 m, c. 1,075 m2) with 320 EUR-palette storage locations (with dimensions of 1.3 x 0.9 m) and 10 two-way 3m wide aisles, including vertical and horizontal, the front and the back, ones. Thus the vertical aisles are 18 m long.

The Within-Aisle and the Random storage strategies with the ABC-based storage classes (assortment groups) were considered. The low-level and person to goods single order picking system was used. The Within-Aisle storage strategy assumes that the ABC-storage classes are located aisle by aisle, starting from an A-class next to depot and locating B- and C-classes further from it. In the case of the depot located in the middle of the a front aisle, the above holds for both the left and the right sides (directions) from it. The Random storage strategy assumes that the items from a particular ABC storage classes are located evenly throughout the whole storage area (with a uniform distribution, so the average distance to particular ABC-storage classes is almost the same).

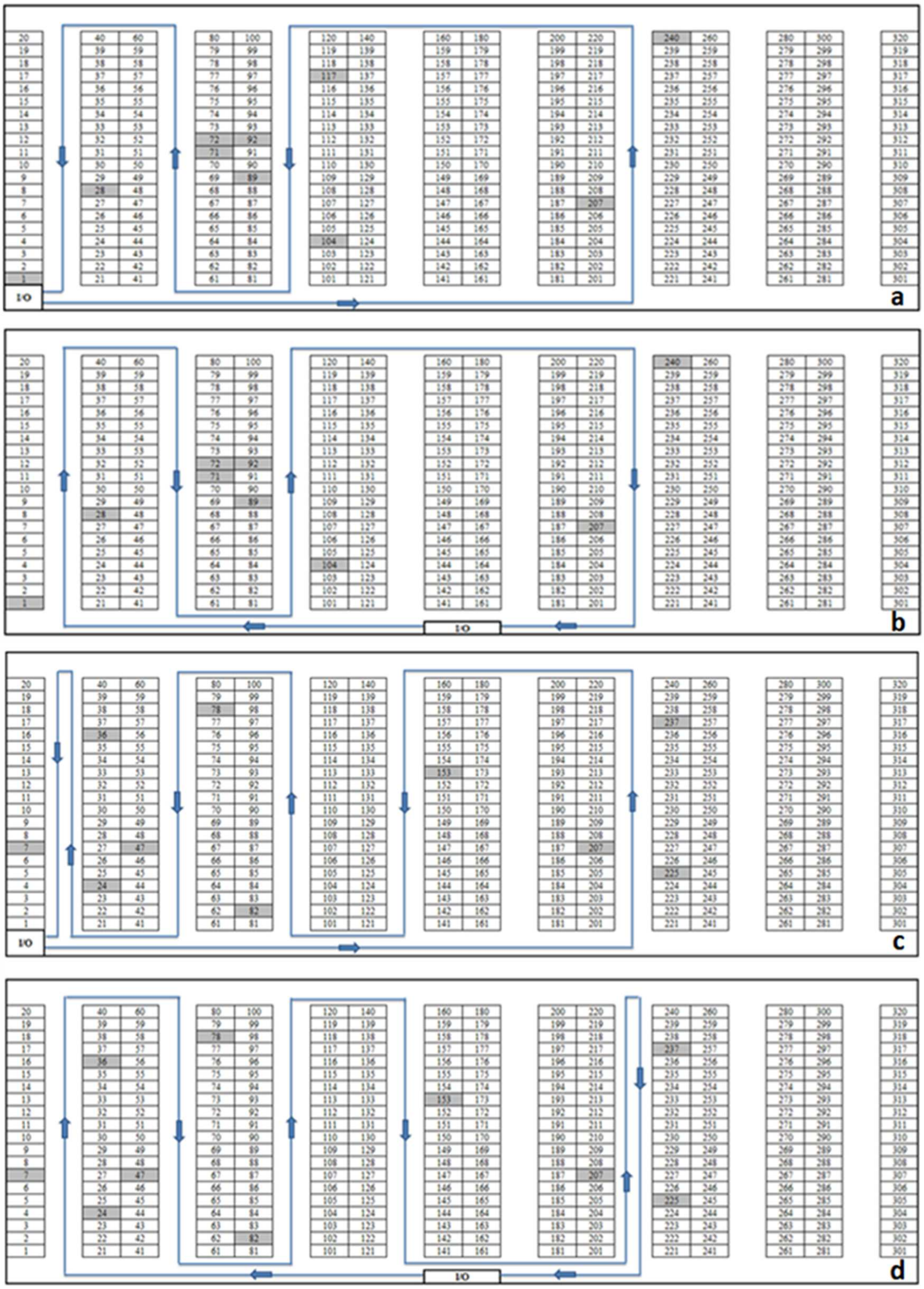
The depot located in the corner of a warehouse (the bottom left one) and in the middle of a front aisle was taken into consideration (see Fig. 1 where the S-shaped picking order paths for odd and even numbers of aisles to be traversed to pick an exemplary, randomly selected items/storage locations are presented as well). Such a layout is commonly used in the literature [Henn 2012, Zare Mehrjerdi et al. 2018], although usually with the depot located in the corner of a warehouse. Locating the depot in the middle of a front aisle is rather rare (see, for example Roodbergen and Vis 2006).

Orders to be picked with a different numbers of lines/SKUs (including 5, 10 and 15 lines) have been considered. The storage locations of the particular items on an order are drawn at random, taking into account such factors as the sizes of ABC storage classes and the predefined probability of retrieving items belonging to each class. It is assumed that when the whole orders are picked at once by a one warehouse picker traversing all storage locations characteristic for items on the order, this gives single-order/piece/discrete picking. Picking paths are determined using the S-shape method.

The 240 variants were analyzed, which are combinations of the following parameters, i.e. the different:

– storage strategies (2),
– depot (I/O) locations (2),
– order sizes, i.e. number of lines/items/SKUs (3),
– sizes of ABC-storage classes, i.e. percentage of all SKUs/storage locations (5),
– probability of retrieving items belonging to a particular ABC-storage classes (4),

On each occasion, items (in fact, their storage locations) on the order were drawn at random under the aforementioned parameters assumed for the current variant values. For the Random storage strategy-based variants for every 20 different orders drawn, the locations of SKUs were also changed (20 different orders multiplied by 5 different locations of SKUs giving 100 repetitions of the analysis).



Source: author's research

Fig. 1. Exemplary order picking paths a-b) for even and c-d) for odd number of (vertical) aisles to be traversed

The way the variants are constructed is presented in Table 2. The variants are the same for both depot (I/O) locations - in the bottom-left corner of a warehouse and in the middle of its front aisle and both storage strategies (i.e. the Within-Aisle and the Random ones) as well.

Table 2. Variants of analysis

Size of ABC-storage class	Probability of retrieving	Order size
A/B/C 5/35/60%	A/B/C 60/20/20%	5
		10
		15
	A/B/C 70/20/10%	5
		10
		15
	A/B/C 80/15/5%	5
		10
		15
	A/B/C 90/5/5%	5
		10
		15
A/B/C 10/35/55%	Combinations of the values of particular parameters as above	
A/B/C 20/30/50%		
A/B/C 30/25/45%		
A/B/C 40/20/40%		

Source: author's research

Based on the above assumptions, the length of picking paths for each variant was calculated for every repetition of the analysis. Finally, the average values were calculated.

The length L of picking paths was calculated based on equations 1 and 2, depending on the location of the depot. Equation 1 concerns a depot located in the corner of a warehouse (the bottom-left one), while Equation 2 concerns a depot located in the middle of a front aisle. It is assumed that order pickers retrieve items from both sides of the aisles without moving sideways (move in straight lines in the exact middle of the aisles).

$$L = 2 \cdot (x - 1) \cdot (2 \cdot SL_L + Av_W) + z \cdot (Av_L + Ah_W) \quad (1)$$

$$L = 2 \cdot (x - y) \cdot (2 \cdot SL_L + Av_W) + z \cdot (Av_L + Ah_W) \quad (2)$$

where:

- L length of picking path determined using the S-shape method [meters],
- x the highest (rightmost) number of a (vertical) aisle to be traversed (aisle containing at least one item to be picked); x = 2, 3, … [–],
- y the lower (leftmost) number of a (vertical) aisle to be traversed (aisle containing at least one item to be picked); y < x, y = 1, 2, 3, …, x – 1 [–],
- z number of (vertical) aisles to be traversed; z∈{2n:n∈N} [–],
- SL_L storage location length [meters],
- Av_W aisle (vertical) width [meters],
- Av_L aisle (vertical) length [meters],
- Ah_W aisle (horizontal – front/back) width [meters].

The formulas (1) and (2) are based on the way of calculating the S-shape picking distance presented by Zhang et al. [2017], and also used by Zare Mehrjerdi et al. [2018]. However, the proposed formulas are first extended to take into account aisles' width (which is not included in the original formulations) and, secondly, corrected: the original formulas are somehow imprecise. as they assume the number of aisles in which there are pick locations that must be visited for picking (containing at least one item to be picked) is equivalent to the number of aisles (vertical ones) to be passed by/crossed. It holds true then and only then that those aisles are consecutive ones (with no aisles to be skipped due to having no items to pick). Finally, the formulas are simplified, skipping the U-turn at the last visited aisle (it is assumed that the number of traversed aisles is even – if not, one extra aisle with no picks is added). It does not matter here, since the S-shape method is not compared with the other methods of determining order-picking paths. However, it is recognized in the literature that an S-shaped route shortens the travel distance if the U-turn at the last visited aisle prevents pickers from travelling along it twice [De Koster et al. 2007]. On the other hand, the formulas (1) and (2) can be used for both one- (also narrow) and two-way aisles.

RESULTS

Tables 3 and 4 present the study results, i.e. the average length (in meters) of order-picking paths for the Within-Aisle and the Random storage strategies combined with a depot located in the corner of a warehouse (the bottom-left one) and in the middle of a front aisle, accordingly.

Table 3. The average length (in meters) of order picking paths for a depot located in the corner of a warehouse (the bottom left one)

The depot (I/O) location – the bottom left one corner of a warehouse											
Probability of retrieving A/B/C%	Order size	Size of ABC-storage classes A/B/C%									
		5/35/60		10/35/55		20/30/50		30/25/45		40/20/40	
		WA*	R*	WA	R	WA	R	WA	R	WA	R
60/20/20	5	109	126	112	126	114	124	119	129	125	125
	10	123	156	130	155	138	155	144	155	151	155
	15	141	169	143	171	152	168	156	168	164	170
70/20/10	5	47	128	52	128	75	124	85	127	92	129
	10	111	158	114	155	124	155	131	154	140	157
	15	112	170	113	170	128	169	136	167	140	169
80/15/5	5	45	127	49	125	73	126	85	126	92	128
	10	58	159	69	158	82	153	92	153	106	156
	15	108	172	113	169	124	168	134	169	141	168
90/5/5	5	32	130	32	130	42	128	64	126	75	127
	10	32	161	32	155	42	154	71	154	82	154
	15	106	172	111	171	116	168	133	169	142	170

* Within-Aisle storage strategy ** Random storage strategy
Source: authors' research

Table 4. The average length (in meters) of order picking paths for a depot located in the middle of the front aisle

The depot (I/O) location – the middle of a front aisle											
Probability of retrieving A/B/C%	Order size	Size of ABC-storage classes A/B/C%									
		5/35/60		10/35/55		20/30/50		30/25/45		40/20/40	
		WA*	R*	WA	R	WA	R	WA	R	WA	R
60/20/20	5	85	116	93	113	95	113	101	118	111	114
	10	105	151	121	150	128	150	135	150	140	149
	15	127	167	136	167	142	165	149	165	159	167
70/20/10	5	43	120	59	113	66	114	75	117	84	119
	10	91	154	98	149	105	151	119	149	128	151
	15	95	168	101	166	112	166	125	163	135	166
80/15/5	5	41	119	53	114	63	116	75	117	84	116
	10	55	156	71	152	77	147	88	148	107	150
	15	91	170	97	165	107	165	122	165	131	165
90/5/5	5	33	123	40	116	41	120	61	116	75	116
	10	33	157	41	150	41	151	69	150	82	149
	15	83	170	92	167	96	165	116	165	127	167

* Within-Aisle storage strategy ** Random storage strategy
Source: authors' research

It can be observed in Tables 3 and 4 that the average length of order-picking paths significantly varies. Much better results for shorter (by 34%) average order-picking paths were obtained for the Within-Aisle storage strategy (97 meters long on the grand average) than for the Random storage strategy (148 meters long on the grand average). That corresponds to the study by Rao and Adil [2013b], who established that a maximum of two to three classes (ABC) is sufficient to gain a significant (10-40%) improvement over the Random policy in pick travel distances for practical pick sizes. Also the better the results, the shorter the average order picking paths were obtained for the depot located in the middle of a front aisle (119 meters long on the grand average) than for the depot located in the bottom left corner of a warehouse (126 meters long on the grand average). This in turn corresponds to the research by Petersen and Schmenner [1999], who recognized the middle location to be better by 4.4%, as far as the picking distance is concerned over the corner one (here this difference is 5.9%). However, their research concerned the six methods mentioned earlier in this paper for determining the order-picking paths together, so the result is the grand average.

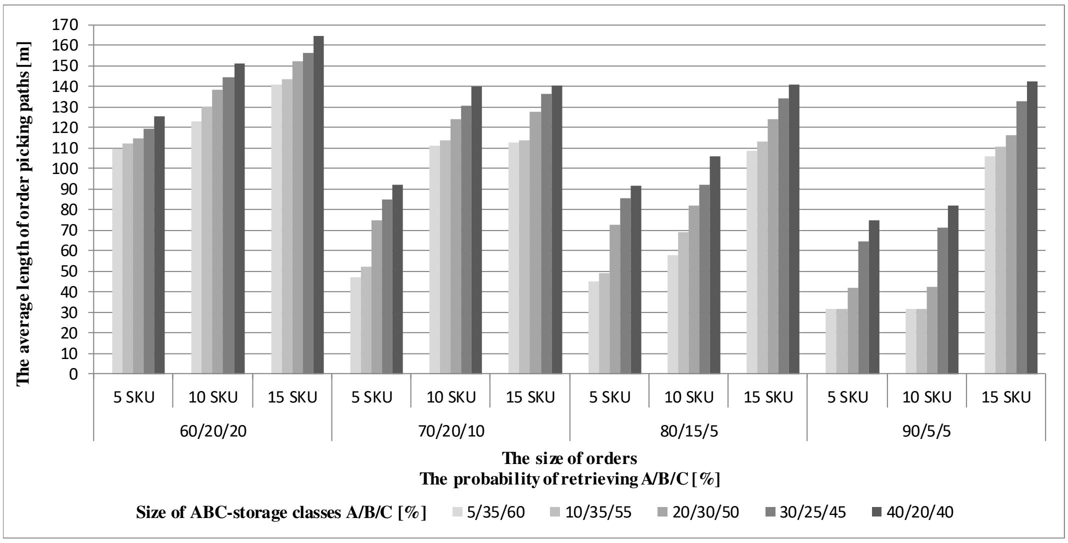
But the best results, the shortest average order-picking paths were obtained for the four variants of the order-picking system defined by the following combinations of the parameters analyzed:

- the Within-Aisle storage strategy,
- the depot located in the bottom left corner of a warehouse,
- the order sizes equal to 5 or 10,
- the sizes of ABC-storage classes equal to 5/35/60% or to 10/35/55% of all storage locations,
- the probability of retrieving items belonging to a particular ABC-storage classes equal to 90/5/5%.

These four variants of the order picking system result in the average length of the order-picking paths equal to 32 meters. Very similar or even the same results (within the error limits) were obtained for the 2 variants characterized by 5 or 10 order sizes, variants of the Within-Aisle storage strategy, sizes of ABC-storage classes equal to 5/35/60% of all storage locations, the probability of retrieving items belonging to a particular ABC-storage class equal to 90/5/5%, but with the depot located in the middle of a front aisle (33 meters).

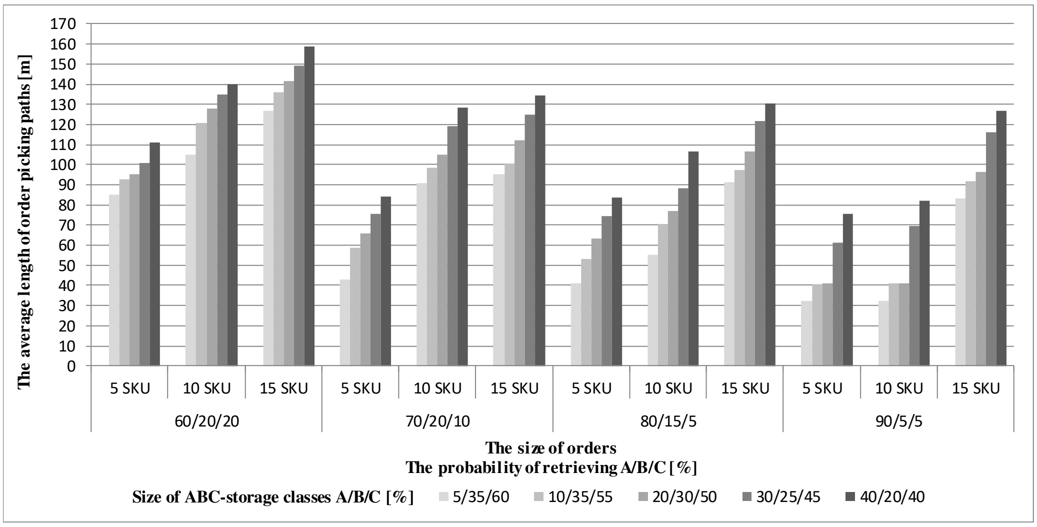
As far as the Random storage strategy is concerned, in the results obtained, the average order-picking path length was 148 meters on average. In this case, slightly better results, shorter average order-picking paths were obtained for the depot located in the middle of a front aisle (145 meters long), whereas for the depot located in the bottom-left corner of a warehouse, the average order-picking paths were 4% longer (151 meters long).

Fig. 2 and 3 present the same results in a graphical way, i.e. the average length (in meters) of order-picking paths for the Within-Aisle storage strategy combined with a depot located in the corner of a warehouse (the bottom-left one) and in the middle of a front aisle, accordingly.



Source: authors' research

Fig. 2. The average length (in meters) of order picking paths for the Within-Aisle storage strategy and the depot located in the corner of a warehouse (the bottom left one)



Source: authors' research

Fig. 3. The average length (in meters) of order picking paths for the Within-Aisle storage strategy and the depot in the middle of a front aisle

As far as the characteristics of the orders (their sizes) and inventories (sizes and probability of retrieving ABC-storage classes) are concerned, the shortest average length of order-picking paths can be found for a narrow A-storage class (covering a small number of SKUs), the high probability of retrieving items belonging to this class and short orders (with a small number of lines). The wider the A-storage class, the lower the probability of retrieving items belonging to this class and the longer the orders, the longer the picking paths. However, for the Random storage strategy, the differences in picking paths' lengths are smaller and they depend mostly on the order size than on inventory characteristics.

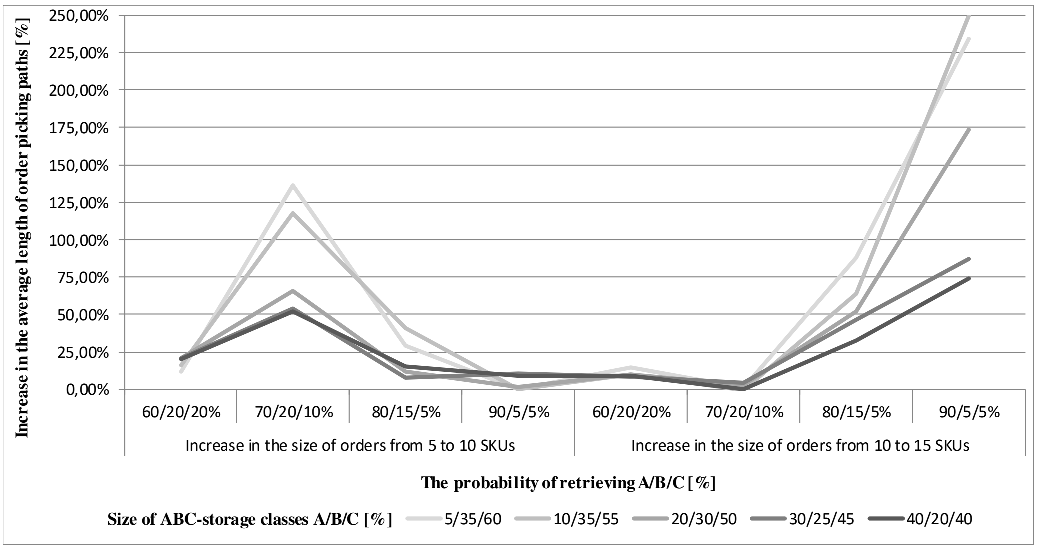
For the Within-Aisle storage strategy, the highest increase in the picking paths' length when changing the order size from 5 to 10 lines was observed for the probability of retrieving items belonging to a particular ABC-storage classes equal to 70/20/10%. However, when changing the order size from 10 to 15 lines, what was the critical for picking paths' length was the probability of retrieving equal to 90/5/5%. On the other hand, the smallest increase in the picking paths' length when changing the order size from 5 to 10 and from 10 to 15 lines was observed for the opposite probabilities of retrieving - 90/5/5% and 70/20/10%, respectively. The changes described in the picking paths' length were observed for both locations of the depot (in the corner of a warehouse and in the middle of its front aisle). In particular, the highest increase (136%) in the picking paths' length when changing the order size from 5 to 10 lines was observed for the sizes of ABC-storage classes of 5/35/60% and the depot located in the corner of a warehouse (under the probability of retrieving given above). When changing the order size from 10 to 15 lines, the length critical for picking paths increased by 250% , where the sizes of ABC-storage classes equal to 10/35/55% (at the same location of the depot and the probability of retrieving given above). For the Random storage strategy, the increase in the picking paths' length was quite different (in general, significantly smaller) in comparison to the one for the Within-Aisle storage strategy. When changing the order size from 5 to 10 lines, the picking paths' length increased by:

– 20-26% for the depot located in the corner of a warehouse,
– 26-34% for the depot located in the middle of its front aisle,
– whereas when changing it from 10 to 15 lines, the paths' length increased by:
– 7-10% for the depot located in the corner of a warehouse,
– 8-12% for the depot located in the middle of its front aisle.

Comparing the Within-Aisle and the Random storage strategies, the narrower the A-storage class and the higher probability of retrieving items belonging to it, the more significant difference in the average length of picking paths. The most significant differences were equal to:

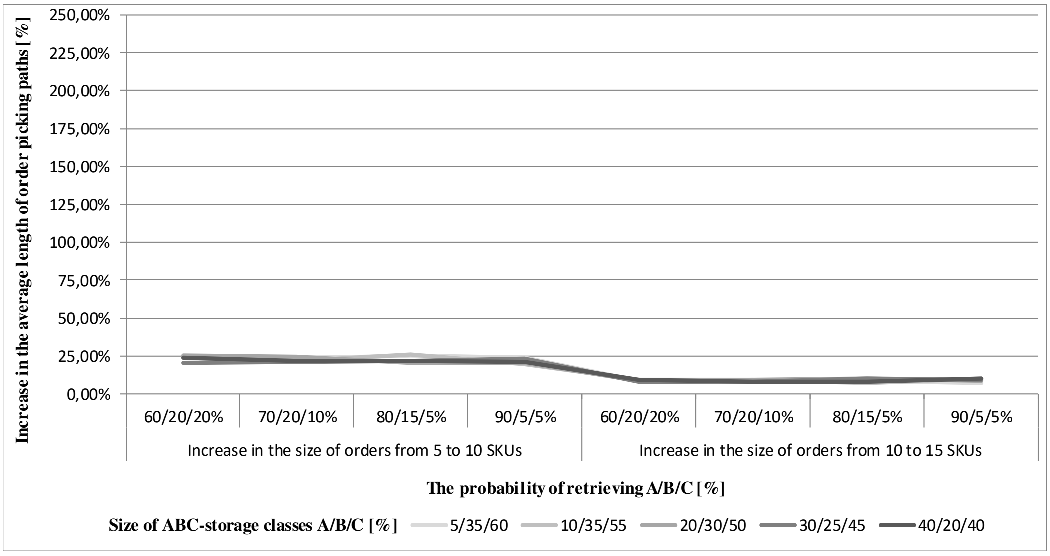
– 129 meters for the depot located in the corner of a warehouse, the size of ABC-storage classes equal to 5/35/60% and the probability of retrieving equal to 90/5/5%,
– 125 meters for the depot located in the middle of a front aisle and the same size of ABC-storage classes and the probability of retrieving.

Figs. 4-7 present the changes in the average length of order-picking paths, depending on the order size. The value (Y) axis scale in Figs. 4-7 have been set to the same range to make the charts comparable.



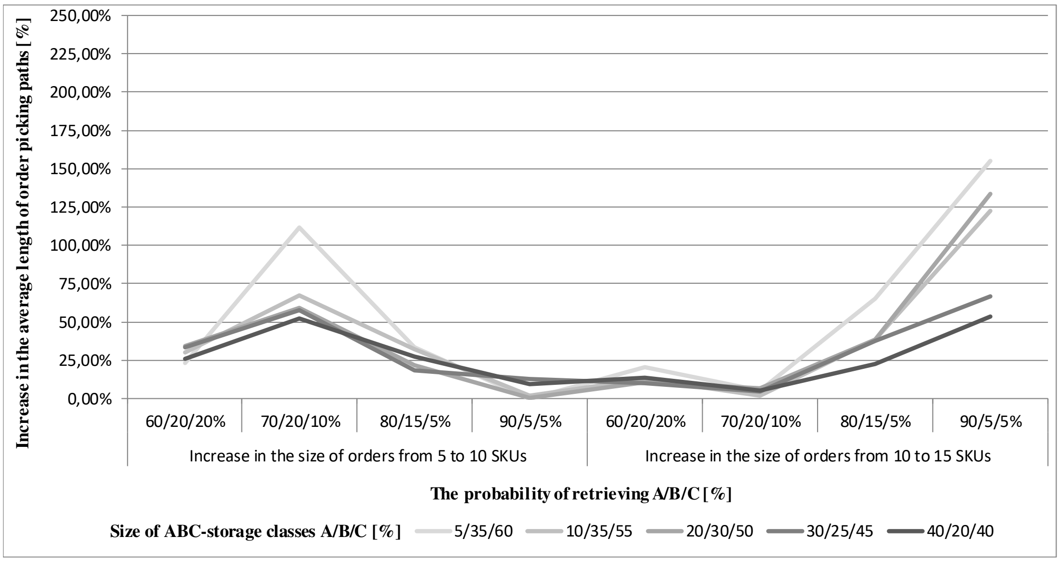
Source: authors' research

Fig. 4. The changes of the average length of order picking paths for the Within-Aisle storage strategy and the depot located in the corner of a warehouse (the bottom left one) depending on the order size



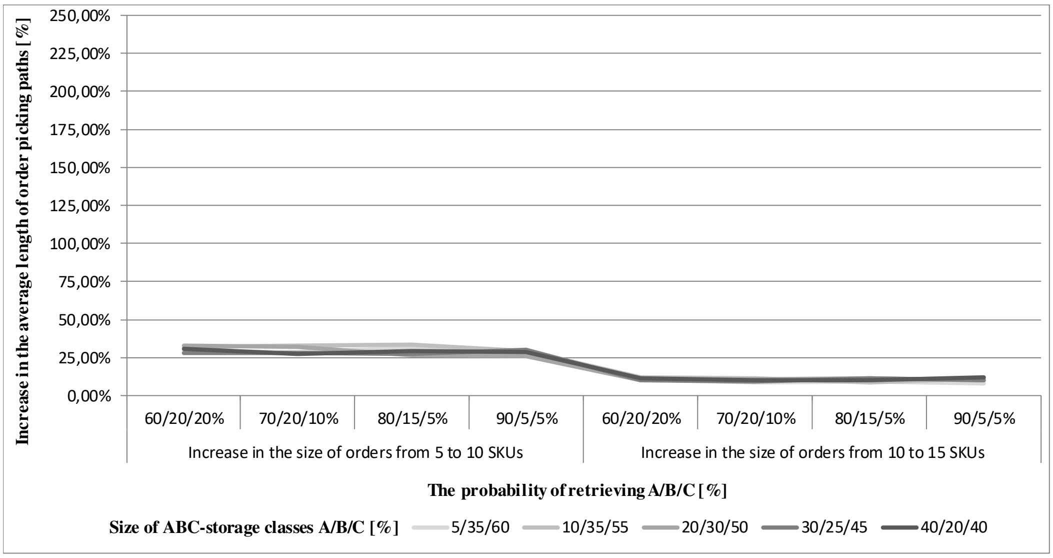
Source: authors' research

Fig. 5. The changes of the average length of order picking paths for the Random storage strategy and the depot located in the corner of a warehouse (the bottom left one) depending on the order size



Source: authors' research

Fig. 6. The changes of the average length of order picking paths for the Within-Aisle storage strategy and the depot located in the middle of a front aisle depending on the order size



Source: authors' research

Fig. 7. The changes of the average length of order picking paths for the Random storage strategy and the depot located in the middle of a front aisle depending on the order size

In general, the picking path's length is sensitive to the size of orders, which is commonly recognized (what turned out to be more crucial here were the changes from 10 to 15 than from 5 to 10 lines/items to be picked), but also to the probability of retrieving items belonging to particular ABC-storage classes. However, both the dependences are not direct ones. It can be stated than the distance to be covered depends more on the number of aisles (vertical ones) to be traversed than their (close or far) location in relation to the depot, thus the length of the horizontal aisles (front and back ones) to be covered. That is why the increase in the picking paths' length is higher when changing order size from 5 to 10 than from 10 to 15, when the Within-Aisle storage strategy is considered. This is not the case for the Random storage strategy. Extra lines on an order add more aisles to be traversed for Band C- storage classes than for class A, which is relatively narrow and thus located in the small number of aisles. For comparison, see the study by Dijkstra and Roodbergen [2017]. The authors consider a similar situation (the order sizes, in fact, numbers of picks per route of 2, 10 and 20 lines, the probability of retrieving items belonging to a particular ABC-storage classes being 80/15/5 and 50/30/20% and the size of ABC-storage classes of 20/30/50%). The results are partially coherent: more aisles (in the case of the analysis presented here and also more lines/items on orders) longer distances to be covered. However, according to Dijkstra and Roodbergen's [2017] study, the size of orders changed from 2 to 10, resulting in a much more higher increase in the picking paths' length than from 10 to 20 lines/items to be picked. Both Dijkstra and Roodbergen's [2017] analysis and the present one revealed some specific probabilities of retrieving items belonging to a particular ABC-storage classes, resulting in higher or lower increases in the length of picking paths.

CONCLUSIONS

The overriding aim of the analysis was to find the relationship between the length of picking paths determined using the S-shape method and such parameters as the storage strategy, the depot location, the order size, the ABC-storage class size and the probability of retrieving items belonging to particular ABC-storage classes (where the three last ones characterize a demand pattern). Combinations of values of these parameters defined 240 variants of a picking system analyzed.

In general, much better results and shorter average order-picking paths were obtained for the Within-Aisle storage strategy (in comparison to the Random one) for the depot located in the middle of a front aisle (in comparison to the depot located in the bottom-left corner of a warehouse).

The S-shape method for determining order-picking paths is one of the simplest and most frequently used. It is easy to implement and its logic is easy to comprehend, even for inexperienced warehouse pickers. One of the important drawbacks of this method is its inelasticity, since picking paths determined this way always have the same, characteristic shape resembling the "S" letter. As a result, this requires aisles containing at least one pick to be traversed entirely (with or without the exception of U-turn in the last, odd traversed aisle). Moreover, in some cases, it causes empty movements, but on the other hand, some aisles can be skipped due to there being no picks.

As a direction for future research, the analysis presented in this paper will be carried out for the other methods of determining order-picking paths to allow for a comparison with the S-shape one. Other (e.g. Across-Aisle) storage strategies will also be taken into consideration.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Burinskienė A., Davidavičienė V., Raudeliūnienė J., Meidutė-Kavaliauskienė I., 2018, Simulation and order picking in a very-narrow-aisle warehouse, Economic Research-Ekonomska Istraživanja, 31 (1), 1574-1589. http://doi.org/10.1080/1331677X.2018.1505532.

Coyle J.J., Bardi E.J., Langley C.J., 2002, The management of business Logistics, 7th edition, South-Western College Publishing.

De Koster R., Le-Duc T., Roodbergen K.J., 2007, Design and control of warehouse order picking: A literature review, European Journal of Operational Research, 182 (2), 481-501.

Dijkstra A.S., Roodbergen K.J., 2017, Exact route-length formulas and a storage location assignment heuristic for picker-to-parts warehouses, Transportation Research Part E, 102, 38-59.

http://doi.org/10.1016/j.tre.2017.04.003.

Dukic G., Cedomir O., 2007, Order picking methods: improving order-picking efficiency, International Journal of Logistics Systems and Management, 3 (4), 451-460.

Emmett S., 2005, Excellence in warehouse management: How to minimise costs and maximise value, John Wiley & Sons Ltd.

Gajšek B., Đukić G., Opetuk T., Cajner H., 2017, Human in manual order picking systems, in: Ćosić P. (ed.) MOTSP 2017 conference proceedings „Management of Technology – Step to Sustainable Production", Zagreb.

Garbacz M., Łopuszyński M., 2015, Optymalizacja procesu kompletacji w magazynie, część 1 i 2 (Optimization of order picking in warehouse, part 1 and 2), Logistyka, (6), 628-647.

Grosse E.H., Glock C.H., Jaber M.J., Neumann W.P., 2015, Incorporating human factors in order picking planning models: framework and research opportunities, International Journal of Production Research, 53 (3), 695-717.

Gudehus T., 1973, Grundlagen der Kommissioniertechnik – Dynamik der Warenverteil- und Lagersysteme, Verlag W. Gidaret, Essen.

Gudehus T., Kotzab H., 2009, Comprehensive Logistics, Springer-Verlag, Berlin Heidelberg.

Hall R.W., 1993, Distance approximations for routing manual pickers in a warehouse, IIE Transactions, 25 (4), 76-87.

Henn S., 2012, Algorithms for on-line order batching in an order picking warehouse, Computers & Operations Research, 39, 2549-2563.

Kostrzewski A., Kostrzewski M., 2014, Wybrane problemy związane z procesami kompletacji w magazynie [Selected problems connected to the processes of order-picking in a warehouse], Gospodarka Materiałowa i Logistyka, (5), 327-338.

Le-Duc T., 2005, Design and control of efficient order picking processes, Erasmus Research Institute of Management, Rotterdam.

Le-Duc T., De Koster R., 2005, Travel distance estimation and storage zone optimization in a 2-block class-based storage strategy warehouse, International Journal of Production Research, 43, 3561-3581.

Moeller K., 2011, Increasing warehouse order picking performance by sequence optimization, Procedia Social and Behavioral Sciences, 20, 177-185.

Oudijk D., Roodbergen K.J., De Koster R., Mekern M., 2013, Interactive Erasmus Logistics Warehouse Website – http://www.roodbergen.com/warehouse [accessed August 2019].

Parikh P.J., Meller R.D., 2008, Selecting between batch and zone order picking strategies in a distribution center, Transportation Research Part E, 44, 696-719.

Petersen C.G., 1997, An evaluation of order picking routing policies, International Journal of Operations & Production Management, 17 (11), 1098-1111.

Petersen C.G., Aase G.R., 2017, Improving order picking efficiency with the use of cross aisles and storage policies, Open Journal of Business and Management, 5, 95-104. http://doi.org/10.4236/ojbm.2017.51009.

Petersen C.G., Schmenner R.G., 1999, An evaluation of routing and volume-based storage policies in an order picking operation, Decision Sciences, 30 (2), 481-501.

Rao S.S., Adil G.K., 2013a, Class-based storage with exact S-shaped traversal routing in low-level picker-to-part systems, International Journal of Production Research, 51 (16), 4979-4996.

Rao S.S., Adil G.K., 2013b, Optimal class boundaries, number of aisles, and pick list size for low-level order picking systems, IIE Transactions, 45, 1309-1321. http://doi.org/10.1080/0740817X.2013.772691.

Roodbergen K.J., Vis I.F.A., 2006, A model for warehouse layout, IIE Transactions, 38, 799-811. http://doi.org/10.1080/07408170500494566

Sadowsky V., Hompel M., 2011, Calculation of the average travel distance in a low-level picker-to-part system considering any distribution function within the aisles, Logistics Journal, (01). http://doi.org/10.2195/2011_03_sadowsky

Tompkins J.A., White J.A., Bozer Y.A., Tanchoco J.M.A., 2010, Facilities planning, 4th edition, John Wiley & Sons, New York.

Zając J., 2014, Kompletacja jednostopniowa a dwustopniowa – wydajność kompletacji a aspekty organizacyjne [Single-stage and two-stage picking – picking performance and organizational aspects], Logistyka, (2), 44-50.

Zare Mehrjerdi Y., Alipour M., Mostafaeipour A., 2018, Integrated order batching and distribution scheduling in a single-block order picking warehouse considering S-shape routing policy, IJE TRANSACTIONS A: Basics, 31 (10), 1723-1733.

Zhang J., Wang X., Chan F.T.S., Ruan J., 2017, On-line order batching and sequencing problem with multiple pickers: A hybrid rule-based algorithm, Applied Mathematical Modelling, 45, 271-284.

ANALIZA DŁUGOŚCI ŚCIEŻEK KOMPLETACJI WYZNACZANYCH METODĄ S–SHAPE

STRESZCZENIE. **Wstęp:** Kompletacja to podstawowa czynność realizowana w magazynach. Koszty kompletacji stanowią ponad 60% kosztów magazynowania, a jej najbardziej pracochłonnym elementem jest przemieszczanie się pracowników. Dlatego planowanie ścieżek kompletacji odgrywa tak ważną rolę. Najczęściej stosowną tu metodą jest metoda S-shape.
Metody: Celem oceny długości ścieżek kompletacji dla różnych parametrów strefy składowania (lokalizacja pola odkładczego, strategia składowania), składowanych zapasów (wielkość grup asortymentowych ABC i prawdopodobieństwo pobrania) i zamówień klientów (liczba linii – 5, 10, 15) zdefiniowano 240 wariantów analizy i dla każdego z nich wykonano 100 symulacji ścieżki kompletacji wyznaczając jej średnią długość. Analizy przeprowadzono z wykorzystaniem arkusza kalkulacyjnego MS Excel oraz makr (VBA).
Wyniki: Zestawienie długości ścieżek kompletacji dla magazynu jednoblokowego o 320 miejscach składowania (wg strategii Within-Aisle i losowej) oraz kompletacji z poziomu podłogi. Uwzględniono lokalizację pola odkładczego w narożniku magazynu oraz na środku przedniej alejki głównej. Długość ścieżek kompletacji okazała się mocno zmienna zależnie od analizowanego wariantu. Najkrótsze ścieżki kompletacji zaobserwowano dla strategii składowania Within-Aisle, pola dokładczego zlokalizowanego w narożniku magazynu, liczby linii na zamówieniu 5 lub 10 oraz grup asortymentowych ABC o wielkości 5/35/60% lub 10/35/55% wszystkich 320 lokacji przy prawdopodobieństwie pobrania asortymentów z każdej z grup 90/5/5%.
Wnioski: Istnieją lepsze i gorsze warianty kompletacji wpływające istotnie na długość ścieżek planowanych metodą S-shape. Generalnie mniejsze znaczenie ma tu lokalizacja pola odkładczego (jakkolwiek najlepsze rozwiązanie uzyskano dla lokalizacji w narożniku magazynu, to lokalizacja na środku przedniej alejki głównej daje przeciętnie krótsze ścieżki kompletacji), a większe strategia składowania. Brak tej strategii (losowość) istotnie wydłuża długość ścieżek kompletacji (średnio o 50%).

Słowa kluczowe: magazynowanie, kompletacja, metoda S-shape, długość ścieżek kompletacji

Adam Redmer ORCID ID: https://orcid.org/0000-0003-2154-232X
Division of Transport Systems
Institute of Machines and Motor Vehicles
Faculty of Transportation Engineering
Poznan University of Technology
3 Piotrowo street, 60-965 Poznan, **Poland**
phone: +48 61 665 21 29
e-mail: adam.redmer@put.poznan.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (1), 47-60

http://doi.org/10.17270/J.LOG.2020.384

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

THE ROLE OF CLAN IN THE HYBRID AND ALTERNATIVE MODES OF SUPPLY CHAIN GOVERNANCE

Artur Świerczek

University of Economics in Katowice, Katowice, **Poland**

ABSTRACT. **Background:** Recent studies in the domain of supply chain management underline the significance of the contractual and relational aspects of governance, at the same time ignoring the relevance of classical hierarchy. To respond to this challenge, our study posits that the market and hierarchy are both embedded in the wider social context, and as such they can only apply to some degree of relational aspects, referred in this research to as clan. Concomitantly, clan rarely acts as a sole mode of supply chain governance; quite the contrary, it can be either a hybrid (anchored between market and hierarchy) or an alternative (neither market nor hierarchy) mode of governance. By returning to the classical roots of governance of market and hierarchy as two bipolar modes, the goal of the paper is to compare diverse modes of supply chain governance (with the emphasis on the hybrid and alternative modes) in terms of the strength of clan.

Methods: The study involves two stages of multivariate statistical analysis. In the first step, the variables indicating certain modes of market and hierarchy of upstream and downstream dyads were narrowed down to the main underlying multi-item constructs through Principal Component Analysis (PCA) with Varimax Rotation. In the second step of the analysis, the factor scores obtained through the PCA for market and hierarchical governance were used in cluster analysis.

Results: The study reveals that the hybrid modes of governance (especially relational governance) anchored between bipolar modes of market and hierarchy demonstrate a higher portion of clan in comparison to hierarchy as the sole mode of governance in triadic supply chains. At the same time, triadic supply chains run by both market and hybrid governance do not differ from each other, as they indicate similar and significantly higher mean ranks for clan. The study reveals that the alternative (neither market nor hierarchical) modes of governance do not indicate higher portion of clan as compared to market and hierarchy as two sole modes of governance in triadic supply chains.

Conclusions: The study shows that as the mode of governance clan takes a leading role in the hybrid modes of governance as compared to the alternative mechanisms. This may suggest that either the hybrid modes are much stronger enhanced by social dimensions encapsulated in clan than the alternative modes or the essence of clan in the hybrid modes is not the same as the essence of clan in the alternative modes of governance. Consequently, we conclude that the silver bullet for solving this problem may reside within the nature of clan, which is significantly different in both modes of governance.

Key words: market governance, relational governance, hierarchy.

INTRODUCTION

The concept of supply chain management shows the simultaneous pursuit of multiple governance mechanisms to overcome trade-offs and leads to synergistic results [Denolf et al. 2015, Dolci et al. 2015, Crisan 2016, Ghozzi et al. 2016, Dolci et al. 2017, In et al. 2019]. In recent studies, the relational aspects combined with market governance have rapidly risen to prominence. For instance, Blome et al. [2013] extend ambidexterity research to the supply chain management domain by focusing on ambidextrous governance, defined as the simultaneous pursuit of both relational and market governance elements. By the same token, Brito and Miguel [2017] investigate the two modes of governance from the perspective of power

Citation: Świerczek A., 2020. The role of clan in the hybrid and alternative modes of supply chain governance. LogForum 16 (1), 47-60, http://doi.org/10.17270/J.LOG.2020.384

Received: 20.09.2019, Accepted: 25.10.2019, on-line: 30.12.2019.

asymmetry and its impact on value creation. Similarly, Mirkovski et al. [2016] explore the influence of both market and relational governance on the ICT-enabled information sharing of small and medium firms in developing economies. The above studies mainly revolve around the market and relational modes, thus particularly ignoring the significance of classical hierarchy. As the market and hierarchy are both embedded in the wider social context, we postulate that they can only apply to some portion of relational aspects [Ouchi 1980]. Consequently, the actors strive to stick to the norms of supply chains, as larger systems, through socialization efforts. This normative process can be defined as clan governance (Heide, 1994). Clan governance underscores the necessity of self-awareness among the actors, that is, the interests of one actor cannot be furthered by stratagems of any sort [Ghoshal, Insead 1996]. Accordingly, drawing upon the prior studies, this research posits that clan rarely acts as the sole mode of supply chain governance, because it may lead to so-called 'overembeddedness', bringing about negative inertia and lower performance [Uzzi 1996]. Similarly, Vilena et al. [2013] evidence that when clan is taken to an extreme, it can reduce the ability to be objective and make effective decisions, increase opportunistic behavior, and ultimately harm performance. Likewise, prior research indicates that clan can be either a hybrid (anchored between market and hierarchy) or alternative (neither market nor hierarchy) mode of governance [Powell 1990, Jones et al. 1997]. To yield several hybrid modes of governance, market and hierarchy, two basic modes of governance, are intertwined and combined together in various ways. They usually contain some degree of relational aspects indicating the extent to which an interorganizational relationship is governed by social relations and shared norms, such as informal structures and self-enforcement [Mirkovski et al. 2016]. Consequently, by adhering to the twin pillars of market and hierarchy, this study compares the strength of clan across different modes of supply chain governance, with a particular emphasis on the hybrid and alternative modes. Moreover, empirical studies on the modes of governance, especially market governance, are preoccupied with the dyadic perspective, so that, in consequence, the wider network view is "given short shrift" [Williamson 1994, Jones et al. 1997]. This is an important issue, as networks operate on the logic of embeddedness, while the market is built upon the logic of economic exchange. To respond to this challenge, our study employs the triadic context, as the exemplary network form, by investigating the triadic (three-tier) supply chains, composed of the manufacturer positioned between its supplier and customer.

Accordingly, in the next section of the paper, the theoretical framework is presented, followed by a description of the research methodology. The following part contains the findings and a discussion. Finally, the major conclusions from the research are drawn.

THEORETICAL BACKGROUND

Historically, a dichotomous perspective covering the market and hierarchy as bipolar modes is perceived to be the starting point for elaborating on the hybrid mechanisms of supply chain governance. In line with the original framework developed by Williamson [1975], the governance decisions are fundamentally a choice between the market and hierarchy.

The mode of market governance as a price-based mechanism aims to establish contractual relationships over property rights [Poppo, Zenger 2002]. These contracts serve two functions. First, they seek to control opportunism, stemming from misaligned actions, and second, they tend to coordinate the expectations and behavior of actors [Malhotra, Lumineau 2011]. Market governance thus provides a high degree of flexibility to the companies so that they can remain independent and terminate the relationships established with other actors any time they are willing to. Hierarchy, as another mode of governance, is positioned at the other end of the market-hierarchy continuum. It seeks to overcome the problems of non-engaged and loose relationships typical for market governance. Therefore, hierarchy emphasizes a necessity to impose a supervisory structure and apply bureaucratic routines. It specifically refers to the level of control determined by explicit rules, procedures and standards that establish the rights and obligations of actors in supply chains [Choi, Hong 2002]. In this way, hierarchy assumes that the companies are more engaged in established and committed long-lasting relationships [Lowndes, Skelcher 1998, Pilbeam et al. 2012]. However, on the other hand, it may reduce flexibility and innovation due to the higher level of formalization and centralization of power [Powell 1990]. Between these two extremes of the market-hierarchy continuum are interplay and the complementarity. Consequently, they produce hybrid modes of governance to be located between market and hierarchy [Jarillo 1988]. For instance, Heide [1994] identifies bilateral governance, positioned between bipolar modes of market and hierarchy, whereas Williamson [2008] distinguishes among muscular, benign and credible governance mechanisms. Correspondingly, Gereffi et al. [2005] recognize three mediating modes of modular, relational and captive governance, anchored between two extremes of market and hierarchy. On the other hand, Peterson et al. [2001] use the concept of governance to identify a wide spectrum of relationships, including contracts, relation-based alliance and equity-based alliance, which take into account the attributes of transaction and environment. Jones et al. [1997] recommend that these hybrid modes fall under a common umbrella of network governance. In essence, network governance is characterized by informal social ties rather than bureaucratic structures typical for hierarchy and the formal contractual relationships distinctive for the market. Network is hence composed of close-knit groups of actors that maintain and sustain exclusive relationships with one another [Uzzi 1996]. Therefore, to conduct an in-depth analysis, we employ the triadic supply chain perspective in our study by investigating triads composed of two dyads with the manufacturer, as the middle actor linking both dyadic arrangements - one established with the supplier in the upstream dyad, and the other one with the customer, in the downstream dyad [Li, Choi 2009]. This kind of triad pertains to the basic triadic supply chains formed by three sequentially interconnected actors (supplier, manufacturer, customer) that establish linear product and information flows [Mentzer et al., 2007]. Network governance, in line with the Ouchi's notion of clan, refers to a kin-type network which is not necessarily based on blood relations [Orru 1996]. As a mode of governance, clan is produced by the embedded pattern of exchange ties [Powell 1990]. Embeddedness shifts actors' motivations from a narrow pursuit of achieving short-term goals to enriching the relationships with trust and reciprocity [Uzzi 1996]. In essence, "Embeddedness refers to the fact that economic action and outcomes ... are affected by actors' dyadic (pairwise) relations and by the structure of the overall network of relations" [Granovetter, 1992]. Embeddedness therefore suggests that no organization is 'suspended in a vacuum' and each operates under the influence of the social network in which the companies are embedded. In the supply chain context, embeddedness can be defined as the extent to which a firm relies on a network of other actors [Kim 2014a]. Clan highlights that purely economic exchanges may be shaped by social capital, which is a tacit resource attainable by individual actors through the networks of relationships [Whipple et al. 2015]. In other words, embeddedness creates opportunities for economic exchanges of goods which are difficult to price and enforce contractually [Uzzi 1996]. In the course of time, a discussion unfolded as to whether clan should be rather understood as a unique, non-market and non-hierarchical, and thus not an intermediate form of governance, possessing complementary, multi-relational and reciprocal characteristics [Powell 1990]. In line with this view, clan is rather considered to be positioned between neither market nor hierarchical modes of governance. In the light of the above, regardless of the distinct opinions concerning the position of clan on the market-hierarchy continuum, we posit that hybrid modes of governance, anchored between market and hierarchy, as well as neither market nor hierarchical modes of governance are enriched with social ties, trust and reciprocity in the triadic supply chains. Thus, we postulate the following hypotheses:

H1: The hybrid modes of governance, anchored between bipolar modes of market and hierarchy, demonstrate higher portion of clan in comparison to market and hierarchy as the sole modes of governance in the triadic supply chains.

H2: The alternative (neither market nor hierarchical) modes of governance indicate higher portion of clan as compared to market and hierarchy as two sole modes of governance in the triadic supply chains.

METHODOLOGY

Sample and Data Collection

To test the hypotheses stated above, data were collected from all three actors forming the triadic supply chain. To gather the necessary information, we combined probability and non-probability sampling to collect data from the manufacturers and two remaining actors, respectively. First, stratified sampling was employed to conduct a study of a group of 98 Polish manufacturers, followed by the snowball sampling method used to obtain data from the suppliers and customers. These two groups were indicated by the manufacturers. Out of 98 manufacturing companies, 10 firms refused to fill in the questionnaire, maintaining that their suppliers or customers would not be willing to participate in this sort of research. Likewise, a large group of 50 manufacturers encountered problems with a bad attitude towards the questionnaire among suppliers or customers. Finally, 4 manufacturers managed to encourage their suppliers and customers to participate in the survey. However, after receiving the questionnaire, they refused to take part in the research. Consequently, the remaining 34 triads that establish a simultaneous relationship with both a supplier and a customer were investigated in the study.

Survey Administration and Measures

To conduct the survey, a questionnaire consisted of several measurement items covering the issues of market and hierarchy, as two bipolar modes of governance, and clan. Most of the measurement items were operationalized in prior research; however, some of them were derived from the literature review (Table 1). The structure of the survey questionnaire was adapted to certain groups of respondents – actors playing different roles in the examined triadic supply chains. Accordingly, depending on the function served in a triad, each responding company answered a specific set of questions. Due to its central location, the manufacturer answered the questions concerning different modes of governance (market, hierarchy and clan) in the upstream and downstream dyad, separately for both dyads – one formed with its supplier, and the other one established with its customer. The other two groups of actors in a triad, the suppliers and the customers, answered the questions concerning governance yielded in a certain dyad formed with the manufacturer, respectively.

Two groups of measures were used that demonstrate the market and hierarchical modes of governance in reference to both dyads separately. Drawing upon the prior studies [Noordewier et al. 1990, Wang 2002, Mirkovski et al. 2016], the set of following 5 indicators manifesting market governance: the use of price as a predominant factor that determines the interorganizational collaboration; active searching for new partners who can potentially substitute the current ones; easiness to switch to another partner, dropping out the collaboration with the existing one; easiness to deliver the products by competitors; easiness to replace the current partner, if it does not offer good deals. Building on previous research [Eccles et al. 1992, Grant 1996, Jones et al. 1997, Ashenbaum et al. 2009], the following set of 5 indicators demonstrated hierarchy: active interference in the operations performed by the partner; using certain formal methods to control the partner; exposure to high costs when switching the partner; providing the partner with formal guidelines concerning how to solve problems and/or deal with disruptions; resolving ongoing disputes with the partner by referring to clauses in signed contracts. Further on, the review of past studies [Mesquita et al. 2008, Liu et al. 2009] brought the following group of 4 measures reflecting clan, as the third basic mode of governance: striving to build trust and sense of community by organizing meetings and trainings to encourage the partner to share empathy and mutual understanding; maintaining a discussion with the partner which concerns all relevant issues of its operations and strategy; trying to develop trust with the partner; resolving the disruptions in collaboration with the partner in the spirit of mutual understanding.

Table 1. An Excerpt of the Questionnaire

Categories	No.	Abbreviation	Question
Please rate mechanisms of network governance with reference to company B in the following areas: (1- 'strongly disagree', 3- 'neutral', 5- 'strongly agree')			
1. Market	4.1.	MUD_1/MDD_1	The price is a predominant factor that determines my collaboration with B
	4.2.	MUD_2/MDD_2	My company is very active in searching for new partners who can potentially substitute B
	4.3.	MUD_3/MDD_3	My company can easily switch to another partner, dropping out the collaboration with B
	4.4.	MUD_4/MDD_4	The goods delivered by my company to B can be easily delivered by my competitors
	4.5.	MUD_5/MDD_5	My company keeps reminding our partner that it can be easily replaced, if it does not offer good deals
2. Hierarchy	5.1.	HUD_1/HDD_1	My company very actively interfere in the operations performed by B
	5.2.	HUD_2/HDD_2	My company controls B using certain formal methods
	5.3.	HUD_3/HDD_3	My company would be exposed to high costs when switching B
	5.4.	HUD_4/HDD_4	My company provides B with formal guidelines concerning how to solve problems and/or deal with disruptions.
	5.5.	HUD_5/HDD_5	My company resolves ongoing disputes with B by referring to clauses in signed contracts
3. Clan	6.1.	CUD_1/CDD_1	My company strives to build trust and sense of community by organizing meetings and trainings to encourage B to share empathy and mutual understanding
	6.2.	CUD_2/CDD_2	My company maintains a discussion with B which concerns all relevant issues of its operations and strategy
	6.3.	CUD_3/CDD_3	My company keeps trying to develop trust with B
	6.4.	CUD_4/CDD_4	Disruptions in collaboration with B are productively resolved in the spirit of mutual understanding

The responses obtained from both actors forming a dyad were then captured as average scores indicating the modes of governance in a bilateral arrangement. Correspondingly, the measures of clan were established by the average scores obtained separately for both upstream and downstream dyads in the triadic supply chain.

Research Methods and Analysis

To investigate the role of clan in supply chain governance, a two-step statistical analysis was performed. In the first step, the variables indicating certain modes of market and hierarchy of upstream and downstream dyads were narrowed down to the main underlying multi-item constructs through Principal Component Analysis (PCA) with Varimax Rotation. In the second step of the analysis, the factor scores obtained through PCA for market and hierarchical governance were used in the cluster analysis. First, a hierarchical cluster analysis was employed to determine the number of clusters, followed by K-means cluster analysis to perform group profiling and make necessary comparisons between the clusters in terms of the items manifesting clan in the upstream and downstream dyads.

Principal Component Analysis

To identify the basic modes of governance in the triadic supply chains, the PCA was carried out originally in two groups of variables, which manifested governance of both upstream and downstream dyads. Each group was comprised of 11 variables reflecting market and hierarchical governance. In the group of variables concerning governance in the upstream dyad, one variable was dropped for its moderate exploratory relevance, as its factor loading that did not exceed 0.6 (Kline, 1994). The remaining ten variables in the first group indicated satisfying values of individual sampling adequacy and factor loadings. In the second group of items concerning the downstream dyad, all variables were accepted for further analysis, as they demonstrated satisfying values of individual sampling adequacy and factor loadings. Based on the Kaiser criterion and own values for each factor, the analysis showed a clean factor-loading pattern with minimal cross-loadings and high loading on the one construct.

In both groups reflecting the modes of governance in the upstream and downstream dyads, the PCA produced three constructs - two constructs of hierarchical governance and one construct of market governance – Table 2.

Table 2a. Rotated Component Matrices for the upstream dyad

	Component		
	HUD_1	MUD	HUD_2
M5_UD	0.917		
H1_UD	0.898		
H2_UD	0.786		
H3_UD	0.694		
M1_UD		0.881	
M4_UD		0.834	
M2_UD		0.786	
H5_UD			0.927
H6_UD			0.893
H4_UD			0.737

More specifically, the constructs of governance in the upstream dyads (hierarchical modes of upstream dyad - HUD_1 and HUD_2, and market mode of upstream dyad - MUD) and downstream dyads (hierarchical modes of downstream dyad - HDD_1 and HDD_2, and market mode of downstream dyad - MDD) explain 77.90 and 76.44 of total variance, respectively. Interestingly, almost all variables were logically classified to their corresponding constructs. In other words, the items demonstrating market governance, except for one variable (M5), were grouped into the market governance construct in both types of dyads, while all items manifesting hierarchy were split into two constructs in both dyads.

Table 2b. Rotated Component Matrices for the downstream dyad

	Component		
	MDD	HDD_1	HDD_2
M4_DD	0.920		
M2_DD	0.902		
M3_DD	0.825		
M1_DD	0.702		
H2_DD		0.890	
H1_DD		0.851	
M5_DD		0.824	
H3_DD		0.624	
H5_DD			0.917
H6_DD			0.884
H4_DD			0.834

The Cronbach's alpha coefficients were then estimated to check the internal consistency of extracted constructs. For each of all three governance constructs in both dyads, the Cronbach's alpha coefficients demonstrated a satisfying level of at least 7.

Cluster Analysis

Characteristics of Clusters

The scores obtained for all constructs manifesting governance were employed as clustering criteria in the second step of the analysis. At first, to determine the number of clusters a hierarchical cluster analysis with Ward's partitioning method and squared Euclidean distance was performed. Ward's method attempted to minimize the sum of squares of any hypothetical clusters, which can be formed at each step. To determine the optimal number of groups, we used a dendrogram to display dissimilarity levels between clusters – Figure 1. The heights of the links represent the distance at which each fusion is made, so that a greater dissimilarity between the objects indicates a greater distance between them and a taller link [Montalbano, Nenci 2014]. The optimal number of groups was derived by comparing the coefficients in the agglomeration schedule [Ketchen, Shook 1996]. The greatest difference between the coefficients can be observed when four clusters are derived. To assign each case to the appropriate cluster, the number of 4 clusters was used to conduct K-means cluster analysis. The criterion of the cluster membership was the minimal Euclidean distance between each case and classification center represented by centroid (cluster center). To validate the results of clustering, the outcome of K-means cluster analysis was compared with the class assignment obtained from the hierarchical cluster analysis. The Rand Index showed that 78.4 percent of pairs of objects are placed in the same class. It means a high level of agreement and confirming the correct choice of K-means cluster analysis as the leading clustering method [Krieger, Green 1999].

Based on the intensity of constructs manifesting certain modes of governance, very interesting results across the four clusters might be delineated (Figure 2). First, two out of four clusters unequivocally cover the triadic supply chains governed by sole mechanisms of market (cluster 2) and hierarchy (cluster 4). On the other hand, two remaining groups include the triadic supply chains governed by hybrid modes of governance (cluster 3), whereas cluster 1 consists of supply chains governed by neither market nor hierarchy. Correspondingly, it is also worth mentioning that the clusters of triadic supply chains demonstrate consistency in terms of the modes of governance across both dyads. In other words, the upstream dyad is governed by the same mode as the downstream dyad in the particular triad grouped into each of four constructs. For instance in cluster 2, both dyads are governed by the high intensity of market governance, whereas in cluster 4 both dyads are run by the high intensity of hierarchy. Very similar tendencies might be observed when considering the remaining two clusters.

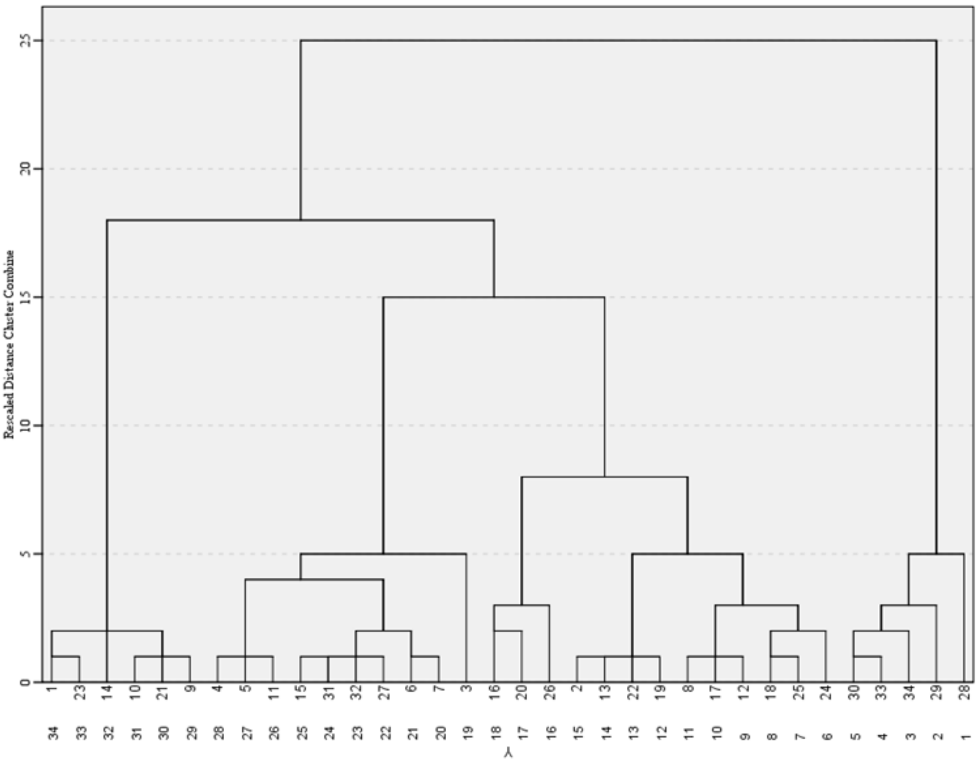


Fig. 1. Dendrogram using Ward Linkage

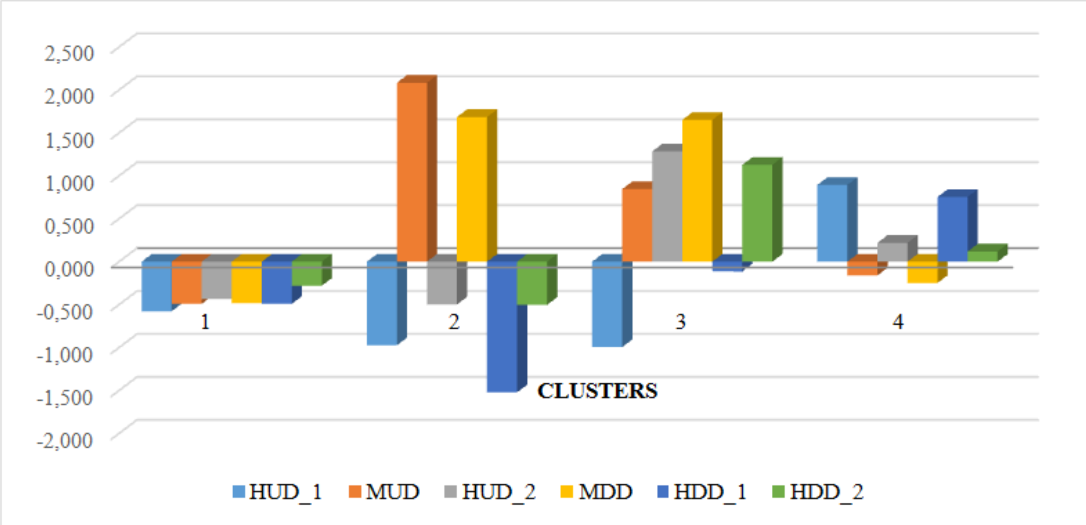


Fig. 2. The characteristics of clusters regarding the intensity of the modes of governance

RESEARCH FINDINGS AND DISCUSSION

In order to reveal the strength of clan in the triadic supply chains applying different modes governance, we first tested whether the differences among clusters are significant for clan in the upstream and downstream dyads. Then, the Mann-Whitney U mean ranks for clusters in the upstream and downstream dyads were estimated, as depicted in Table 3.

Drawing upon the results obtained, the clusters of triadic supply chains governed by both the hybrid and market modes demonstrate significantly higher mean ranks. In actual fact, as shown in Table 3, both groups do not differ significantly from each other in terms of variables reflecting clan, and their significant ranks take rather similar values across all clusters. Therefore, building on previous studies, we conclude that the hybrid modes of governance investigated here might be described primarily as relational governance. In this vein, Josi and Campbell [2003] acknowledged that relational governance can be defined as the extent to which the supply chain actors employ relational norms and joint actions, to establish relationships full of commitment, openness, reciprocity, and goal congruence that aim to curb opportunism and selfishness. For that reason, relational governance is often referred to as "informal, self-enforcing governance" [Dyer, Singh 1998]. Interestingly, however, in the light of the findings, the same characteristics might also be assigned to market governance. This may stem from the fact that both market and hybrid governance share a number of common characteristics that describe these two modes. For instance, market governance offers adaptability and flexibility [Powell 1990], which can also be distinctive for the hybrid mode of governance. By the same token, Heide and John [1992] maintain that relational governance is an important hybrid structure that allows exchange partners to adapt flexibly in responding to uncertainty. In the same vein, Wang and Wei [2007] provide evidence that relational governance benefits information visibility and enhances supply chain flexibility. Also, more generally, the findings are also supported by previous studies underscoring that market governance is embedded within social and cultural circles. Consequently, "market is not an amoral self-subsistent institution, but a cultural and social construction" [Powell 1990]. We believe that the above arguments at least partially substantiate and elucidate why the clusters of triadic supply chains, which are run by both hybrid and market modes of governance, demonstrate similar and significantly higher mean ranks for clan.

Table 3. Mann-Whitney U test ranks for clusters in the upstream and downstream dyads†

Cluster		Mean Ranks (Upstream dyad)				Mean Ranks (Downstream dyad)			
No.	Description	Building trust and sense of community	Discussion on relevant issues	Keep trying to develop trust	Resolving disruptions in the spirit of understanding	Building trust and sense of community	Discussion on relevant issues	Keep trying to develop trust	Resolving disruptions in the spirit of understanding
1	Alternative			7.04 **	7.23 *			7.00 **	7.00 **
2	Market			14.83 **	14.00 *			15.00 **	15.00 **
1	Alternative	7.27 *	7.00 **	7.04 **	7.31 *	7.00 **	7.00 **	7.00 **	7.00 **
3	Hybrid	13.83 *	15.00 **	14.83 **	13.67 *	15.00 **	15.00 **	15.00 **	15.00 **
1	Alternative		11.04 *		17.73 *		10.12 **		
4	Hierarchy		17.50 *		11.70 *		18.30 **		
2	Market								
3	Hybrid								
2	Market			16.33 *	16.33 *			16.00 *	16.33 *
4	Hierarchy			8.13 *	8.13 *			8.20 *	8.13 *
3	Hybrid			16.33 *	16.33 *			16.00 *	16.67 **
4	Hierarchy			8.13 *	8.13 *			8.20 *	8.07 **

† Only significant ranks are shown
* Assymp. Sign. (two-tailed) at $p < .05$
** Assymp. Sign. (two-tailed) at $p < .01$
*** Assymp. Sign. (two-tailed) at $p < .001$

On the other hand, the remaining two clusters of triadic supply chains – one governed by the sole mode of hierarchy, and the other one run by neither market nor hierarchy appear to be rather similar regarding the basic characteristics of clan. Specifically, the findings obtained here suggest relative scepticism of triadic supply chains run by hierarchy towards establishing the social ties. This research outcome is clearly highlighted by Vlachos [2014], who argues that running hierarchy is not a straightforward governance process in supply chains as it involves a degree of exposure and sharing, and not all companies keep doors open to external actors. Among the barriers of hierarchical governance in supply chains one may enumerate: deficiency of trust and awareness, fear of missing out control over the internal processes, incongruence of goals, short-term orientation [Barratt 2004, Ellinger et al. 2006]. This probably makes the triadic supply chains governed by hierarchy rather reluctant towards incorporating the clan context into their operations, as compared with the market and hybrid clusters. In the light of the aforementioned, the findings only partially support H1. More specifically, the hybrid modes of governance (especially relational governance), anchored between bipolar modes of market and hierarchy demonstrate a higher proportion of clan in comparison to hierarchy as the sole mode of governance in the triadic supply chains. Concomitantly, the triadic supply chains run by both market and hybrid governance do not differ from each other, as they indicate similar and significantly higher mean ranks for clan.

Interestingly, however, a more in-depth analysis of the findings may also suggest that the cluster gathering the triadic supply chains run by neither market nor hierarchy shows, in fact, the lowest mean ranks, compared to all remaining groups. More importantly, the study reveals that alternative (neither market nor hierarchical) modes of governance do not indicate a higher proportion of clan as compared to market and hierarchy as two sole modes of governance in the triadic supply chains. In the light of the above, the findings do not give support to H2. As evidenced in the study, the alternative modes of governance differ significantly from the hybrid modes of governance in terms of all variables manifesting clan. This clearly suggests that both clusters of triadic supply chains are not the same. The simplest explanation for this finding is that the hybrid modes are much more strongly enhanced by the social dimensions encapsulated in clan than the alternative modes. However, when looking for a more-in-depth explanation, we assert that the essence of clan in the hybrid modes can differ significantly from the essence of clan in alternative modes of governance. This is a very striking finding obtained from the empirical analysis adding an apparent novelty to the prior conceptual studies. For the last few decades, the discussion has revolved around whether clan is a hybrid or alternative mode of governance [Williamson 1985, Ouchi 1980, Powell 1990]. Departing from this issue, Demil and Lecocq [2006] developed the concept of bazaar governance, which indicates distinct features in terms of coordination. By employing the coordination characteristics of the means of communication (coordination mechanism governing the exchange), intensity of incentives and intensity of control, one may distinguish between some common but also some distinct features of bazaar and clan governance [Susha et al. 2017].

In this study, some variables appear to be much better indicators of clan than others across the clusters of supply chains that were investigated. For instance, trying to develop trust with the other actor in a dyad as well as resolving the disruptions in the spirit of mutual understanding is more significant for partitioning the research sample. However, it is also worth mentioning that all variables demonstrating clan turned out to be significant clustering criteria with greater or lesser partitioning strength. Likewise, the study also revealed that there is a balance between the upstream and downstream dyads in terms of specific variables manifesting clan. Put differently, there is the same set of variables manifesting clan that differentiates two clusters in both dyads. For instance, trying to develop trust with the other actor in a dyad as well as resolving the disruptions in the spirit of mutual understanding are two variables that are significant across two dyads when conducting three comparisons run between the following couple of clusters: alternative-market, market-hierarchy and hybrid-hierarchy. In addition, all variables manifesting clan the alternative cluster differs significantly from the hybrid group in the upstream and downstream dyads.

CONCLUDING REMARKS

The goal of the paper was to compare diverse modes of supply chain governance (with the emphasis on hybrid and alternative modes) in terms of the strength of clan. The study shows that although the pure mechanisms of market and hierarchy can still be revealed in governance of triadic supply chains, they are enhanced by clan to a different extent. In addition, clan as the mode of governance takes a leading role in the hybrid modes of governance, as compared to alternative mechanisms. This may suggest that either the hybrid modes are much more strongly enhanced by social dimensions encapsulated in clan than the alternative modes or that the essence of clan in the hybrid modes is not the same as the essence of clan in the alternative modes of governance. Following the latter line of reasoning, we conclude that the silver bullet for solving this problem may reside within the nature of clan, which is significantly different in both modes of governance. If it turns out to be true, then it would require shifting the scope of future research from searching for common themes to searching for the differences among the dimensions of clan in both modes of governance. Consequently, we argue that there is a need to look for other characteristics of clan to indicate differences between the hybrid and alternative (neither marker nor hierarchy) modes of governance.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The study was financed by the National Science Centre, Poland as a research project no. 2015/18/M/HS4/00388.

REFERENCES

Ashenbaum B., Maltz A., Ellram L., Barratt M.A., 2009. Organizational alignment and supply chain governance structure, International Journal of Logistics Management, 20, 2, 169-186.

Barratt M., 2004. Understanding the meaning of collaboration in the supply chain, Supply

Chain Management, 9, 1, 30-42. http://doi.org/10.1108/13598540410517566

Blome C., Schoenherr T., Kaesser M., 2013. Ambidextrous Governance in Supply Chains: The Impact on Innovation and Cost Performance. Journal of Supply Chain Management, 49, 59-80. http://doi.org/10.1111/jscm.12033.

Brito R.P., Miguel P.L., 2017, Power, Governance, and Value in Collaboration: Differences between Buyer and Supplier Perspectives. Journal of Supply Chain Management, 53, 61-87. http://doi.org/10.1111/jscm.12134.

Choi T., Hong Y., 2002. Unveiling the structure of supply networks: Case studies in Honda, Acura, and DaimlerChrysler. Journal of Operations Management, 20, 5, 469-493. http://doi.org/10.1016/S0272-6963(02)00025-6.

Crisan E., 2016. A separation between supply chain management and supply chain governance. Revista De Management Comparat International, 17, 3, 240-249.

Demil B., Lecocq X., 2006. Neither Market nor Hierarchy nor Network: The Emergence of Bazaar Governance. Organization Studies, 27, 10, 1447–1466, http://doi.org/10.1177/0170840606067250.

Denolf,. Van der Vorst, Jack Omta O., 2015. The role of governance structures in supply chain information sharing. Journal on Chain and Network Science, 15, 1, 83-99. http://doi.org/10.3920/JCNS2014.0004.

Dolci P.C., Maçada A., Gastaud C., Grant, G. G., 2015, Exploring information technology and supply chain governance: Case studies in two brazilian supply chains. Journal of Global Information Management, 23, 3, 72-91. http://doi.org/10.4018/JGIM.2015070104.

Dolci P.C., Maçada A., Gastaud C., Paiva E.L., 2017. Models for understanding the influence of supply chain governance on supply chain performance. Supply Chain Management, 22, 5, 424-44. http://doi.org/10.1108/SCM-07-2016-0260.

Dyer J.H., Singh H., 1998. The Relational View: Cooperative Strategy and Sources of Interorganizational Competitive Advantage, Academy of Management Review, 23, 4, 660-679.

Eccles R. G., Nohria N., Berkley J.D., 1992, Beyond the Hype: Rediscovering the Essence of Management, Harvard Business School Press, Boston.

Ellinger A.E., Keller S.B., Hansen J.D., 2006, Bridging the Divide between Logistics and Marketing: Facilitating Collaborative Behavior. Journal of Business Logistics, 27, 1-27. http://doi.org/10.1002/j.2158-1592.2006.tb00215.x.

Gary G., Humphrey J., Sturgeon T., 2005. The governance of global value chains, Review of International Political Economy, 12, 1, 78-104. http://doi.org/10.1080/09692290500049805

Ghoshal S., Insead, P. M., 1996. Bad for practice: A critique of the transaction cost theory. Academy of Management Review, 21, 1, 13-47. http://doi.org/10.2307/258627.

Ghozzi H., Soregaroli C., Boccaletti S., Sauvée, L., 2016. Impacts of non-GMO standards on poultry supply chain governance: Transaction cost approach vs resource-based view. Supply Chain Management, 21, 6, 743-758. http://doi.org/10.1108/SCM-03-2016-0089.

Granovetter M.S., 1992. Problems of explanation in economic sociology, in Nohria N., Eccles R.G. (Eds), Networks and Organizations, Harvard Business School Press: Boston, MA: 25-56.

Grant R.M., 1996. Towards a knowledge-based theory of the firm, Strategic Management Journal, 17, 2, 109-122.

Heide J.B., 1994. Interorganizational governance in marketing channels. Journal of Marketing, 58, 1, 71-85.

Heide J.B., John G., 1992. Do Norms Matter in Marketing Relationships? Journal of Marketing, 56, 2, 32-44.

In J., Bradley R., Bichescu B. C., Autry C. W., 2019. Supply chain information governance: Toward a conceptual framework. International Journal of

Logistics Management, 30, 2, 506-526. http://doi.org/10.1108/IJLM-05-2017-0132.

Jarillo J. C., 1988. On strategic networks, Strategic Management Journal, 9, 1, 31-41.

Jones C., Hesterly W., Borgatti S., 1997. A General Theory of Network Governance: Exchange Conditions and Social Mechanisms, Academy of Management Review, 22, 4, 911-945.

Josi A.W, Campbell A.J., 2003. Effect of environmental dynamism on relational governance in manufacture-supplier relationships: A contingency framework and an empirical test. Journal of the Academy of Marketing Science, 31,176-188. http://doi.org/10.1177/0092070302250901

Ketchen D., Shook C., 1996. The application of cluster analysis in strategic management research: an analysis and critique, Strategic Management Journal. 17, 6, 441-458. http://doi.org/10.1002/(SICI)1097-0266(199606).

Kim D.Y., 2014. Understanding supplier structural embeddedness: A social network perspective, Journal of Operations Management, 32, 5, 219-231. http://doi.org/10.1016/j.jom.2014.03.005.

Kline P., 1994. An Easy Guide to Factor Analysis, TJ Press, Padstow.

Krieger A.M., Green P.E., 1999, A generalized rand-index method for consensus clustering of separate partitions of the same data base. Journal of Classification, 16, 1, 63-89. http://doi.org/10.1007/s003579900043.

Li M., Choi T.Y., 2009, Triads in Services Outsourcing: Bridge, Bridge Decay and Bridge Transfer. Journal of Supply Chain Management, 45, 27-39. http://doi.org/10.1111/j.1745-493X.2009.03169.x.

Liu Y., Luo Y., Liu T, 2009. Governing buyer-supplier relationships through transactional and relational mechanisms: evidence from China, Journal of Operations Management, 27, 4, 294-309. http://doi.org/10.1016/j.jom.2008.09.004.

Lowndes V., Skelcher C., 1998. The Dynamics of Multi-organizational Partnerships: an Analysis of Changing Modes of Governance. Public Administration, 76, 313-333. http://doi.org/10.1111/1467-9299.00103.

Malhotra D.K., Lumineau, F., 2011. Trust and Collaboration in the Aftermath of Conflict: The Effects of Contract Structure. Academy of Management Journal, 2011, 54, 5, 981-998.

Mentzer J., Stank T.P., Myers M.B., 2007. Why Global Supply Chain Management? SAGE Publications, Inc.

Mesquita L.F., Anand J., Brush T.H., 2008. Comparing the resource-based and relational views: knowledge transfer and spillover in vertical alliances, Strategic Management Journal, 29, 913-941. http://doi.org/10.1002/smj.699.

Mirkovski K., Lowry P.B., Feng B., 2016. Factors that influence interorganizational use of information and communications technology in relationship-based supply chains: evidence from the Macedonian and American wine industries, Supply Chain Management: An International Journal, 21, 3, 334-351. http://doi.org/10.1108/SCM-08-2015-0343.

Montalbano P., Nenci S., 2014. The Trade Competitiveness of Southern Emerging Economies: A Multidimensional Approach Through Cluster Analysis. World Economy, 37, 6, 783-810. http://doi.org/10.1111/twec.12195.

Noordewier T.G., John G., Nevin J.R., 1990. Performance outcomes of purchasing arrangements in industrial buyer-vendor relationships, Journal of Marketing, 54, 4, 80-93.

Orru M., 1996. Practical and Theoretical Aspects of Japanese Business Networks. In: Hamilton, G.G. (Ed.), Asian Business Networks, de Gruyter, Berlin, 201-228.

Ouchi, W.G., 1980. Markets, Bureaucracies, and Clans. Administrative Science Quarterly, 25, 1, 129-141.

Peterson H.C., Wysocki A., Harsh S.B., 2001. Strategic choice along the vertical coordination continuum. International Food and Agribusiness Management Review, 4, 149-66.

Pilbeam C., Alvarez G., Wilson H., 2012. The governance of supply networks: A systematic literature review. Supply Chain Management: An International Journal. 17, 358-376. http://doi.org/10.1108/13598541211246512

Poppo L., Zenger T., 2002. Do formal contracts and relational governance function as substitutes or complements? Strategic Management Journal, 23, 707–725. http://doi.org/10.1111/jscm.12033.

Powell W., 1990. Neither Market Nor Hierarchy: Network Forms of Organization. Research in Organizational Behaviour. 12, 295-336.

Susha I., Janssen M., Verhulst, S., 2017. Data collaboratives as 'bazaars'? Transforming Government: People, Process and Policy, 11, 1, 157-172. http://doi.org/10.1108/TG-01-2017-0007.

Tachizawa E.M., Wong, C.Y., 2015. The Performance of Green Supply Chain Management Governance Mechanisms: A Supply Network and Complexity Perspective. Journal of Supply Chain Management, 51, 3, 18-32.

Uzzi, B., 1996. The Sources and Consequences of Embeddedness for the Economic Performance of Organizations: The Network Effect. American Sociological Review, 61, 4, 674-698.

Villena V.H., Revilla E., Choi T., 2011. The dark side of buyer-supplier relationships: A social capital perspective. Journal of Operations Management, 29, 6, 561-576. http://doi.org/10.1016/j.jom.2010.09.001.

Vlachos I. P., 2014. The impact of private label foods on supply chain governance. British Food Journal, 116, 7, 1106-1127. http://doi.org/10.1108/BFJ-09-2012-0228.

Wang C.X., 2002. A general framework of supply chain contract models, Supply Chain Management: An International Journal, 7, 5, 302-310.

Wang E. T., Wei H., 2007. Interorganizational Governance Value Creation: Coordinating for Information Visibility and Flexibility in Supply Chains. Decision Sciences, 38, 647-674. http://doi.org/10.1111/j.1540-5915.2007.00173.x.

Whipple J.M., Wiedmer R., Boyer K.K., 2015. A Dyadic Investigation of Collaborative Competence, Social Capital, and Performance in Buyer–Supplier Relationships, Journal of Supply Chain Management, 51, 3-21. http://doi.org/10.1111/jscm.12071.

Williamson O.E., 1985. The Economic Intstitutions of Capitalism, Free Press, New York, NY.

Williamson O.E., 2008. Outsourcing: transaction cost economics and supply chain management, Journal of Supply Chain Management, 44, 5-16. http://doi.org/10.1111/j.1745-493X.2008.00051.x.

Williamson O.E., 1975. Markets and Hierarchies: Analysis and Antitrust Implications. New York, The Free Press.

Williamson O.E, 1994. Visible and Invisible Governance, American Economic Review, American Economic Association, 84, 2, 323-326.

ROLA KLANU W HYBRYDOWYCH ORAZ ALTERNATYWNYCH MECHANIZMACH KOORDYNACJI DZIAŁAŃ W ŁAŃCUCHACH DOSTAW

STRESZCZENIE. Wstęp: Ostatnie publikacje dotyczące zarządzania łańcuchem dostaw podkreślają znaczenie kontraktowej i relacyjnej koordynacji działań, jednocześnie ignorując istotność koordynacji hierarchicznej. W celu sprostania temu wyzwaniu artykuł zakłada, że zarówno koordynacja rynkowa, jak i hierarchiczna są osadzone w kontekście społecznym, i jako takie, w pewnym stopniu stosują aspekty relacyjne, określane w tym artykule mianem klanu. Jednocześnie, klan rzadko występuje jako samodzielny mechanizm koordynacji działań, przeciwnie może przyjmować postać formę hybrydy (osadzonej między rynkiem i hierarchią) lub może być mechanizmem alternatywnym (nie rynkowym i zarazem nie hierarchicznym). Poprzez nawiązanie do klasycznej koordynacji rynkowej i hierarchicznej,

celem artykułu jest porównanie różnych mechanizmów koordynacji działań w łańcuchu dostaw (w tym przede wszystkim mechanizmu hybrydowego i alternatywnego) ze względu na siłę aspektów relacyjnych, zakotwiczonych w klanie.
Metody: W artykule przeprowadzono dwa etapy wielowymiarowej analizy statystycznej. W pierwszym etapie zmienne odzwierciedlające mechanizm rynkowy i hierarchiczny oddzielnie dla obu diad, zostały zredukowane za pomocą analizy czynnikowej z rotacją varimax w celu identyfikacji podstawowych konstruktów. W drugim etapie badania, otrzymane oceny czynnikowe zostały wykorzystane w grupowaniu obiektów.
Wyniki: Przeprowadzone badanie pokazuje, że hybrydowa koordynacja działań (w szczególności mechanizm relacyjny), osadzona między dwoma biegunowymi mechanizmami rynku i hierarchii wykazuje wyższy stopień wykorzystania aspektów relacyjnych, typowych dla klanu, aniżeli hierarchia, stosowana jako jedyny mechanizm w triadycznych łańcuchach dostaw. Jednocześnie, triadyczne łańcuchy dostaw koordynowane za pomocą mechanizmu rynkowego i hybrydowego nie różnią się istotnie, pokazując podobne wartości średnie rang dla klanu. Badanie pokazuje również, że alternatywne (nie rynkowe i zarazem nie hierarchiczne) mechanizmy koordynacji działań nie wskazują wyższych wartości średnich rang dla klanu w porównaniu do mechanizmu rynkowego i hybrydowego.
Wnioski: Badanie pokazuje, że klan pełni przewodnią rolę w koordynacji hybrydowej w po-równaniu do alternatywnych mechanizmów koordynacji. Może to sugerować, że albo koordynacja hybrydowa jest wzbogacona aspektami relacyjnymi, typowymi dla klanu, w porównaniu do alternatywnych mechanizmów koordynacji, albo istota klanu w koordynacji hybrydowej nie jest tożsama z istotą klanu w alternatywnych mechanizmach koordynacyjnych. W świetle powyższego, rozwiązanie tego problemu może wynikać z natury klanu, który istotnie różni się w obu mechanizmach koordynacji działań w łańcuchach dostaw.

Słowa kluczowe: koordynacja rynkowa, koordynacja relacyjna, hierarchia

Artur Świerczek, ORCID ID: https://orcid.org/0000-0001-6198-6377
University of Economics in Katowice
Department of Business Logistics
ul. 1 Maja 50
40-287 Katowice, **Poland**
email: artur.swierczek@uekat.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (1), 61-74

http://doi.org/10.17270/J.LOG.2019.376

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

DELINEATING THE INFLUENCE OF BOARDROOM GENDER DIVERSITY ON CORPORATE SOCIAL RESPONSIBILITY, FINANCIAL PERFORMANCE, AND REPUTATION

Aiman Ajaz, Zhou Shenbei, Muddassar Sarfraz

Hohai University, Jiangsu, **PR China**

ABSTRACT. **Background:** The current study reveals the effectiveness of gender diversity in the boardroom and considers its impact on a firm's corporate social responsibility, financial performance and reputation, which leads towards business sustainability. The study is based on stakeholder theory assumptions which state that female directors play a vital role in board diversification.

Methodology: 100 index firms listed on the Pakistan Stock Exchange were chosen as a sample size. The firm's financial performance was measured by using three proxies in order to get robust results. Panel data of 6 years from 2010 to 2015 was applied for data analysis. The data was analyzed by applying the Fixed-Random OLS regression, which revealed that gender diversity in the boardroom has no significant relationship with corporate social responsibility (CSR), financial performance, and the reputation of a firm.

Results: Study results revealed that HODI mitigates corporate social responsibility activity. According to the Fixed-Random Regression results, PW has no significant impact on shareholder return. Sales and ROA have a significant positive relationship with SHR.

Conclusions: There is a negative relationship between boardroom gender diversity and a firm's financial performance. Females in boardrooms either cause negative effects or have no impact on the firm's financial performance. Similarly, there is no significant relationship between the presence of women in boardrooms and a firm's reputation.

Key words: Gender Diversity Corporate Social Responsibility, Firm Performance, Firm Reputation, Pakistan.

INTRODUCTION

Gender diversity in the workplace, and especially in boardrooms, has gained much attention around the globe in recent times. Not only is the number of female and male executives in top positions important, but also many other perspectives, namely that the decisions being made in boardrooms are a reflection of the current market situation and the community as well. The corporate world has to face different challenges daily, which necessitates a variety of different personalities with different views, ideas, and mindsets within the boardroom.

Diverse boardrooms are expected to increase the effectiveness of the boards. However, the question of the effectiveness of this decision is still being considered, not only by the corporate world but in academia as well. Sixteen countries have made it compulsory to enhance women's representation in boardrooms, while some others have asked corporate boards to increase the quota of women voluntarily. The concern for the influence of these decisions is considered by many, but efforts to find practical progress are slow [Rhode, Packel 2014]. A green supply chain is vital for business sustainability. There are different studies which have produced

Citation: Ajaz A., Shenbei Z., Sarfraz M., 2020. Delineating the Influence of Boardroom's Gender Diversity on Corporate Social Responsibility, Firm's Financial Performance, and Reputation. LogForum 16 (1), 61-74, http://doi.org/10.17270/J.LOG.2019.376

Received: 29.07.2019, Accepted: 19.09.2019, on-line: 30.12.2019.

different results in different demographic settings about the impact of diverse boardrooms. Previously, studies have tried to find out the impact of having more women in boardrooms on its financial performance. However, in recent years, more concern is being shown about how it affects corporate social responsibility performance as boards are increasingly held responsible for corporate social responsibility and sustainability decisions.

Along with these factors, researchers have also analyzed the influence of gender composition in boardrooms on a vital factor, i.e. corporate reputation based on the fact that increased female representation on boards sends a signal to stakeholders about an organization's concern for women's rights [Bear, Rahman, Post 2010]. Hope and work have a mediating relationship with creativity [Sarfraz, Qun, Abdullah, Tahir 2019]. Gender diversity in boardrooms is one of the controversial topics in behavioral finance [Rhode, Packel 2014]. Corporate boards affect the lives of millions, including their employees, community, and the global market-place as well. Concern over the composition of boards has increased even more after scandals like Enron. Some researchers insisted on the fact that, besides the importance of the topic, research on practical progress does not match the required pace. Literature available on all the variables collectively chosen to be studied under this research paper in the context of Pakistani firms is insufficient and unreliable as well [Rhode, Packel 2014].

THEORETICAL FRAMEWORK AND HYPOTHESIS DEVELOPMENT

Critical Mass Theory

Kanter analyzed the behaviors and experiences of women and minorities in the corporate sector [Sarah, Mona 2008]. Critical mass theory has analyzed the token status of women and stated that the number of people matters when it comes to adopting an innovative feature in a system. It requires a sufficient number for the rate of adoption to be sustained and grow on its own. She argued that, as the numerical proportion changes, experience within a group also changes [Kanter 1977].

She titled the majority (by the number) of the group as "Dominants" and the numerically few or the minority of the group as "tokens." Tokens have to face many difficulties of survival within a social or corporate system as they either have to face hyper-visibility or sometimes invisibility. They also have to bear the stress of performing better and all the stereotypes attached to their gender instead of being considered an individual, which hinders their influence on decision making [Konrad, Kramer, Erkut, 2008].

Over time, this theory has received lots of recognition; it has been analyzed and applied to other fields as well, including the study of legislative behavior in women in order to study its impact on political settings [Sarah, Mona 2008]. Discussions about gender diversity in boardrooms can be viewed from two perspectives: ethical and economic. Underrepresentation of women in board rooms on the grounds of their gender is an unethical practice. Secondly, the economic view supports equal opportunities for women in boardrooms because denying capable and skilled women the right to be in boardrooms indirectly damages a firm's performance [Campbell, Mínguez-Vera 2008].

The economic perspective on the underrepresentation of women on boards has given rise to the resource dependence theory. This theory states that boardroom members are a source of assets (both tangible and intangible) to the firm which not only play an essential role in shaping its behaviour, but also its performance and environment as well [Pfeffer, Salancik 2003]. This theory agrees with the economic perspective, as it suggests that denying their right for presence in boardrooms leads to a failed attempt to gather the most skilled candidates. Failing to gather the best candidates and paying no heed to the women's talent pool leads to a failure to gain a competitive advantage which is critical to a firm's performance [Pfeffer, Salancik 2003].

People coming from diverse backgrounds are more likely to have different experiences of life which make their approach to specific issues different from each other. New skills, an understanding based on knowledge and resources are sources of positive impacts on the performance of board members. Contrary to homogeneous groups, performance improves as their decision-making process gets better through the evaluation of more creative ideas for problem-solving [Ferreira 2010].

The composition of boards has been under the spotlight since scandals like Enron and Lehman Brothers. The presence of women and their slow advancement in boardrooms, besides having the purported equality, has been a great concern for researchers, the media, and the general public, who have lost their faith in industry giants. This concern has revived the debate about the role of gender diversity in boardrooms in the context of Corporate Governance and CSR [Terjesen, Sealy, Singh 2009].

GENDER DIVERSITY IN BOARDROOMS AND CSR

CSR itself is considered a term with many dimensions and perspectives which is quite complicated and challenging to define. It is considered to be a mix of social and environmental concepts which help in defining CSR. Corporate Social Responsibility or Responsiveness has been quite a provocative subject in the corporate world since the 1960s as it has been the topic of a great many types of research which have tried to elucidate its effects [Arlow, Gannon 1982]. In recent years, the importance of corporate social responsibility has increased immensely, not only in policymaking, but in academia as well. The researchers believe that it is not enough for an organization to be successful only in economic terms, but managing the interests of all stakeholders, including the general public, is also essential [Carroll 1979, Jamali, Safieddine, Rabbath 2008]. Hierarchical CEO succession boots a firm's innovation [Sarfraz, Qun, Shah, Fareed 2019].Women are ahead of men in philanthropic activities, which indirectly indicates the fact that, the more women on a board, the more a firm will focus on corporate social responsibility. This means that, in order to increase their involvement in corporate social responsibility, firms must also increase the representation of women on their board. Many researchers have tried to prove this relationship, and there is still much room for research on this topic in order to find out the consistency of the results in different geographical areas. Based on the literature above on gender diversity on boards and corporate social responsibility, which is reportedly pointing out the presence of a relationship between them, the following hypothesis can be stated:

H1: Gender diversity in the boardroom has an impact on a firm's CSR performance.

GENDER DIVERSITY IN BOARDROOMS AND FINANCIAL PERFORMANCE OF THE FIRM

Research conducted in Spain tried to find the short- and long-term impacts of passing the Gender Equality Act in 2007, which made it necessary for organizations to have a 40% representation of women in boardrooms. Before that, it was a voluntary decision. Making it mandatory to have 40% of women in boardrooms led to an increase in stock prices. The stock exchange's positive reaction to women having additional representation in boardrooms has given rise to the belief that investors think women can add value to the firm. The same belief has been proved by finding the long-term impacts of an increased quota of women in boardrooms, which has resulted in a substantially increased value [Campbell, Vera 2010].

Although the same positive impact of a boardroom's gender diversity on a firm's financial performance has been confirmed by the Netherlands and Denmark as well, in some countries, this particular stance has not been supported. 102 Dutch and 84 Danish firms, 40 percent of which had at least one woman on the board, were analyzed in 2007. This particular study found that gender diversity in the boardroom has no impact on the financial performance of a firm, which is similar to many European types of research [Marinova, Plantenga, Remery 2016]. However, in response to a debate about the relationship between gender diversity and FP, a comparison of firms with and without women on the board proved otherwise. According to this study, the firms where there was a presence of women on board worked better than those which did not have a representation of women [Lückerath-Rovers 2013]. Another study conducted in the same year found that there is even a weak negative correlation between having multiple women on boards and financial performance by analysis of the portfolios of the firms under study. The fact of having a positive correlation between gender diversity (GD) and FP in some industries has not been negated by this research [Chapple, Humphrey 2014].

Even after so much debate over this topic, the issue has not been settled. 255 Swedish OMX-listed firms analyzed through panel data over six years found no significant impact of a boardroom's gender diversity on the firm's financial performance [Alm, Winberg 2016]. One of the reasons for the positive impact of GD on a firm's financial performance is said to be the fact that having women on boards leads to less riskiness, which results in better performance [Perryman, Fernando, Tripathy, 2016]. Based on the above literature, it can be assumed that gender diversity in boardrooms has varying results which fluctuate in different situations. As mentioned earlier, based on the literature review, the following hypothesis can be made for further investigation of the relationship:

H2: Gender Diversity has an impact on a firm's financial performance.

GENDER DIVERSITY IN BOARDROOMS AND REPUTATION OF THE FIRM

Signaling theory has been put forward in support of the expected relationship between gender diversity in boardrooms and reputation. This theory has been explained in the following way: "Signaling theory assumes asymmetric information, and proposes that parties may convey, intentionally or not, relevant, but not readily observable information, through observable signals that are meaningful to the other party". It has been proved that gender diversity on boards contributes to the reputation of the organization [Bear et al. 2010]. Not only was it found that the presence of women on a board increases the ratings for corporate social affairs, but it was also established that the percentage of women in boardrooms has a positive relationship with the reputation of the firm. According to Signaling theory and the literature,

H3: Gender Diversity in boardrooms has an impact on a firm's reputation.

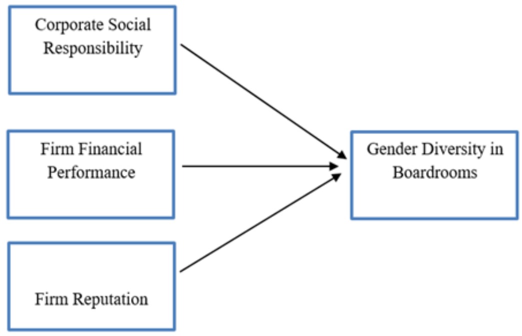


Fig. 1. Theoretical framework

MATERIALS AND METHODS

A sample of KSE-100 index companies was selected from the population of all the listed firms on the Pakistan Stock Exchange Limited, using a type of non-probability sampling technique called purposive sampling. Many small firms follow the lead of the top firms, and hence their impact on society is high when compared to other organizations. So, there is a need to research these firms to fulfil the scarcity of research in this area, particularly in Pakistan [Iqbal, Ahmad, Basheer, Nadeem 2012]. These 100 firms were analyzed for the required information using the six-year panel's data from 2010 to 2015. The primary source of gathering the required information for these 100 firms is financial reports which were uploaded on their official websites, as they are considered to be the most significant way of sharing information regarding companies [Belal 2000]. Financial reports are considered to be the most consistent tool for analyzing information about companies in many previous types of research as well.

Data for all the 100 firms was compiled for a percentage of women in boardrooms and CSR for all six years, which revealed that there were only 34 non-financial and 9 financial firms out of the entire 100 which had a gender diversity in their boardroom in at least one year out of all the six under consideration. After careful, necessary examination, 34 non-financial firms were analyzed using STATA in order to investigate the proposed relationships between gender diversity in boardrooms and all the dependent variables.

Measurement of variables

Gender diversity in boardrooms

Gender diversity in boardrooms or the composition of female directors has been made operational in two ways. First of all, it was measured by finding the percentage of women as compared to total directors in the boardrooms [Isidro, Sobral 2015]. Based on the above literature regarding the theory of critical mass, the second measure for gender diversity in boardrooms was an analysis of the data under critical mass theory. If the percentage of women in boardrooms was at least 30% or more, it was coded 1, and it was coded 0 if the percentage is below 30% [Isidro, Sobral 2015].

Corporate Social Responsibility

CSR performance or social performance of a firm can be estimated by the social disclosures made by that particular firm [Orlitzky, Schmidt, Rynes 2003]. Some methods can be employed under a content analysis technique in order to measure disclosures from a social welfare perspective. Support for the association of social performance to social reporting can also be found in literature, where social reporting consists of observing, assessing, and improving the impact of a firm's business activities on the community and the environment as a whole [Wood 1991].

Some methods were identified in the literature for content analysis while using different unit analysis, which includes word counts, number of sentences, number of pages, and quantity of pages [Khan 2010]. For that matter, they generated an instrument for CSR disclosure using previous research in the same area [Cowen, Ferreri, Parker 1987, Mian, 2010]. If a particular item mentioned in the CSR disclosure index has been disclosed in the annual report or the CSR report of the firm for a particular year, it will be coded "1". If it has not been disclosed in any of them, it will be coded "0".

Firm's financial performance

Financial performance of the firm was calculated using the measures of ROA and ROS previously used by Isidro and Sobral [Isidro, Sobral 2015], along with ROE following Luckerath-Rovers [Lückerath-Rovers 2013]. Financial performance was measured using a natural log of ROA (Return on Assets), ROE (Return on Equity) and ROS (Return on sales) in order to control for outliers.

Firm's reputation

In order to operationalize the variable of reputation, the proxy of shareholder returns previously used by researchers was followed [Mukasa, Lim, Kim 2015]. The reason for using this proxy is that it represents the fundamental reputation drivers. Secondly, it reveals the substantial value and emotional appeal of shareholders, i.e. how successful a company has been in attracting its shareholders through its performance over time [Mukasa et al. 2015].

Control variables

Gender diversity and corporate social responsibility

Size based on total sales of the firm was used as a control variable to measure the relationship between gender diversity (GD)and corporate social responsibility (CSR) [Khan 2010].

Gender diversity and the firm's financial performance

The size of the firm and leverage were used as control variables to measure the relationship of gender diversity (GD) with ROA and ROS. The size of the firm was calculated as the natural logarithm of the total assets of the firm. The formula used for the calculation of leverage was the ratio of total debt to total assets [Isidro, Sobral 2015]. The controlling factor for ROE in order to find out the impact of gender diversity (GD) on ROE was the natural log of board size [Lückerath-Rovers 2013].

Gender diversity and firm reputation

The natural logarithm of sales has been used in the study to find the impact of gender diversity (GD) in boardrooms on the reputation of the firm along with the natural log of ROA. Both these variables are said to be correlated with the total shareholder's return used as a proxy for measuring reputation [Mukasa, Kim, Lim 2015].

STATA 13 was used to analyse the panel data under study in this research, which has both time series and cross-sectional properties. Regression analysis refers to regression models, which investigate the relationship between explanatory and outcome variables while keeping in control the impact of control variables, which goes with the objective of this study [Long, Freese 2006]. The ordinary least square regression model has been used in this study to find the impact of gender diversity in boardrooms on the variables under study in this research.

RESULTS

Table 1 represents the descriptive statistics of the study variables. The data were collected over six years, from 2010 to 2015. Panel data of 34 non-financial firms included in this study is actively balanced according to STATA 13. After getting this indication, the table for descriptive statistics was obtained, which is quite useful in providing some necessary information on data analysis.

Table 1. Descriptive Statistics

Variables	Mean	Min.	Max.	Std. Dev.
CSR	0.318	0	0.7	0.168
ROA	2.025	-4.616	3.972	1.190
ROE	2.687	-2.721	5.086	1.272
ROS	2.058	-0.776	4.387	1.099
SHR	2.520	-2.086	6.411	1.979
LEV	0.170	0	1.676	0.199
Size	15.994	0	19.171	3.433
Sales	15.743	0	19.340	3.797
BS	2.029	0	2.708	0.525

Note. N = 34, T = 6, obs. = 204

Table 2. Pair-wise Correlation Matrix

	PW	CM	ROA	LEV	Size	Sales	BS
PW	1						
CM	0.616	1					
ROA	0.180	0.113	1				
LEV	0.000	-0.036	-0.198	1			
Size	0.107	-0.036	0.230	0.175	1		
Sales	0.123	-0.002	0.319	0.090	0.870	1	
BS	0.119	-0.014	0.279	0.074	0.769	0.786	1

Table 2 represents the values of correlation among variables. It is visible that all the values of table 2 are less than 0.9. Although the value of the correlation between Size (Natural logarithm of total assets) and Sales (Natural logarithm of total sales) is 0.870, which is quite high, the data is declared to be lacking the issue of multicollinearity.

Table 3. Variance Inflation Factor

	Percentage of Women		Critical Mass	
Variables	VIF	1/VIF	VIF	1/VIF
PW	1.01	0.98		
CM			1.00	0.88
ROA	1.14	0.87	1.13	0.87
LEV	1.03	0.96	1.03	0.96
Size	1.04	0.95	1.03	0.96
Sales	1.12	0.89	1.00	0.99
BS	1.01	0.98	1.00	0.99

Table 4. Breusch-Pagan Test for Heteroscedasticity

	PW		CM		PW			CM		
	Chi^2	Prob.	Chi^2	Prob.	Chi^2	Lags	Prob.	Chi^2	Lags	Prob.
CSR	0.00	0.96	0.02	0.90	110.60	1	0.00	112.85	1	0.00
ROA	0.04	0.84	2.50	0.11	57.65	1	0.00	60.09	1	0.00
ROS	0.12	0.72	2.16	0.14	99.78	1	0.00	106.58	1	0.00
ROE	0.20	0.65	0.07	0.79	42.59	1	0.00	43.52	1	0.00
SHR	3.48	0.06	2.44	0.11	11.52	1	0.00	11.41	1	0.00

Variance inflation factor, i.e. VIF, and tolerance values, i.e. 1/VIF, were used to detect the issue of multicollinearity in the study models. Table 3 represents the values of VIF for all the models used to study the impact of PW and CM on variables. All values of VIF in Table 3 are less than 5, whereas all values of 1/VIF are more significant than 0.1. These results are indicative of the fact that there is no multicollinearity among these variables in all models.

Table 4 provides that there is no issue of heteroscedasticity in the data. Chi^2 values are less than the probability in all cases, but for some variables, the value of Chi^2 is more than the probability. Although the null hypothesis can be rejected at all levels, robust standard errors in OLS regressions were used in order to get unbiased results for all models.

BREUSCH-GODFREY TEST FOR SERIAL CORRELATION

Significant probability values are represented in Table 5. High values of Chi^2 reveal the presence of strong autocorrelation in the data with a degree of freedom of 1. Robust standard errors will be applied in the OLS regression for the correction of this issue.

Table 5a. Breusch-Pagan Test for Heteroscedasticity

	Model 1			Model 2			Model 3		
	Random Effect			Fixed Effect			Fixed Effect		
Variable	CSR			ROA			ROS		
	Coeff.	z-stats	Std. Err.	Coeff.	t-stats	Std. Err.	Coeff.	t-stats	Std. Err.
Constant	0.102	1.69*	0.060	-1.270	-1.39	0.912	-1.204	-1.50	0.804
PW	-0.047	-0.66	0.071	0.477	0.43	1.119	-0.347	-0.38	0.922
LEV				-0.347	-1.57	0.221	-0.254	-1.28	0.198
Size				0.202	3.58***	0.056	0.206	4.18***	0.049
BS									
Sales	0.014	3.56***	0.003						
ROA									
	R^2= 0.227			R^2=0.108			R^2= 0.104		
	Chi^2=12.72***								

Table 5b. Breusch-Pagan Test for Heteroscedasticity

	Model 4			Model 5		
	Random Effect			Random Effect		
Variable	ROE			SHR		
	Coeff.	z-stats	Std. Err.	Coeff.	z-stats	Std. Err.
Constant	0.717	1.21	0.594	0.120	0.43	0.277
PW	0.986	1.03	0.959	-0.049	-0.37	0.132
LEV						
Size						
BS	0.913	3.33***	0.274			
Sales				0.092	4.69***	0.019
ROA				0.463	3.93***	0.117
	R^2= 0.150			R^2= 0.133		
	Chi^2= 12.17***			Chi^2= 78.61***		

Fixed-Random Regression with Robust Standard Errors for the impact of PW on CSR, FFP and FR
Note. N = 34, T = 6, obs. = 204
*p < .1, **p < .05, and ***p < .01

Table 6a. Breusch-Pagan Test for Heteroscedasticity

	Model 1			Model 2			Model 3		
	Random Effect			Fixed Effect			Fixed Effect		
Variable	CSR			ROA			ROS		
	Coeff.	z-stats	Std. Err.	Coeff.	t-stats	Std. Err.	Coeff.	t-stats	Std. Err.
Constant	0.102	1.70*	0.060	-1.203	-1.42	0.847	-1.098	-1.54	0.711
CM	-0.007	-0.28	0.028	0.314	0.69	0.455	0.276	0.64	0.433
LEV				-0.325	-1.58	0.206	-0.225	-1.28	0.175
Size				0.200	3.81***	0.052	0.196	4.46***	0.044
BS									
Sales	0.013	3.51***	0.003						
ROA									
	R^2= 0.218			R^2=0.106			R^2= 0.112		
	Chi^2=12.31***								

Table 6b. Breusch-Pagan Test for Heteroscedasticity

	Model 4			Model 5				
	Random Effect			Random Effect				
Variable	ROE			SHR				
	Coeff.	Std. Err.	Coeff.	z-stats	Std. Err.	Coeff.	z-stats	Std. Err.
Constant	-1.098	0.711	0.695	1.17	0.593	0.144	0.56	0.259
CM	0.276	0.433	0.595	1.53	0.389	0.136	0.22	0.622
LEV	-0.225	0.175						
Size	0.196	0.044						
BS			0.964	3.43***	0.280			
Sales						0.091	4.90***	0.018
ROA						0.455	3.89***	0.116
	R^2= 0.157			R^2= 0.133				
	Chi^2= 13.54***			Chi^2= 81.37***				

Table 5 (a, b) and 6 (a, b) provide the results of Fixed-Random Regressions after applying the Haussmann test and Robust Standard Errors. Robust results for the same models have been presented along with the standard errors in a separate column. Given below is the representation of both tables through the model equations after applying robust standard errors:

Model 1

$$CSRit = 0.102 - 0.047PW_{it} + 0.014Salesit + €_{it}$$

$$CSRit = 0.102 - 0.007CM_{it} + 0.013Salesit + €_{it}$$

The results of Fixed-Random Regression with Robust Standard Errors for the impact of PW and sales on CSR point towards the insignificant relationship between GD and corporate social responsibility (CSR). The controlling variable sales had a significant positive impact on corporate social responsibility (CSR) at 1%. The results are more or less similar for CM, and corporate social responsibility (CSR), as its relationship is insignificant, where Sales are significant at all levels. The model's predictability, i.e. R^2, is 22.7% and 21.8% respectively, significant at 1% represented by the value of Chi^2.

Model 2

$$ROA_{it} = -1.270+0.477PW_{it}-0.347LEV_{it}+0.202Size_{it}+€_{it}$$

$$ROA_{it} = -1.203+0.314CM_{it}-0.325LEV_{it}+0.200Size_{it}+€_{it}$$

The second model under consideration was intended to find out the impact of GD on ROA while keeping leverage and size-controlled. The Fixed-Random Regression with Robust Standard Errors results revealed that the relationship between PW and ROA is insignificant. Among variables used as controlled variables, leverage has an insignificant negative impact on ROA. On the other hand, size has a significant positive impact on ROA at all levels. R^2 indicates that 10.8% of the variation in the ROA is due to the variables GD, leverage, and size where the model is significant at 1%. CM and ROA also have an insignificant relationship between them. Control variables of the models include an insignificant relationship between leverage and ROA and a significant relationship between size and ROA. 10.6% R^2 shows the combined impact of these variables on ROA.

Model 3

$$ROS_{it} = -1.204-0.347PW_{it}-0.254LEV_{it}+0.206Size_{it}+€_{it}$$

$$ROS_{it} = -1.098+0.276CM_{it}-0.225LEV_{it}+0.196Size_{it}+€_{it}$$

The third model of the study including GD, ROS, leverage, and size indicated that the Fixed-Random Regression with Robust Standard Errors results for the relationship between PW and ROS are insignificant with a coefficient value of 0.347. Leverage has an insignificant negative impact on ROA where size has a significant positive impact on ROS at all levels. Model is significant at 1% with an R^2 value of 10.4%. CM and ROS also have an insignificant relationship between them. Control variables of the models include an insignificant relationship between leverage and ROS and a significant relationship between size and ROA. 11.2% R^2 shows the combined impact of these variables on ROS.

Model 4

$$ROE_{it} = 0.717+0.986PW_{it}+ 0.913BS_{it}+€_{it}$$

$$ROE_{it} = 0.695+0.595CM_{it}+ 0.964BS_{it}+€_{it}$$

Impact of GD on ROE is insignificant in the fourth model of the study under Fixed-Random Regression with Robust Standard Errors for both PW and CM. Control variable BS is positively related to ROE at 1% in for both proxies of GD. Value of coefficient indicates that a 1% increase in BS increases ROE by 91.3% and 96.4% in the latter case, i.e., for CM. The R^2 value is 15% for the impact of PW and BS which means 15% of the variation in ROE is being caused by the PW and BS, significant at 1%. CM and BS cause 15.7% of the change in ROE at 1% significance.

Model 5

$$SHR_{it} = 0.120-0.049PW_{it} + 0.463ROA_{it}+0.092Sales_{it}+€_{it}$$

$$SHR_{it} = 0.144+0.136CM_{it} + 0.455ROA_{it}+0.091Sales_{it}+€_{it}$$

The last model under consideration is an attempt to find the impact of GD, ROA and sales on the reputation of the firm, i.e. SHR. According to the Fixed-Random Regression results PW has no significant impact on shareholder return. Sales and ROA have a significant positive relationship with SHR, significant at 1% and R^2 is 13.3%. CM also has an insignificant effect on SHR. Sales and ROA in this model are significant at 1%. Where models predictability represented by R^2, in this case, is 13.3%. Both proxies used for measuring the impact of GD on the reputation of the firm show an insignificant impact.

DISCUSSION

The current study is very controversial in the context of Pakistan as it is a male-dominated society, along with some other reservations. Few studies have been conducted on this topic in the Pakistani context. The first study found out that there is a negative link between a boardroom's gender diversity and a firm's financial performance, based on the reasons that their attitudes and behaviors negatively affect a firm's financial performance [Mirza, Mahmood, Andleeb, Ramzan 2012]. Females in boardrooms either cause negative or have no impact on a firm's financial performance [Smith, Smith, Verner 2006]. Over time, the Pakistan economy has become active and, along with that, there is a visible change in the status of women in Pakistan. Education and technical skills of female directors could be one of the things which affects a firm's financial performance. The previous study revealed that there is no significant relationship between gender diversity in boardrooms and a firm's financial performance [Yasser 2012]. So, the results of previous studies are consistent with the current study.

Similar results have been reported for Nordic boards, where results have indicated an insignificant relationship between a boardroom's gender diversity and a firm's financial performance. This suggests that board diversity could be increased without hurting a firm's financial performance. The insignificant relationship between the presence of women in boardrooms and a firm's financial performance is also proved by past studies [Marinova et al. 2016, Rose 2007]. In the recent economic scenario, risk management is one of the highlighted issues around the globe; women are known to be risk-averse and they could add value to the economy [Yasser 2012]. Hence, instead of taking this finding as a setback for women, it must be seen as an opportunity for them to make a difference in the world economy by getting equipped with technical and vocational training.

The third and final hypothesis of the study stated that there is a significant relationship between the presence of women in boardrooms and the reputation of a firm. This was also rejected in the study. These results are consistent with the findings of previous studies [Fuentes-Medina, Morini-Marrero, Verona-Martel 2013]. Major contributing factors to reputation such as financial factors and corporate social responsibility are not affected by gender diversity in boardrooms. If there is no impact of a boardroom's gender diversity on these factors. Brammer et al. [2009] stated that a boardroom's gender diversity only affects a firm's reputation in the final consumer's sectors. Signaling theory does not apply in Pakistan for having an expected positive impact of GD in boardrooms on a firm's reputation.

However, it is evident from the results that there is no significant impact of a boardroom's gender diversity on a firm's social and financial position along with its reputation. Gender diversity in boardrooms was measured using two proxies, and both of them have confirmed the results. The critical mass theory helped in finding robust results. Although Pakistan is among one of the developing countries and is striving to find its way up to the list of developed countries. According to Bukhari, Ramzan [2013], discrimination is prevalent in the society of Pakistan, and there are many contributors, including social norms, traditions, values and lack of awareness regarding religion, which lead to a society where women lack education and awareness as compared to men.

This discussion leads to the deduction that the insignificant impact of women in boardrooms over corporate social responsibility, a firm's financial performance and reputation are due to a lack of knowledge, skills and awareness. This research could provide a basis and a starting point for the debate that women's rights are being denied at all levels and this has been causing Pakistan a significant setback in the corporate world which could be one of the reasons that Pakistan is lagging in the pursuit of becoming a successful world economy.

CONCLUSIONS

The proven relationship between a boardroom's gender diversity and corporate social responsibility (CSR) in other countries is found to be inapplicable in the context of Pakistan. Current study results are consistent with the findings of previous studies that are based on the fact that women have less participation in decision making within boardrooms [Majeed, Aziz, Saleem 2015]. Mostly they are inactive and sleeping partners in firms. Similar results were reported by Williams who proved the fact that there is no link between corporate social responsibility and the presence of women on a board [Williams 2003]. In this study, a firm's financial performance was measured using three proxies in order to get robust results. Similar results were reported for all three proxies. The hypothesis was rejected in this study as well, i.e. there is no significant relationship between GD in boardrooms and financial performance of the firm.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Alm M., Winberg J., 2016. How Does Gender Diversity on Corporate Boards Affect the Firm Financial Performance? https://gupea.ub.gu.se/bitstream/2077/41620/1/gupea_2077_41620_1.pdf

Arlow P., Gannon M.J., 1982. Social responsiveness, corporate structure, and economic performance. Academy of Management Review, 7(2), 235-241. http://doi.org/10.5465/amr.1982.4285580

Bear S., Rahman N., Post C., 2010. The impact of board diversity and gender composition on corporate social responsibility and firm reputation. Journal of Business Ethics, 97(2), 207-221. http://doi.org/10.1007/s10551-010-0505-2

Belal A.R., 2000. Environmental reporting in developing countries: empirical evidence from Bangladesh. Eco-Management and Auditing: The Journal of Corporate Environmental Management, 7(3), 114-121. http://doi.org/10.1002/1099-0925(200009)7:3<114::AID-EMA131>3.0.CO;2-E

Bukhari F.Y., Ramzan M., 2013. Gender discrimination: A myth or truth women status in Pakistan. Journal of Business and Management, 8(2), 88-97.

Campbell K., Manguez-Vera A., 2008. Gender diversity in the boardroom and firm financial performance. Journal of Business Ethics, 83(3), 435-451. http://doi.org/10.1007/s10551-007-9630-y

Campbell K., Vera A.M., 2010. Female board appointments and firm valuation: Short and long-term effects. Journal of Management & Governance, 14(1), 37-59. http://doi.org/10.1007/s10997-009-9092-y

Carroll A.B., 1979. A three-dimensional conceptual model of corporate performance. Academy of Management Review, 4(4), 497-505. http://doi.org/10.5465/amr.1979.4498296

Chapple L., Humphrey J.E., 2014. Does board gender diversity have a financial impact? Evidence using stock portfolio performance. Journal of Business Ethics, 122(4), 709-723. http://doi.org/10.1007/s10551-013-1785-0

Cowen S.S., Ferreri L.B., Parker L.D., 1987. The impact of corporate characteristics on social responsibility disclosure: A typology and frequency-based analysis. Accounting, Organizations and Society, 12(2), 111-122. http://doi.org/10.1016/0361-3682(87)90001-8

Ferreira D., 2010. Board Diversity, Chapter 12 in Corporate Governance: A Synthesis of Theory, Research, and Practice, Anderson, R. and HK Baker. John Wiley & Sons.

Fuentes-Medina M.L., Morini-Marrero S., Verona-Martel M.C., 2013. The women's role in corporate reputation. Proceedings in ARSA-Advanced Research in Scientific Areas, (1). ISBN: 978-80-554-0825-5

Iqbal N., Ahmad N., Basheer N.A., Nadeem M., 2012. Impact of corporate social responsibility on financial performance of corporations: Evidence from Pakistan. International Journal of Learning and Development, 2(6), 107-118. http://doi.org/10.5296/ijld.v2i6.2717

Isidro H., Sobral M., 2015. The effects of women on corporate boards on firm value, financial performance, and ethical and social compliance. Journal of Business Ethics, 132(1), 1-19. http://doi.org/10.1007/s10551-014-2302-9

Jamali D., Safieddine A.M., Rabbath M., 2008. Corporate governance and corporate social responsibility synergies and interrelationships. Corporate Governance: An International Review, 16(5), 443-459. http://doi.org/10.1111/j.1467-8683.2008.00702.x

Kanter R.M., 1977. Men and women of the corporation. New York: Basic Books.

Khan H.U.Z., 2010. The effect of corporate governance elements on corporate social responsibility (CSR) reporting: Empirical evidence from private commercial banks of Bangladesh. International Journal of Law and Management, 52(2), 82-109. http://doi.org/10.1108/17542431011029406

Konrad A.M., Kramer V., Erkut S., 2008. The impact of three or more women on corporate boards. Organizational Dynamics, 37(2), 145-164. http://doi.org/10.1016/j.orgdyn.2008.02.005

Long J.S., Freese J., 2006. Regression models for categorical dependent variables using Stata. Stata press.

LĂźckerath-Rovers M., 2013. Women on boards and firm performance. Journal of Management&Governance, 17(2), 491-509. http://doi.org/10.1007/s10997-011-9186-1

Majeed S., Aziz T., Saleem S., 2015. The effect of corporate governance elements on corporate social responsibility (CSR) disclosure: An empirical evidence from listed companies at KSE Pakistan. International Journal of Financial Studies, 3(4), 530-556. http://doi.org/10.3390/ijfs3040530

Marinova J., Plantenga J., Remery C., 2016. Gender diversity and firm performance: Evidence from Dutch and Danish boardrooms. The International Journal of Human Resource Management, 27(15), 1777-1790. http://doi.org/10.1080/09585192.2015.1079229

Mian S.N., 2010. Corporate social disclosure in Pakistan: A case study of fertilizers industry. The Journal of Commerce, 2(1), 1.

Mirza H.H., Mahmood S., Andleeb S., Ramzan F., 2012. Gender diversity and firm performance: Evidence from Pakistan. Journal of Social and Development Science, 3(5), 161-166.

Mukasa K.D., Lim H., Kim K., 2015. How do corporate social responsibility activities influence corporate reputation? Evidence from Korean firms. Journal of Applied Business Research (JABR), 31(2), 383-396. http://doi.org/10.19030/jabr.v31i2.9119

Orlitzky M., Schmidt F.L., Rynes S.L., 2003. Corporate social and financial performance: A meta-analysis. Organization Studies, 24(3), 403-441. http://doi.org/10.1177/0170840603024003910

Perryman A.A., Fernando G.D., Tripathy A., 2016. Do gender differences persist? An examination of gender diversity on firm performance, risk, and executive compensation. Journal of Business Research, 69(2), 579-586. http://doi.org/10.1016/j.jbusres.2015.05.013

Pfeffer J., Salancik G.R., 2003. The external control of organizations: A resource dependence perspective. Stanford University Press.

Rhode D.L., Packel A.K., 2014. Diversity on corporate boards: How much difference does difference make. Del. J. Corp. L., 39, 377.

Rose C., 2007. Does female board representation influence firm performance? The Danish evidence. Corporate Governance: An International Review, 15(2), 404-413. http://doi.org/10.1111/j.1467-8683.2007.00570.x

Sarah C., Mona L.K., 2008. Critical mass theory and women's political representtation. Political Studies, 56(3), 725-736.

http://doi.org/10.1111/j.1467-9248.2007.00712.x

Sarfraz M., Qun W., Abdullah M.I., Tahir S., 2019. Authentic Leadership, Hope, Work Engagement and Creativity. Journal of Applied Management and Investments, 8(1), 19-31.

Sarfraz M., Qun W., Shah S.G.M., Fareed Z., 2019. Do Hierarchical Jumps in CEO Succession Invigorate Innovation? Evidence from Chinese Economy. Sustainability, 11(7), 2017. http://doi.org/10.3390/su11072017

Smith N., Smith V., Verner M., 2006. Do women in top management affect firm performance? A panel study of 2,500 Danish firms. International Journal of Productivity and Performance Management, 55(7), 569-593. http://doi.org/10.1108/17410400610702160

Terjesen S., Sealy R., Singh V., 2009. Women directors on corporate boards: A review and research agenda. Corporate Governance: An International Review, 17(3), 320-337. http://doi.org/10.1111/j.1467-8683.2009.00742.x

Williams R.J., 2003. Women on corporate boards of directors and their influence on corporate philanthropy. Journal of Business Ethics, 42(1), 1-10. http://doi.org/10.1023/A:1021626024014

Wood D.J., 1991. Toward improving corporate social performance. Business Horizons, 34(4), 66-73. http://doi.org/10.1016/0007-6813(91)90008-j

Yasser Q.R., 2012. Affects of female directors on firms performance in Pakistan. Modern Economy, 3, 817-825.

WPŁYW ZRÓŻNICOWANIA PŁCI CZŁONKÓW ZARZĄDU NA ODPOWIEDZIALNOŚĆ SPOŁECZNĄ, WYNIKI FINANSOWE I REPUTACJĘ FIRMY

STRESZCZENIE. **Wstęp:** Obecne badania ujawniają efektywność dla firmy wynikającą ze zróżnicowania płciowego członków zarządu oraz na społeczną odpowiedzialność tej firmy, jak również jej wyniki finansowe i reputację, co prowadzi do zrównoważonego rozwoju biznesowego firmy. W pracy poddano analizie wpływ udziału żeńskich członków zarządu na dywersyfikację działań firmy.

Metody: Jako próbę losową wybrano 100 firm umieszczonych na liście giełdy pakistańskiej. Wyniki finansowe były mierzone przy pomocy trzech wskaźników w celu uzyskania bardziej dokładnych wyników. Dane do analizy pobrano za okres od roku 2010 do 2015. Uzyskane dane zostały poddane analizie regresji Fixed-Random OLS, która wykazała brak wpływu zróżnicowania płci członków zarządu na społeczną odpowiedzialność (CSR), wyniki finansowe oraz reputację firmy.

Wyniki: Uzyskane wyniki pokazują, że HODI łagodzi aktywność związaną ze społeczną odpowiedzialność. Zgodnie z wynikami przeprowadzonej analizy regresji, PW nie ma istotnego wpływu na zyski finansowe udziałowców. Sprzedaż oraz ROA wykazały pozytywną korelację z SHR.

Wnioski: Uzyskano negatywną korelację pomiędzy zróżnicowaniem płciowym członków zarządu a wynikami finansowymi firmy. Obecność kobiet w zarządzie albo miała negatywny wpływ albo nie miała wpływu na wyniki finansowe firmy. Podobnie, nie zaobserwowano istotnej zależności pomiędzy obecnością kobiet w zarządzenie a firmą.

Słowa kluczowe: zróżnicowanie płciowe, odpowiedzialność społeczna, działalność firmy, reputacja firmy, Pakistan

Aiman Ajaz
Business School, Hohai University,
Nanjing, Jiangsu, **PR China**, 211100
e-mail: aimanajaz92@gmail.com

Zhou Shenbei
Business School, Hohai University
Nanjing, Jiangsu, **PR China**, 211100
e-mail: zsb@hhu.edu.cn

Muddassar Sarfraz, ORCID ID: https://orcid.org/0000-0001-6165-732X
Department of Management and HR
Business School, Hohai University
Nanjing, Jiangsu, **PR China**, 211100
e-mail: muddassar@hhu.edu.cn

LogForum

> Scientific Journal of Logistics <

2020, 16 (1), 75-83

http://doi.org/10.17270/J.LOG.2020.378

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

CAPITAL BUDGET DECISION-MAKING IN LOGISTICS

Jan Vlachý

Czech Technical University in Prague, Prague, **Czech Republic**

ABSTRACT. **Background:** Capital budgeting decisions in the logistics industry often combine three distinct characteristics. Firstly, they relate to capital assets – such as vehicles or equipment – being periodically replaced with different useful lives and efficiency features, and secondly, their performance is subject to particular operating and market risks. Lastly, externalities, such as regulatory interventions and technological evolution, also contribute to innovation – and thus also uncertainty – becoming a significant factor in logistics. Accordingly, this paper develops a valuation model which takes these characteristics into account and facilitates a robust decision-making process.

Methods: In order to properly capture the specifics of the problem, the proposed model is based on an application of the Life Cycle Cost budgeting method benchmarked to an appropriate functional unit, combined with the Monte Carlo simulation and sensitivity analyses of relevant risk factors.

Results: A realistic case study was developed, providing the necessary input parameters for the method's application. It was thus demonstrated that it provides useful and coherent resources for the decision-making process, including the tools needed to test various assumptions and determine project risks.

Conclusions: The presented model and its solution provide results which are superior compared to conventional capital budgeting methods in terms of properly capturing the essential value-determining factors for a common type of problem encountered in logistics. They are also adequately comprehensive to be applied by practitioners in a real-life managerial setting.

Key words: capital budgeting, life cycle costing, Monte Carlo simulation, logistics management.

A part of this study was presented as oral presentation at the „8th International Logistics Scientific Conference WSL FORUM 2019" in Poznan (Poland), 18th-19th of November 2019.

INTRODUCTION

In production industries, fundamental capital budgeting projects typically feature nonrecurring and time-limited investments, allowing most decisions to be made based on conventional criteria, such as the Net Present Value (NPV) or the Internal Rate of Return (IRR). In contrast, logistics frequently uses servicing systems comprising various kinds of vehicles and equipment which periodically need to be replaced, maintained or renewed in order to achieve and sustain the required standard of service at an optimal cost[Christopher, 2011]. Particular decisions are therefore seemingly marginal and relatively small in scale, but their systematic shortcomings are likely to result in a gradual deterioration of the system's efficiency, which would then be extremely difficult to rectify, with potentially critical consequences in regard to a firm's competitive position. A strategic approach therefore needs to be applied to these decisions, integrating a life cycle view with decisions made in uncertainty.

Numerous authors have addressed various aspects of broadly related problems. Current company practices and their impacts have recently been surveyed by Świerczek [2019], who looked at the role of demand planning,

Citation: Vlachý J., 2020. Capital budget decision-making in logistics. LogForum 16 (1), 75-83, http://doi.org/10.17270/J.LOG.2020.378

Received: 20.06.2019, Accepted: 14.10.2019, on-line: 30.12.2019.

and by González-Moralejo et al. [2015], who focused on the issue of logistics coordination through establishing outsourced relationships. The outsourcing decision process was described by Bajec and Jakomin [2010], while Lampe and Hofmann [2014] undertook a thorough econometric review of systematic risk determinants, leading to valuable conclusions on the appropriate costs of capital for logistics service providers. Zhang et al. [2017] explored the use of real options to determine optimal investment timing and capacity of logistics infrastructure.

This paper takes a more particular approach. It aims to resolve a characteristic problem encountered by decision-makers, which will be defined as a case study. A model will be developed allowing its general parametrization, thus serving as a procedural framework for solving a much more broadly defined class of problems. Finally, the model results will be tested in terms of their sensitivity towards selected parametric assumptions, which is, generally speaking, the main issue faced when using economic models, due to the error-in-variable factor [Chen et al., 2015].

LITERATURE REVIEW AND THEORETICAL FOUNDATIONS

The model uses two fundamental techniques, and is novel primarily because of their specific combination and the functional nature of their feedback, while retaining good heuristic characteristics. One is the implementation of life cycle costing [Woodward, 1997], which mainly serves the objective of temporal and functional normalization, while the other is parametric statistical simulation [Mordechai, 2011], which allows the quantitative inclusion of risk factors. In this regard, there is some affinity to the approach taken by Vlachý [2017] when assessing the process of product and production innovation in a highly indeterminate industry development situation.

Applications of the life cycle costing (LCC) approach have been extremely diverse, and notably included the construction industry [Opuku, 2013]and the public sector [Dragos and Neamtu, 2013]. In recent and more closely related applications, Fulton [2018] compared the total life costs of electric and hybrid drive vehicles, and El-Akruti et al. [2016] determined the optimal repair and replacement policies for an electric arc furnace used in the steel industry, while Favi et al. [2018] focused on design process implications in shipbuilding. Highlighting the need to take a strategic view on life cycle cost decisions, Bescherer [2005] noted that up to 70 to 90% of total life costs, depending on the industry, are already defined in the initial design phase.

There are some features of life cycle costing techniques which are particularly relevant in respect to solving the problem considered herein. Any LCC analysis is typically benchmarked against a functional unit rather than a product or service, which allows proper comparisons of different solutions to the same utility need; such a functional unit may then relate to, for example, servicing capacity, degree of protection or system performance over a uniform time horizon [Norris, 2001]. LCC analyses are also typical for decision-making when variant solutions to a particular problem exist, for example with regard to design or constructional alternatives, operational scenarios, logistics, distribution or recycling. Relative, rather than absolute valuation then needs to be applied, which results in somewhat reduced data requirements [Dhillon, 2010].

Finally, as noted by Norris [2001] and elaborated by Kong and Frangopol [2003] (see also Table 1), in contrast to conventional costing LCC frequently extends the scope of costs over and above the usual Type I and Type II (direct and indirect), to include Type III (contingent) and Type IV (intangible). Applicable financial formulas using continuous compounding and their derivations are described in detail by Los [2001].

As suggested by numerous studies, including Fuss and Vermeulen [2008], and Banker et al. [2014], the essential risk factor determining the economic viability of capital budgeting projects is the product demand, while market prices can reasonably be considered its proxy. The risk, in turn, can be integrated effectively in the assessment using contingent claims analysis, as explained from a firm-valuation perspective by Vlachý [2009], and more technically by Meier et al. [2001].

Table 1. Cost type breakdown

Cost type	Description
Type I (Direct)	Direct costs of capital investment, labor, raw material, waste disposal; may include both recurring and non-recurring costs.
Type II (Indirect)	Indirect costs not allocated to the product or process, i.e. overhead; may include both recurring and non-recurring costs.
Type III (Contingent)	Contingent costs such as fines and penalties, personal injury or property damage liabilities, production or service disruption, competition response, etc.
Type IV (Intangible)	Difficult to measure costs, including consumer acceptance, customer loyalty, worker morale, community relations, corporate image.
Type V (Externalities)	Costs borne by other parties than those directly involved in the life cycle, e.g. society.

Source: adapted from Norris [2001] and Kong, Frangopol [2003]

In principle, contingent claims problems can be solved using several methods, including generalized closed-form analytical solutions and decision trees [Broadie and Detemple, 2004], but they would be too complex to be practicable wherever substantial path dependencies are involved, as in the present case, as argued by Vlachý [2016]. We therefore apply a parametric statistical simulation (Monte Carlo) using Oracle Crystal Ball simulation software [Charnes, 2012] with 100,000 simulation cycles; the processing time for such simulation experiments does not exceed units of seconds with standard office hardware. Basic integration of the Monte Carlo simulation in management science problems is explained by Anderson et al. [2016]. Detailed characteristics of statistical distributions and their specific applications in parametric simulations are described by Mun [2006].

CASE DEFINITION

A logistics delivery handling mechanism uses a critical component which may be designed and constructed using two alternative technologies, denoted A and B. These technologies differ in four life cycle phases: production of the component (P), its installation in the equipment (N), its operating use (U), and its disposal (D).

From the perspective of total production and installation costs, the more sophisticated technology A is more expensive, with direct and allocated overhead costs amounting to ${}^{A}CP$ = € 4,800, while those of component B are just ${}^{B}CP$ = € 4,000. Installation of A is also more costly, with ${}^{A}CN$ = € 500 direct costs and a need to provide each newly fitted mechanism with additional control components worth ${}^{A}FN$ = € 1,500, while the installation of B costs just BCN = € 400.

Nevertheless, in the operating phase, technology A brings considerable cost benefits. In particular, due to improved controls and automatization the component decreases power consumption by 1 MWh per 10,000 handled units and reduces personnel costs by € 1,200 per year.

Component B has an expected working life of ${}^{B}\rho$ = 200,000 handled units, and would thereafter be disposed of at a cost of ${}^{B}CD$ = € 500. Component A has the same ${}^{A}CD$ = € 500 disposal cost, but it has a shorter serviceable life of ${}^{A}\rho$ = 175,000 handled units with a higher probability of premature breakdown than B, which is much more reliable. However, A can be refurbished by the producer, normally up to two times, at a cost of ${}^{A}RP$ = € 1,800. In order to avoid highly inefficient new component installations into handling mechanisms shortly before their retirement, old refurbished components will be used whenever a mechanism has less than 100,000 serviced units left until its scheduled retirement. An unscheduled service disruption is estimated to cost ${}^{A}DU$ = € 900, including opportunity costs.

On average, each handling mechanism (which is a universal platform carrying one of the components regardless of the technology used therein) operates 4,800 hours per year and, over that time, handles 160,000 delivery units. Its expected lifespan is 1 million handled units, which implies a replacement interval of cca 6.25 years.

The firm uses an continuously compounded annual discount rate of 8%.

MODEL DESIGN

When using life cycle costing, it is vital to identify all relevant cost types and determine an appropriate functional unit against which total costs will be benchmarked. Clearly, it would not be adequate to simply compare the costs per device, because each alternative has a different structure and duration of its life cycle. Therefore, it is most practical to relate the functional unit to the number of processed units with a convenient benchmark value of 100,000 units, which thus becomes a measure of service time.

One measurement factor which then needs a recalibration is the discount rate. Given the stated 8 % annual rate and the expected average annual handling of 160,000 units, the discount rate per functional unit (i.e. 100,000 handled units) can be determined as d = 8% × 100,000 / 160,000 = 5%. Note that such a simple linear interpolation is facilitated by the use of continuous compounding.

The life cycle and functional unit costs for technology B, which are stipulated solely by Type I and II costs, are simple to estimate. Its complete life cycle is forecast to last 200,000 handled units, and includes the initial € 4,000 cost of production and € 400 component installation cost, and the terminal € 500 disposal cost. Accordingly, the discounted life cycle cost for component B can be calculated as the net present value of all relevant costs according to Equation (1), with t representing multiples of functional units.

$$NPV = \sum_t C_t e^{-td} \qquad (1)$$

Substituting for the actual costs in time results in ${}^{B}NPV$ = 4,400 + 500 e-2×5% = € 4,852, which relates to the component's total life of 200,000 serviced units. The functional unit cost will then be determined using Equation (2), which is an analogy of the well-known equivalent annual annuity formula, where T represents the total life cycle duration in functional unit multiples.

$$C = \frac{NPV}{(1 - e^{-Td})} \qquad (2)$$

Accordingly, we substitute ${}^{B}C = 4,852 / (1 - e^{-2\times5\%})$ = € 2,550. Note that periodic costs of operation (such as energy, maintenance and operator staff) need not be dealt with at this point in time, because only the differential vis-á-vis technology A is relevant for decision-making. There is also an exact fit of five component lives in the planned life of the complete handling mechanism, which allows perfect replacement scheduling.

While Type I and II costs are assessed deterministically, i.e. using their best point estimate, a different approach needs to be taken with Type III costs, constituting statistically random processes. Namely, there is a reliability factor involved, which requires the creation of a statistical model for variant A.

This will be rendered by an exponential distribution with its parameter λ = 250,000 units, representing the mean life expectation of the component. Each 1,000,000 unit-long life cycle of the mechanism fitted with this component will vary because of the different lives (and thus replacement and refit timings) of each component.

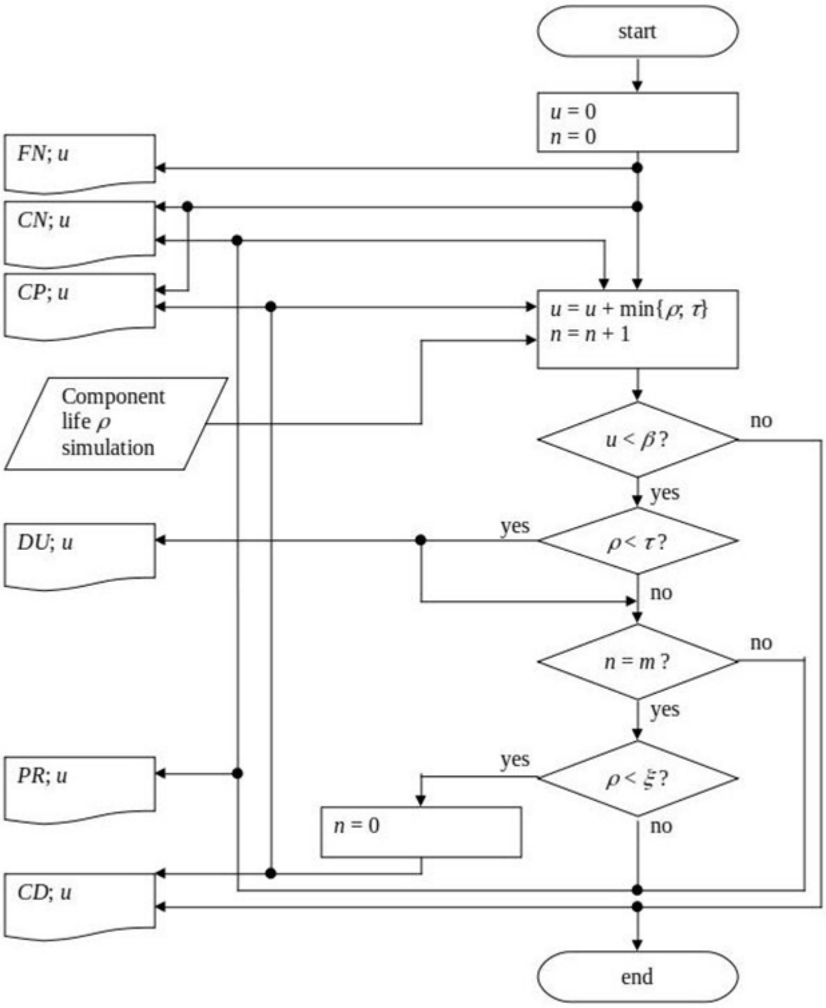
The life cycle can be simulated using a stochastic dynamic process, illustrated by Figure 1, with its control parameters listed in Table 2.

The simulation results in a discounted life cycle cost ${}^{A}NPV$ determined according to Equation (1) over a period of 1 million serviced units. This allows the calculation of a functional unit cost according to Equation (2) as ${}^{A}C = {}^{A}NPV$ / (1 - e-10×5%). For example, a randomly generated ${}^{A}NPV$ = € 1,500 results in ${}^{A}C$ = 1,500 / (1 - e-10×5%) = € 3,812.

The decision-making criterion in terms of preference for technology A or technology B is their functional unit cost differential Δ determined by Equation (3).

$$\Delta = {}^{A}C - {}^{B}C + {}^{Op}\Delta \qquad (3)$$

Note that all its terms represent costs and ${}^{Op}\Delta$ is the operating cost differential per functional unit. A positive value of Δ therefore implies an advantage of A over B, and vice versa.



Source: own work

Fig. 1. Total cost simulation process for component A

Table 2. Control parameters of the cost simulation for component A

Parameter	Description [unit]	Quantity
CP	Cost of component production [€]	4,800
RP	Cost of component refurbishment [€]	1,800
CN	Cost of component installation [€]	500
FN	Cost of controls installation [€]	1,500
DU	Cost of service disruption [€]	900
CD	Cost of component disposal [€]	500
τ	Scheduled life of component [units]	175,000
β	Scheduled life of handling mechanism [units]	1,000,000
ξ	Maximum age of handling mechanism to install new component [units]	900,000
m	Maximum number of new component refurbishments	2
d	Discount rate (per functional unit)	5 %
λ	Mean life expectation of component [units] - stochastic distribution parameter	250,000
ρ	Actual life of component [units]	stochastic
k	Units currently serviced	var.
n	Current number of refits	var.

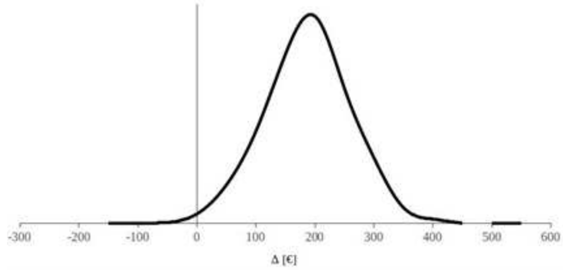
Source: own work

PROBLEM SOLUTION AND DISCUSSION

Decision-making should be based on the result of Equation (3). This requires three inputs, the functional unit cost for technology B, which has already been established as ${}^{B}C$ = € 2,550, the functional unit cost for technology A, determined by statistical simulation using the process in Figure 1, the parameters in Table 2 and the operating cost differential per functional unit ${}^{Op}\Delta$.

The last value requires assessment of relevant factor costs and their proper functional unit (i.e. 100,000 handled units) allocation. Forecasting a wholesale price of energy ${}^{E}P$ = 60 € MWh^{-1} (sensitivity towards this factor will be discussed later) and an energy saving of 1 MWh / 10,000 units, there would be an energy cost differential of ${}^{E}\Delta = 60 \times 1 \times 10$ = € 600 per functional unit. Besides this, there will be a saving in personnel costs amounting to € 1,200 per year, which equates to ${}^{P}\Delta = 1{,}200 \times 100{,}000 \div 160{,}000$ = € 750 per functional unit. The total is ${}^{Op}\Delta = {}^{E}\Delta + {}^{P}\Delta$ = € 1,350 per functional unit.

These are the final inputs needed for the simulation, which generates a probability distribution of functional unit cost differential results shown in Figure 2.



Source: own work

Fig. 2. Functional unit cost differential distribution

Essential results of the simulation include its mean $\mu(\Delta)$ = € 153 and its fifth percentile ${}^{5\%}q(\Delta)$ = € 9, which serves as a convenient measure of risk (in other words, the advantage of A over B is expected to be € 153, and likely to exceed € 9 with a 95 % degree of confidence).

As with any model used for decision-making, it is now necessary to test the results for their robustness in respect to parametric assumptions. Two parameters seem particularly critical, because of their potential volatility or insufficient information; the energy price forecast EP on the one hand, and the mean component life expectation λ for A on the other hand.

The test uses sensitivity analyses as follows: a) the estimates for both parameters were reduced by 10 % and 20 %, and b) their break-even points (B-E) were determined by iteration in respect to $\mu(\Delta) = 0$. The results are summarized in Table 3.

Table 3. Sensitivity analysis results

Parameter	Base scenario	${}^{E}P$(-10%)	${}^{E}P$(-20%)	λ(-10%)	λ(-20%)	B-E(${}^{E}P$)	B-E(λ)
${}^{E}P$ [€/MWh]	60	54	48	60	60	42	60
λ [units]	250,000	250,000	250,000	225,000	200,000	250,000	218,000
$\mu(\Delta)$ [€]	153	105	55	68	-102	0	0
${}^{5\%}q(\Delta)$ [€]	9	-32	-59	-52	-221	-128	-124

Source: own work

The sensitivity analysis clearly shows that the operational risk due to a potentially shorter mean life of the component compared to the expected one is much more significant than the price risk of energy. Whereas even a 20% decline in the price of energy would still clearly merit replacement of component B by A and this conclusion would hold unless the price were to fall under 42 € MWh^{-1} (i.e. by 30%), a relatively moderate increase in the component break down rate - given the uncertainty in its estimation - would suffice to reconsider such a decision.

However, further simulation also suggests an operational measure, which would mitigate this risk and thus again increase the cost advantage of A over B. Provided the firm increases the scheduled life (i.e. replacement time) of component A to τ = 200,000, even an actual value of λ = 218,000 units then results in $\mu(\Delta)$ = € 194. Of course, such an adjustment of operational procedure would be viable only if not constrained by regulatory or other overriding factors.

CONCLUSIONS

This paper developed a model combining Life Cycle Cost budgeting with parametric statistical simulation to solve a problem in the logistics servicing industry related to using different technologies. This allowed the involvement of conventional cost assumptions, as well as operationally dependent contingent costs with disparate replacement timings, providing for a complete assessment of the decision value drivers. It is easy to see how this technique can be adjusted to solve a broad range of similarly defined problems.

In contrast to conventional capital budgeting methods, the model is capable of capturing quality- and customer satisfaction-related factors (i.e. Type III and possibly Type IV costs), which tend to be of particular significance in service industries. As a matter of fact, the model combines several essential components of financial and operational analysis in a single integrated framework.

It has also been shown that developing such a model is perfectly viable for industry practitioners and - when combined with proper sensitivity analyses - simulation-based models can therefore provide meaningful and easily understandable groundwork for practical decision-making.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Anderson D.R., Sweeney D.R., Williams T.A., Camm J.D., Cochran J.J., Fry M.J., Ohlmann J.W., 2016. An introduction to management science: quantitative approaches to decision making, 14th ed., Cengage, Boston.

Bajec P., Jakomin I., 2010. A make-or-buy decision process for outsourcing, Promet - Traffic & Transportation 22(4), 285-291, http://doi.org/10.7307/ptt.v22i4.193.

Banker R.D., Byzalov D., Plehn-Dujowich J.M., 2014. Demand uncertainty and cost behavior, Accounting Review 89(3), 839-865, http://doi.org/10.2308/accr-50661.

Bescherer F., 2005. Established life cycle concept in the business environment, University of Technology, Helsinki.

Broadie M., Detemple J.B., 2004. Option pricing: valuation models and applications, Management Science 50(9), 1145-1177, http://doi.org/10.1287/mnsc.1040.0275.

Charnes J., 2012. Financial modeling with Oracle Crystal Ball and Excel, 2nd ed., John Wiley, Hoboken.

Chen H.-Y., Lee A.C., Lee C.-F., 2015. Alternative errors-in-variables models and their applications in finance research, The Quarterly Review of Economics and Finance 58, 213-227, http://doi.org/0.1016/j.qref.2014.12.002.

Christopher R., 2011. Logistics & supply chain management, 4th ed., Pearson, Harlow.

Dhillon B.S., 2010. Life cycle costing for engineers, CRC Press, Boca Raton.

Dragos D., Neamtu B., 2013. Sustainable public procurement: Life Cycle Costing

(LCC) in the new EU Directive proposal, European Procurement & Public Private Partnership Law Review 8(1), 19-30, http://doi.org/10.21552/EPPPL/2013/1/159.

El-Akruti K., Zhang T., Dwight R., 2016. Developing an optimum maintenance policy by life cycle cost analysis – a case study, International Journal of Production Research 54(19), 5946-5962, http://doi.org/10.1080/00207543.2016.1193244.

Favi C., Germani M., Campi F., Mandolini M., Manieri S., Marconi M., Vita A., 2018. Life cycle model and metrics in shipbuilding: how to use them in the preliminary design phases, Procedia CIRP 69, 523-528, http://doi.org/10.1016/j.procir.2017.11.071.

Fulton L., 2018. Ownership cost comparison of battery electric and non-plugin hybrid vehicles: a consumer perspective, Applied Sciences 8, 1487-1500, http://doi.org/10.3390/app8091487.

Fuss C., Vermeulen P., 2008, Firms' investment decisions in response to demand and price uncertainty, Applied Economics 40(18), 2337-2351, http://doi.org/10.1080/00036840600959909

González-Moralejo S.A., Muñoz P.M., Miquel J.F.L., 2015. Firm size, contractual problems and organizational decision-making: logistics for perishable goods, International Food and Agribusiness Management Review 18(4), 189-203, ISSN: 1559-2448.

Kong J.S., Frangopol D.M., 2003. Life-cycle reliability-based maintenance cost optimization of deteriorating structures with emphasis on bridges, Journal of Structural Engineering 129(6), 818-828, http://doi.org/10.1061/(ASCE)0733-9445(2003)129:6(818).

Lampe K., Hofmann E., 2014. Understanding the cost of capital of logistics service providers: an empirical investigation of multiple contingency variables, Logistics Research 7(1), 119:1-119:25, http://doi.org/10.1007/sl2159-014-0119-7.

Los C.A., 2001. Computational finance: a scientific perspective. World Scientific Publishing, Singapore.

Maier H., Christofides N., Salkin G., 2001. Capital budgeting under uncertainty: an integrated approach using contingent claims analysis and integer programming, Operations Research 49(2), 196-206, http://doi.org/10.1287/opre.49.2.196.13531.

Mordechai S., 2011. Applications of Monte Carlo in Science and Engineering, InTech, The Hague.

Mun J., 2006. Modeling risk: applying Monte Carlo simulation, real options analysis, forecasting and optimization techniques, John Wiley, Hoboken.

Norris G.A., 2001. Integrating life cycle cost analysis and LCA, The International Journal of Life Cycle Assessment 6(2), 118-120, http://doi.org/10.1007/BF02977849.

Opuku A., 2013. The application of whole life costing in the UK construction industry: benefits and barriers, International Journal of Architecture, Engineering and Construction 2(1), 35-42, http://doi.org/10.7492/IJAEC.2013.004.

Świerczek A., 2019. The effects of demand planning on the negative consequences of operational risk in supply chain, LogForum 15(3), 315-329, http://doi.org/10.17270/J.LOG.2019.340.

Vlachý J., 2009. Strategie podniku a finanční teorie [Corporate strategy and financial theory], Politická ekonomie 57(2), 147-162, http://doi.org/10.18267/j.polek.678.

Vlachý J., 2016, Value of contractual assets using statistical simulation, Contemporary Economics 10(2), 153-162, http://doi.org/10.5709/ce.1897-9254.206.

Vlachý J., 2017, The value of innovation in nanotechnology, Engineering Economics 28(5), 535-541, http://doi.org/10.5755/j01.ee.28.5.16770.

Woodward D.G., 1997, Life cycle costing: theory, information acquisition and application, International Journal of Project Management 15(6), 335-344, http://doi.org/10.1016/S0263-7863(96)00089-0.

Zhang D., Jiang J., Li S., Li X., Zhan Q., 2017. Optimal investment timing and size of a logistics park: a real options perspective, Complexity 2017, 2813816:1-2813816:12, http://doi.org/10.1155/2017/2813816.

PODEJMOWANIE DECYZJI BUDŻETOWYCH W LOGISTYCE

STRESZCZENIE. **Wstęp:** Decyzje kapitałowe budżetowe w logistyce często wyróżniają się trzema charakterystycznymi cechami. Są one powiązane z aktywami kapitałowymi, takimi ją pojazdy lub sprzęt, które są okresowo zastępowane, z różnymi okresami życia oraz z faktem, że ich działanie podlega operacyjnemu i rynkowemu ryzyku. Warunki zewnętrzne, takie jak uwarunkowania prawne, rozwój technologii, innowacyjność (wszystko wpływające na niepewność działania) są również istotnym czynnikiem wpływającym na postępowanie w obrębie logistyki. W pracy jest zaprezentowany opracowany model ewaluacji, biorący pod uwagę powyżej wymienione charakterystyki oraz ułatwiający rozbudowany proces podejmowania decyzji.

Metody: W celu prawidłowego ujęcia specyfikacji problemu, proponowany model jest oparty na aplikacji metody budżetowania Life Cycle Cost w odniesieniu do odpowiedniej jednostki funkcjonalnej, w połączeniu z symulacją Monte Carlo and analizą wrażliwości istotnych czynników ryzyka.

Wyniki: Zostało opracowane realistyczne studium przypadku, dostarczające niezbędnych danych wejściowych dla proponowanej metody analizy. Dostarczyło to przydatne spójne dane wejściowe dla procesu podejmowania decyzji, włączając w to narzędzia potrzebne do testowania różnych założeń oraz oceny podejmowanego ryzyka.

Wnioski: Prezentowany model i jego rozwiązane dostarcza wyników porównywanych z konwencjonalnymi metodami budżetowania kapitałowego pod względem prawidłowego ujmowania czynników wartościowych dla powszechnie występujących problemów w logistyce. Można go stosować w szeroko pojętej praktyce zarządzania.

Słowa kluczowe: budżetowanie kapitałowe, kosztorys cyklu życia, symulacja Monte Carlo, zarządzanie logistyczne

Jan Vlachý, ORCID ID: https://orcid.org/0000-0002-2270-3247
Czech Technical University in Prague
MIAS School of Business
Prague, **Czech Republic**
e-mail: jan.vlachy@cvut.cz

LogForum
> Scientific Journal of Logistics <
http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X
2020, 16 (1), 85-102
http://doi.org/10.17270/J.LOG.2020.364
ORIGINAL PAPER

DOES BEING CENTRAL IN FORMAL NETWORK IMPROVE TRUST PROJECTION? A SOCIAL NETWORK ANALYSIS OF SUPPLY NETWORK STRUCTURE

Lokhman Hakim Osman, Abdullah Sanusi Othman, Mohd Rizal Palil

Universiti Kebangsaan Malaysia, Selangor, **Malaysia**

ABSTRACT. **Background:** This research attempts to extend the understanding and application of embeddedeness theory beyond the general network structure. Previous research on network analysis largely focused on the context of the decentralized network structure and how it impacts on the performance of the network member. However, each member of a supply network is embedded in a centralized network structure. The focal firm often plays the commanding role in such structure. Thus, the supply network is a centralized network because of the existence of the focal firm. The existence of the focal firm may influence the impact of firm performance, particularly on the generation of relational capital. Hence, the objective of this research is to determine how formality derives from the centralization of the supply network and influences trust projection in the supply network structure so that it is possible to organize supply network resources to their optimum capacity.

Methods: Basing on the previously applied approach of Social Network Analysis from the sociology research field, we adopted the Social Network Analysis methodology to collect data on supply network connectivity or relations. Using an Exponential Random Graph Model [ERGM], we developed a random search algorithm for network relational capital optimization. Exponential Random Graph Modeling [ERGM] is a statistical method for modeling the generative processes that create social networks. In ERGM, the log-odds of a tie between members of a dyad of nodes or actors in the network are essentially modeled using an exponential form analogous to logistic regressions.

Results: The findings of this study indicate that centrality negatively influences trust projection in the supply network. Hence, a firm embedded in upstream supply network benefits differently in terms of relational capital through the different degree of embeddedness. The firm's resources should be re-aligned to match the benefits of the different network structural positions.

Conclusion: The results of the statistical network analysis reveal interesting findings in terms of prominent structural forms and the impact of involvement or embeddedness in the formal of a supply network. What this means is that the more embedded a firm is in the upstream supply network based on the formal contract tie, the less the likelihood that it will be perceived as trustworthy by other network members. Consequently, this tells us that firms' embbedeness in a centralized network structure which is based on a formal contract ties have a negative impact on the firms' level of trust perception.

Key words: network analysis, information sharing, social capital resources.

INTRODUCTION

This research aims to extend the understanding and application of the embeddedness theory by determining the impact of firms' embeddedness in a centralized network structure such as a supply network. More specifically, this research investigates the implications of a firm's embeddedness or involvement in a centralized upstream supply chain network structure on relational capital outcomes.

There is an extensive amount of literature in the field of operation and supply chain

Citation: Osman L.H., Othman A.S., Palil M.R., 2020. Does being central in formal network improve trust projection? A social network analysis of supply network structure. LogForum 16 (1), 85-102, http://doi.org/10.17270/J.LOG.2020.364
Received: 20.06.2019, Accepted: 09.10.2019, on-line: 30.12.2019.

management indicating that the supply chain network and, more particularly, the upstream supply chain network, has become more complex [Bozarth, Warsing et al. 2009, Li, Yang et al. 2010, Sivadasan, Smart et al. 2010]. Scholars have also concluded that the inter-firm relationship is one of the drivers of upstream supply chain network complexity and deeper understanding is needed to elucidate and comprehend the complexity of these inter-firm relationships [Choi, Krause 2006, Li, Yang et al. 2010].

Issues regarding inter-firm relations have increased concerns related to the problem of supply chain complexity [Bode, Wagner 2015, Dubey, Gunasekaran et al. 2017]. Beyond the direct implications, it has far-reaching consequences for firms in a supply chain network, which originated from disrupted interactions and communications. One disruption to the communications and interaction system could cause butterfly [or ripple] effects [Lee, Padmanabhan et al. 1997] that can create havoc throughout the network.

The literature on operation and supply chain management indicates that there has been extensive research carried out concerning complexity in the supply chain. Many early scholars in operations and supply chain management have adopted both a system perspective [Anderson 1999] and a complex adaptive system perspective [Gell-Mann 1995] in order to comprehend, describe and understand complexity in the supply chain network [Lee, Padmanabhan et al. 1997, Pathak, Day et al. 2007, Osman 2018]. The literature also indicates that there has been a great advance in the drivers of complexity [Wilding 1998, Choi, Kim 2008, Bozarth, Warsing et al. 2009]. However, the focus of these studies has been largely on the attributes of the system elements, but less on the relations between the firm's organizations [the terms organizations and firms are used interchangeably throughout this thesis] that formed the basic, important components of an integrated network of firms [Borgatti, Li 2009, Kim, Choi et al. 2010, Kim, Chen et al. 2015].

Furthermore, network scholars and organizational study scholars have not only advanced the motivation and drivers of firms' embeddedness in network relationships, but also the impact of firms' embeddedness on the network relationships [Borgatti, Jones et al. 1998, Cross, Borgatti et al. 2002, Cousins, Handfield et al. 2006, Borgatti, Li 2009]. It was argued that a decentralized, integrated network of firms generates social capital or relational capital that can be an important source of competitive advantage to related firms when facing complexity in the market environment [Zaheer, Bell 2005, Polyviou, Croxton et al. 2019]. One important stream of embeddednesss research is that relational capital such as trust has emerged from recurrent commercial transactions and the inter-weaving of commercial transactions with webs of social exchanges in a decentralized network structure [Gulati 1998, Nayak, Bhatnagar et al. 2018, Schell, Hiepler et al. 2018]. In this business environment, firms depend upon these relational capital items to coordinate and safeguard their interests against unintended and opportunistic acts from other network members.

Clearly, complexity in the upstream supply chain network arising from the extensive inter-firm relations offers a unique source of competitive advantage that can be accessed by the embedded firms in the integrated network structure.

However, a supply chain network or, more particularly, an upstream supply chain network is a centralized network structure because of the existence of a focal firm which is involved in administering and managing transactions in the upstream supply chain network [Giannoccaro 2018, Lin, Su et al. 2018]. This important structural characteristic might have an implication for the firm's relational capital outcomes. Thus, this research is an examination of the impact of a firm's network involvement or its embeddedness in a complex upstream supply chain network on relational capital outcomes trust. Using social network analysis methodology, this research collects data on network ties from firms involve in maritime industry in South East Asia region. Network data were analysed using the Exponential Random Graph Model. Findings indicate that centralizing the structure of the supply network affects relational capital development among the supply network members. Research limitations and future research directions were also presented. The following sections of the article will discuss the literature that indicates the importance and this research, followed by a methodology section. The findings of the data analysis are presented next and the significance of the findings discussed.

LITERATURE REVIEW

Embeddedness theory posits that firms' embeddedness in the network not only increases economic performance, but also enhances the relational capital, which often translates into an economic payoff [Uzzi 1996]. Pierre Bourdieu [2010] defines relational capital as outcomes which have emerged from inter-firm relations. This definition stresses the benefits of network embeddedness. Through relational capital, firms gain direct access to economic resources or align themselves with firms that provide the resources [Nahapiet, Ghoshal 1998].

Starovic and Marr [2003] consider relational capital to include customer satisfaction and interactions with other firms by employees, distribution channels, supplier channels and franchising channels respectively. This is the information accumulated by the firm as a result of its interactions with other parties and the potential of future information arising from these exchanges.

A firm's embeddedness in networks facilitates the creation of relational capital [Putnam 1993, Lee, Tuselmann et al. 2019]. Burt [2001] added that values of relational capital create business opportunities for the related parties. Relational capital such as trust provides firms with values like solidarity, especially when interactions are fixated and regulated based on rules and reciprocity.

Trust emerges as connectivity increases among the organizations in the network. For example, Uzzi [1997] shows how firms have embedded ties with each other in addition to the arm's-length relationship. Uzzi [1997] refers to the arm's-length relationship as an opportunistic relationship, while embedded ties induce cooperation, and coordination among network organizations. Others further emphasized three features of embedded ties, which include fine grained information exchange, joint problem-solving and trust [Powell 2003, Lee, Tuselmann et al. 2019]. The findings of Lee, Tuselmann et al. [2019], Powell [2003] and Uzzi [1997] all point to the competitive advantage for organizations in a network form of relationships.

In social network terminology, affiliation with other organizations with high network centrality not only provides peripheral organizations with access to capital, these ties also provide other organizations with reputational spill-over benefits. Network centrality refers to an organization's position in the network relative to others [Scott 1988]. As one of the most important properties of network structure, network centrality evaluates an actor's status, prominence and power [Knoke, Kuklinski 1982]. Knoke and Kuklinski [1982] further stated that actors who are the most important or prominent in the network are usually located in the most central positions within the network. Being central means the actors or organizations are connected to almost all other actors in the network. The connections can be in the form of formal ties, which include contractual relationships. Exchange of resources occurs between actors that are tied together either formally or informally.

Thus, extensive contacts or associations with the central organizations in the network increase the availability of information and inflate the reputational spill over benefits [Luoma-aho 2007, Yan, Zhang et al. 2019]. Hence, the embeddedness in the exchange network not only begets tangible returns, it also warrants the accumulation of other intangible ones such as relational capital outcomes.

However, many of these inter-organizational network outcomes studies have focused on the decentralized network structure [Uzzi 1996, Uzzi 1997, Nahapiet, Ghoshal

1998, Li, Yang et al. 2010, Yan, Zhang et al. 2019]. Little to no research has paid attention to firms' embeddedness in centralized networks with focal firms, such as in the upstream supply chain network. There is a clear difference in terms of the network structure [Giannoccaro 2018]. In the supply network, it is argued that an upstream supply network is likely to be a centralized network structure [Choi, Kim 2008, Kim, Choi et al. 2010]. Thus, it is not certain what the effects of firms' embeddedness in such a centralized network structure are on network relational capital outcomes as per a decentralized network structure. One important element that may influence diverse relational capital effects is the nature of the network governance between a decentralized network and a centralized network structure. A centralized coordination approach often involves a lead firm or a focal firm or manufacturer that would manage the transactions of materials and other webs of social exchanges. This is the case that this research intends to investigate.

The basic idea behind a centralized network structure is that an administrative entity will function as the manager or administrator of the network and its activities. Although network members still interact with one another, the existence of the focal actor or firm determined that the network model is centralized [Giannoccaro 2018]. The focal firm plays a key role in coordinating and sustaining the network.

However, because the focal firm is the most powerful firm in the network structure [and often the firm with the most investment compared to other network members], this may generate a Machiavellian image on this focal firm. The literature has indicated some trade-offs, such as a reduced level of commitments and reduced horizontal connections among firms in the network structure.

The commitments of network actors and horizontal connections between the network actors are important factors towards generating relational capital. Thus, the existence of a centralized firm may mean that network members may experience lower levels of relational capital as the outcome of a reduction in commitments from network actors and a reduction in horizontal connections [Wegner, Faccin et al. 2018].

Network centralization reduces horizontal connections that are important for the creation of relational capital. As relational capital emerges through informal, horizontal connections between firms in the network, the introduction of a central focal firm may reduce the generation of relational capital or centralize relational capital upon the focal firm alone [Lincoln, Sargent 2018].

Applying this argument to the centralized upstream supply chain network structure, the level of relational capital experience by network members may be reduced, because their levels of embeddedness are suppressed by the central focal firms in the lean relationships.

However, the literature has also indicated that a history of successful collaboration between firms can help maintain the level of relational capital between network actors. Thus, the relational capital outcomes that have forged successful collaboration activities within or outside the network's particular network boundary may be resilient in the eyes of certain network actors. Despite the reduction of embeddedness, some network members will still be perceived as more trustworthy by other network members.

In summary, as indicated earlier, the upstream supply chain network is a centralized network structure within the focal firm, i.e. the main manufacturer managing and administering the transactions between the firms in the supply base or the upstream supply chain network. To the extent that negative and positive effects influence the centralized network governance, a perplexing issue may also emerge regarding the impact of firm embeddedness in a centralized upstream supply chain network structure. It is not clear whether embeddedness in the centralized upstream supply chain network will improve a firm's level of relational capital, or, conversely, whether centralized network governance will impede the generation of the relational capital outcomes. This perplexity raises the following question regarding the impact of a firm's embeddedness or involvement in the centralized upstream supply chain network structure: Is the embeddedness of firms in the centralized upstream supply chain network related to their respective relational capital outcome?

NETWORK DEGREE CENTRALITY AND TRUST

Idris and Saridakis [2018] proposed classifying network ties through the increasing formality of the ties. Poppo and Zenger [2002] found that governance of inter-firm relationships involves formal and informal coordination. Under formal coordination or inter-firm relations, Cousins, Handfield et al. [2006] argue that long-term resource dependencies between firms or organizations are forged to ensure future commitments and cooperation. Examples of this formal coordination include inter-firm relations such as contract ties and joint planning programs [Poppo, Zenger 2002, Idris, Saridakis 2018]. Thus, in this study, the researcher argues that contract ties constitute networks among firms in the centralized upstream supply chain network structure. Wasserman and Galaskiewicz [1994] stated that a network is made up of a finite set of actors and relations. The authors added that the relations between the actors defined the actors of the network. In the contract tie networks, actors are the firms. Similarly, the relations are specifically contracts which all exist in the upstream supply chain. An important characteristic of the formal inter-firm relation is the existence of a hierarchical or a top-down approach to the governance of the inter-firm network. Through the hierarchical or top-down approach, governance benefits such as administration and control are realized through the centrality of ties [Powell 2003].

Centrality relates to the coreness of a firm's position in a network of inter-firm relationships [Freeman 1979]. What is meant by coreness the central location of the firms in the network. In this study, the researcher adopted network centrality measures through which to illustrate firms' centrality in the centralized upstream supply chain network structure, i.e. degree centrality index. Degree centrality measures the number of other firms in the centralized upstream supply chain network to which a firm is tied. Extensive interactions generate trust among firms. For example, Eccles [1981] found that extensive interactions among a network of homebuilder firms also create trust among network members. The authors found that exchanges of information among the contractors regarding materials' prices create stronger inter-firm relationships and thereby facilitate the creation of trust. Similarly, in order to obtain information regarding a potential partner before collaboration activities can be carried out, firms resort to trusted firms for information. The trust between the firms is the result of multiple exchanges in the past. In the same vein, it is argued that years of inter-firm relationships generate trust among them. Extensive interactions are a catalyst for trust in networks of inter-firm relations [Wegner, Faccin et al. 2018, Lee, Tuselmann et al. 2019, Polyviou, Croxton et al. 2019].

Thus, the literature indicates that firms in a network having an extensive relationship with other firms in the network may be perceived as trustworthy by others. Since extensive relationships in network analysis can be pictured based on the level of firms' coreness in the network structure, this thesis hypothesizes that firms that are more embedded in the centralized upstream supply network following their central position in formal contract ties may experience greater trust.

RESEARCH METHODOLOGY

Social network analysis is a powerful methodology for describing and analysing the inter-relationship of nodes within a particular network [Knoke, Kuklinski 1982]. The relations can represent, for instance, communication, workflow, information sharing or the exchange of goods among actors representing individuals, organizations or even nations [Knoke, Kuklinski 1982, Borgatti and Li 2009]. Nodes within a network can be individuals, a group of individuals, such as a department within an organization, or even an organization itself within a larger network such as the supply chain. Given the flexibility defining these nodes, SNA can be effectively used to study both the organizational and inter-organizational phenomena [Borgatti, Li 2009]. At the organizational level, the network describes the relationship among individuals or groups within organizations, while at the inter-organizational level, SNA concerned the interrelationship or organizations within horizontal and vertical network [Lazzarini, Chaddad et al. 2001].

Unlike the traditional multivariate analysis performed in logistics and supply chain management research, which focus on individuals or organizations as the unit of analysis, SNA has an added advantage. SNA also focuses on the patterning of relationships among actors in the network. Several literature sources state that in social network analysis an actor e.g. individuals, or group of individuals and an organization or group of organizations, is seen as embedded in a larger network structure that both constrains and liberates [Granovetter 1985, Baum, Oliver 1992, Romo, Schwartz 1995, Choi, Kim 2008]. The analysis of such network embeddedness can result in potential findings that could not be obtained with conventional survey and case study methodology [Knoke, Kuklinski 1982, Diani 2002]. For instance, SNA allows for the uncovering of the informal relationship and formal relationship that employees within an organization or inter organizations had established with one another. These relationships, particularly informal relationships, often cut across formal functional boundaries and reporting channels, and help meet difficult deadlines and perform challenging tasks [Krackhardt 1999, Rowley, Behrens et al. 2000, Moran 2005].

For this study, the supply network of a small maritime industry seemed to be an ideal setting. A supply network in the maritime industry is a material-intensive enterprise. Much of the activities and activities are highly dynamic and are widely dispersed throughout the network. Materials and information are transferred through interactions among different buyer-supplier organizations. Because buyer-supplier organizations in the supply network operate in an environment of a high degree of complexity [Bozarth, Warsing et al. 2009] and uncertainty [Wilding 1998], these buyer-supplier organizations seek an edge through connections or interactions with the members of the network. Lambert and Cooper [2000] stated that the key to these issues is the on-going relationship with the other partners. They stress the importance of investigating the relationships suppliers and customers have with competitors ["non-member process links"] using other theoretical perspectives. This model begs the question of who manages whom, who coordinates what, and how coordination and integration are maintained.

A survey was used to collect majority of the information needed for this study. Surveys and questionnaires are traditional tools to help network researchers to obtain data on inter-organizational relation-ships [Wasserman, Galaskiewicz 1994]. Leading network researchers such as Galaskiewicz [2011] and Borgatti and Li [2009] established the credibility of this technique for collecting network data on inter-organizational transactions such as information transfer, resource transfer and joint activities. A survey is suitable for this type of study, because it allows the researcher to tap into the participants' subjective perceptions of interactions rather than objectively measure interactions, which in many situations are hard to gain access to for confidentiality reasons [Diani 2002].

The network survey questionnaire entitled "Structural Embeddedness and Organizational Performance" is comprised of 13 main questions, including the demographics section. The network questionnaire is designed so that it is contained within A4 pages with no blank spaces. It is prefaced by an introductory preamble at the top of page one asking for the respondents' participation and signed by the author. In order to make the network questionnaire as easy as possible, it is broken up into the sections. In addition, some necessary questions such as the network ties questions are preceded by instructions on how to answer the questions. The survey instrument is divided into several sections consisting of 3 types of questions. The first type of question seeks general demographic information from the respondents with regard to the firms that they are serving. This set of questions also provides the descriptive statistics of the responding firms. Information acquired through this type of question consists of material regarding the firms' address, and total number of employees or staff, as well as the number of years in operation. The second category of questions investigates the network ties between the firms in the centralized upstream supply network. In this section, the survey shows a table with the names of all the firms listed in the first column of the table. Based on this, the respondents were asked to indicate by making a tick in the table the list of firms that they have been in communication with for the certain types of relationships listed in the last six months. These ties are important in order to understand both formal and informal relationships between organisations (Choi, Hong, 2002, Corteville, Sun, 2009, Provan, Milward, 1995). The types of ties investigated were contracts and information-sharing ties. The contractual tie questions show how formally linked one firm is with another in the upstream supply network. The survey instrument asked the key informants to indicate on the roster the list of firms with which they have formal service contracts relating to the supply of materials. The firms can be in tier two, supplying materials to the tier one supplier, who in turn supplies the focal firm with the materials necessary for the production of RHIB.

DATA ANALYSIS

Many leading network scholars have claimed that traditional statistical analysis disregards the possibility of relations between the individual nodes or actors through the assumption of independence of observation [Robins, Pattison et al. 2009, Bamber, Jiang et al. 2010, Shumate, Palazzolo 2010, Lusher, Robins et al. 2012], when in fact, in social networks, the node and actor are an interdependent, related unit of analysis [Knoke, Kuklinski 1982]. It is for this interdependency and relatedness argument that a special class of statistical models is preferred when investigating social relations, in particular, the Exponential Random Graph Model [ERGM] [Shumate, Palazzolo 2010].

Exponential Random Graph Modeling [ERGM] is a statistical method for modeling the generative processes that create the social networks [Handcock et al. 2004]. In ERGM, the log-odds of a tie between members of a dyad of nodes or actors in the network are essentially modeled using an exponential form analogous to logistic regressions. One of the advantages of ERGM is that it allows the researchers to model the structural elements of the network as covariates [Robins, Pattison et al. 2007].

In ERGM, a tie can be modeled as a function of node and edge variances. ERGM are sometimes known in the social network literature as P-star [P*] models [Robins et al., 2007]. The purpose of ERGM is to simulate the probability distribution function of a given class of graphs. The stochastic process giving rise to the observed network is modeled as a function of network configurations. However, on networks, even a small one, the number of possible configurations of ties is rather large. Because of this, the probability distribution of the network structural elements must be estimated. The estimation is done using the Markov Chain Monte Carlo [MCMC] method to sample the distribution of the structural features of interest among networks having the same number of nodes as the observed network. With the outcome information, the coefficients can be estimated using the Maximum Likelihood Estimates [MLE] methods [Robins et al., 2007].

In general, the analysis technique performed in this section is known as the generative model [Robins et al. 2007]. This technique provides a full stochastic representation of the process of the network formation, which allows the dependence among the observation to become the focus of the models. An ERGM model allows the researcher to control the impacts of higher order structures with lower ones. Exponential random graph models [ERGM] have the following form:

$$P_r\,(Y = y) = \; 1/k]\, \exp\left(\sum \eta A(g)\, A(y)\right) \qquad (1)$$

where:

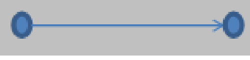
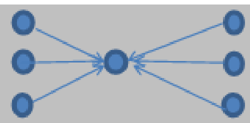
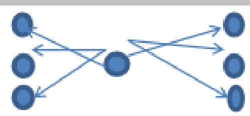
- The summation is over all configurations A;
- ηA is the parameter corresponding to configuration A [and is non-zero only if all pairs of variables in A are assumed to be conditionally dependent];
- gA[y] is the network statistic corresponding to configuration A; gA[y] = 1 if the configuration is observed in the network y, and is 0 otherwise.

All ERGM models are in the form of equation (1), which describes a general probability distribution of graphs on n nodes. The probability of observing any particular graph y in this distribution is given by the equation, and this probability is dependent both on the statistics gA(y) in the network y and on the various non-zero parameters ηA for all configurations A in the model. Configurations might include reciprocated ties, transitive triads and so on [Robins et al., 2007]. Hence, the model enables us to examine a variety of possible structural regularities [Handcock et al., 2004]. The probability of observing the graph is dependent on the presence of various structural characteristics introduced in the model. It is worth stressing that a model for the network y consists of n (n – 1) possible network ties. In this study the total research population is comprised of 37 firms. Thus, the total number of possible ties under investigation is 37(37-1) = 1332. The total tie is large enough to provide valid statistical inference of the results. The model specification for the trust networks is briefly described as follows. For the ERGM analysis to take place, the researcher adopted the PNet program to run the network data set of each of the ties in the network and the prevailing structural embeddedness variables (i.e. degree centrality) as the model parameters.

The generative models analysis presented here was conducted using the PNet program [Wang, Robins et al. 2006]. Overall, in this section of the data analysis, the covariates of the thesis are modelled in two different ways. The first method is to model the impact of each covariate on the log-odds on the different type of ties under consideration [formal contract ties and informal information sharing ties]. The second method involves modelling the impact of the structural embeddedness parameter in the different types of network generated from the network survey questionnaire. The model's network effects are tested for fit using the Monte Carlo Maximum Likelihood Estimates [MCMCMLE] estimation techniques and calculate the estimated coefficient using the PNET package.

Network effects in ERGM refer to the associations between social network ties and the actor attributes of the particular network [Robins, Pattison et al. 2007]. An example of network effects include the tendency of dyadic ties to be mutual i.e. Actor A likes Actor B and Actor B likes Actor A in return. However, there are also other effects that incorporate nodes or actors' attributes that may help explain the forming of ties between the network members. For instance, a highly popular node or actor of the network may be attributed to the actor's level of education or the actor's age. In the ERG model, a number of effects can be included in the model by the researcher just as adding variables into a regression analysis to determine the explanatory power of particular variable/s. As the ERG model is statistical, it is possible to determine whether certain network effects occur at levels greater or less than chance. The complexities of social relations suggest that there are many interdependent network effects that are occurring at the same time within the network. ERGM provides the means to explore these network effects together, manage the different attributes and explore the network complexity as a whole [Lusher 2011]. This study applied these capabilities of ERGM analysis to answer the arguments of this study hypothesis.

The network effects are divided into pure structural effects. Pure structural effects are the self-organizing characteristics of a social network that do not rely on the characteristics or the attributes of the individual nodes or actors [Robins, Elliott et al. 2001, Wang, Robins et al. 2006, Wang, Robins et al. 2006, Lusher, Robins et al. 2012]. For instance, the fact that people would shake hands with others regardless of the attributes of these other individuals is a form of pure structural effects which indicate mutuality or reciprocity of ties. Transitive relation is another form of structural effects. Transitive pure structural effects relate to a condition whereby a friend of a friend is a friend. Transitive pure structural effects are also known specifically in ERGM as triadic parameter effects [further discussion in Table 1]. In principle, pure structural effects explain the conditions where the presence of one or more ties leads to the formation of other social ties.

Parameter	Interpretation	Description	Explanation
Density Arc	Baseline tendency for a tie to occur		One firm nominating another firm
Reciprocity	Tendency for reciprocation		Mutual ties between two firms
Degree Based Popularity A-in-S	Tendency of Spread of in-degree distribution. Centrality, coreperiphery as a result of actor popularity		Indicative of presences of highly nominated firms within the network
Activity Based A-out-S	Tendency of Spread of out-degree distribution.		Indicative of the activity of firms to engage many others

Source: Robins et al.[2012]

Fig. 1. Summary of purely structural ERGM network effects

Figure 1 presents a list of purely structural network parameters which measure [and control for] endogenous, or self-organizing, structuring within the networks of this study and related to the study hypotheses, and consequently helping to answer the research question. The first column of Figure 1 lists the names of pure structural effects parameters [as well as the codes] relevant for this study. These parameters are selected based on the theoretical objectives of this thesis. The relevant parameter is the Arc parameter. The Arc is the baseline parameter in any network. It represents the tie that connects [minimum] two nodes into a dyad. Using the Arc parameter estimates, the researcher is able to determine the density or cohesiveness of the network under consideration [Wang, Robins et al. 2006]. The second groups of pure structural effects parameters are degree-based parameters. For the ERG models, this research include two degree-based pure structural parameters which represent degree centrality. The parameters are the popularity-based and the activity degree centrality parameters, coded as A-in-S and A-out-S respectively. The significance of these parameter estimates will help support the hypothesis in this study. The second column of Table 1 shows an interpretation of the parameters. What it means in the second column of Table 1 is the propensity of the structural parameters effects to take effects given the network size and number. For instance, an ERG model with positive and significant reciprocity estimates [details of determining the parameter significant is given in the following sections] indicates the high propensity for mutual ties to occur in the network given the network size and number of nodes. The third column of Table 1 describes the pure structural effects parameters in graphical formats. In column three, buyer-supplier organizations are represented by the blue nodes, while the lines between two nodes represent the ties that connect them. The lines also have arrows indicating the direction of the tie, either inward or outward. The final column discusses the meaning of the parameters from the supply chain perspectives. From the perspective of supply relationships, the Arc parameter refers to the tendency of the organizations to forge ties with other buyer-supplier organizations in the network given the size and number of the nodes in the network. Reciprocity relates to the presence of mutual ties between the buyer-supplier organizations in the trust network of the MMEA supply system. The popularity parameter [A-in-S] suggests that popular buyer-supplier organizations tend to receive more ties from shared alters and to communicate together. Activity spread [A-out-S] relates to the activity of organization to engage other buyer-supplier organizations in the network.

FINDINGS AND DISCUSSION

In this section, the researcher presents the ERGM analysis result in involving the network embeddedness measure a degree of centrality in the contract tie. To test for the trust network structural variations in a more systematic way, this thesis ran a series of ERG models, which allow the researcher to determine statistically whether certain configurations are more prevalent in the network than would occur by chance alone [Snijders, Pattison et al. 2006, Robins, Pattison et al. 2009]. Statistically, the researcher conducted the ERGM analysis with one main objective: to determine whether the significant structural parameters in the trust network reflect the parameters that represent embeddedness property i.e. degree-based parameters. This objective is achieved by analyzing the outcome of the Pure Structural Effect ERG models.

The ERGM analysis was conducted following Robins, Lewis et al.[2012], Lusher [2011] and Lusher, Robins et al.'s [2010] methods of analysis. Basically, in this section, we analyzed the network data based on an important principle parameter. In the initial analysis, we conducted the Pure Structural Parameter Effects model ERGM analysis to determine the relevant structural formation of the trust network. With this analysis, the researcher was able to determine the patterns of tie formation propensity.

It is important to note that throughout this statistical network modeling analysis there will only be only one Pure Structural Effects models with the relevant, converged, structural parameters. This Pure Structural Effects model is for the trust network alone.

In Model 1, this thesis runs a dyad-independence model in which we only test for the significance of the structural parameter. Model 1 will provide the general sense of how trust network ties are being formed.

The correct interpretation of the outcome parameters in the ERG models requires the investigation of three parameters features, which are the MLE [Maximum Likelihood Estimate], Magnitude or Effects, and the associated convergence t-statistics. The sign of the MLE [" +" or "-"] provides an indication of whether the particular network structure occurs more or less likely than predicted by chance. The Magnitude or Effects of the parameter assess the significance of the parameter in the model. If the Magnitude or Effects of the parameter estimates is greater than two times the standard error, it is considered significant and is denoted by an asterisk [*]. For a model to be considered well converged, the t-statistics must be near zero [generally less than 0.1 is an absolute value]. All of the parameters included in these study models are under the convergence threshold, indicating that the models fit the data well. This allows for the testing of hypotheses associated with the specific parameters. It is important to note that these ERG models are conditional, meaning that each subsequent parameter added into the models represent a mechanism that is operating over and above other mechanisms. The next section of this thesis discusses the analysis results of the ERG model for the trust network and embeddedness attributes based on degree centrality in contract ties.

The parameter estimates [MLE], Magnitude or Effects, and convergence t-statistics for the MMEA trust network are presented as follows:

Table 1 presents the attributes-based network effects and the structural parameters effects in the models.

Table 1. The attributes based network effects and the structural parameters effects in the models

Parameter	ML Estimates	Standard Error	Magnitude [MLE/Std Err]	Convergence *t*-ratio
***Model 1**: Pure Structural Effects [Embeddedness Based on Degree Centrality in Contract tie]*				
Arc	-1.101	0.082	13.33	0.014*
Reciprocity	1.478	0.401	3.69	0.048*
A-in-S	-1.350	0.429	3.14	0.014*
A-out-S	0.128	0.399	0.32	0.019

*A parameter estimates is considered significant when the absolute value of the ML is greater than twice the magnitude of standard error.

Model 1 were used to test embeddedness based on degree centrality in contract tie effects on the trust relationship. Model 1 is the Pure Structural Parameter Effects model for the trust network, which includes only the structural parameters. This model is used to show the propensity of ties structure to be formed in the trust network of the MMEA supply system. In Model 1, to obtain a converged Pure Structural Effects model for trust network, the following parameters are included conditionally until the model is converged i.e. until the t-statistics of each relevant parameter are less than 0.1. Consequently, the parameters that are included in the Pure Structural Effects model of the trust network are as follows: Reciprocity, A-in-S, and A-out-S. Structurally, these parameters reflect certain forms of ties structural formations in the trust network. Evidently, these parameters reflect centralization [A-in-S, A-out-S], [Wang, Robins et al. 2006, Robins, Pattison et al. 2009]. However, in this section of the analysis, greater attention will be given to the parameters that represent the degree-based or centrality parameters of the trust network, as these parameters reflect the core argument of the hypothesis. As this thesis argues in the hypothesis that embeddedness based on degree centrality would influence the trust level of the embedded buyer-supplier organizations, this thesis expects to find the presence of A-in-S and A-out-S parameters in the trust network. Quantitatively, it is expected that the centrality parameters estimates to be positive and significant in the models.

In Model 1, the Arc ML estimate is a significant and negative parameter [ML estimates = -1.101, SE =0.014], suggesting fewer trust relationships are expected in the MMEA supply system to be observed than would have been expected by chance. In other words, buyer-supplier organizations of the MMEA supply network forge trust relationships with only a few of the potential other buyer-supplier organizations in the network. This phenomenon is expected as trust relationships are built over time and rely on other endogenous variables, such as the size of the participating organizations and the length of the relationships [Doney, Cannon 1997, Laaksonen, Jarimo et al. 2009, Jiang, Chua et al. 2011]. Supplier size encompasses the firm's overall size and its market share position. Supplier size provides a signal to the buying firm that the selling firm can be trusted. Overall size and market share indicate that many other businesses trust this supplier enough to do business with it. This suggests that the supplier consistently delivers on its promises to others or it would not have been able to maintain its position in the industry. In addition, length of time represents an investment both parties make in the relationship. To the extent that buyers perceive such investments on the part of suppliers, they could calculate that a supplier would incur losses by acting in an opportunistic [i.e., untrustworthy] manner.

Furthermore, in Model1, the ERGM analysis provides interesting insights into the reciprocity in trust relationships of the MMEA buyer-supplier organizations. In Model1, for the purely structural parameter effects, we have significant and positive effects of reciprocity for trust relationship [MLE = 1.478, SE = 0.048]. Therefore, relative to chance and given the other effects in the models, buyer-supplier organizations are likely to nominate each other. Reciprocity is an important feature of many other social networks studies, and it is expected in trust relationships [Robins, Pattison et al. 2009, Bamber, Jiang et al. 2010, Lusher, Ackland 2010, Lusher, Robins et al. 2010, Lusher 2011, Lusher, Robins et al. 2012, Robins, Lewis et al. 2012]. What this means is that in the trust network of the MMEA supply system, the trust relationships are likely to be mutual, whereby if buyer-supplier organization A trusts B, it is highly likely that B will also trust A.

With regard to degree-based structural formations, two parameters, i.e. A-in-S and A-out-S are included in Model 1 to assess the presence of network centrality structural formation in the trust network. In Model 1, the A-in-S parameter is an indication of the presence of highly nominated buyer-supplier organizations within the trust network. Model 1 shows that the A-in-S parameter is significant but negative [MLE = -1.350, and SE = 0.014]. What can be taken from these parameter estimates is that in the trust network, controlling for other effects, although there is a significant parameter estimate for A-in-S, a negative MLE score indicates that it is unlikely that the trust ties relationship will be forged based on degree-based structural formation. In other words, in trust relationships or networks of the MMEA supply system, there is low propensity for buyer-supplier organizations to be embedded in a degree-based structure.

CONCLUSIONS

This research attempts to extend the understanding and application of the embeddedness theory by determining the impact of firms' embeddedness in a centralized network structure such as the supply network. Specifically, the question that this study attempt to answer looks at how the embeddedness of firms in the centralized upstream supply chain network is related to their respective relational capital outcome. The results of the statistical network analysis reveal some interesting findings and contribute partially towards the conclusions of this study. The researcher found interesting findings in terms of prominent structural forms and the impact of involvement or embeddedness in the formal of a supply network. The ERGM analysis revealed that there were significant negative effects of firms' embeddedness based on degree centrality in contract tie and trust, the Maximum Likelihood Estimate [MLE] is significant but negative when firms are highly embedded in the contract tie. What this means is that the more embedded a firm is in the upstream supply chain network based on the formal contract tie, the less the likelihood that it will be perceived as trustworthy by other network members. Consequently, this tells us that firms' embeddedness in a centralized network structure which is based on a formal contract ties have negative impacts on the firms' level of trust perception.

As a firm becomes more embedded in the upstream supply chain network structure, it will experience varying levels of relational capital depending on the type of activity that the firm is involved in. However, the same cannot be said when the type of network tie is rather formal and based on terms and regulations. The more embedded a firm is in the supply network based on its degree centrality network position, the less likelihood there is that the firm will be perceived as trustworthy by other firms embedded in a similar network structure. In other words, in a network of formal connectivity, putting oneself to the front by emphasizing on contracts terms will result in negative impact upon the firm level of trust.

This finding is in incongruence with Uzzi [1997] and Giannoccaro [2018]. The authors found that in inter-firm relationships, active relational governance such as information-sharing is associated with trust. An information sharing tie is not a form of a formal tie but rather an informal one. An important implication of this is that these findings provide support for the idea that firm commitment to contract activities could not enhances the perception of trust that the firm may receive from other network members.

This research is not without its limitations. Firstly, the scope of this study only focuses on the maritime industry. More works which focuses on other industries may reveal interesting new findings. Furthermore, it would also be valuable to view the dynamic of firms' relationships, for instance, to see how firms' relationships are linked to one another through time as industries, technology and other factors evolve. Because inter-organizational relationships are dynamic rather than static, their nature and form are expected to change over time. The ability to see which conditions would result in different outcomes would provide significant implications for the management of the firms' relationships and inter-organizational relationships in general, as well as to the general theory of embeddedness in explaining the implications of firm embeddedness and relational capital outcomes.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This work was supported by the MPOB Endowment Chair @ FEP UKM [grant numbers EP-2017-033].

REFERENCES

Anderson P., 1999. Complexity Theory and Organization Science, Organization Science 10[3]: 216-232. http://doi.org/10.1287/orsc.10.3.216

Bamber et al., 2010. What's my style? The influence of top managers on voluntary corporate financial disclosure. The Accounting Review 85: 1131. http://doi.org/10.2308/accr.2010.85.4.1131

Baum J.A.C., Oliver C., 1992. Institutional embeddedness and the dynamics of organizational populations. American sociological review: 540-559. https://www.jstor.org/stable/2096100

Bode C., Wagner S.M., 2015. Structural drivers of upstream supply chain complexity and the frequency of supply chain disruptions. Journal of Operations Management 36: 215-228. http://doi.org/10.1016/j.jom.2014.12.004

Borgatti, Li, 2009. On Social Network Analysis in a Supply Chain Context. Journal of Supply Chain Management 45[2]: 5-22. http://doi.org/10.1111/j.1745-493X.2009.03166.x

Borgatti S., Li X., 2009. On Social Network Analysis In a Supply Chain Context. Journal of Supply Chain Management 45[2]: 5-22. http://doi.org/10.1111/j.1745-493X.2009.03166.x

Borgatti S.P., Jones C., Everett M.G., 1998. Network measures of social capital., Connections, 21[2]: 27-36.

Bourdieu P., 2010. "The Forms of Capitalâ [1986]." Cultural Theory: An Anthology: 81.

Bozarth C.C., Warsin D.P., Flynn B.B., Flynn J., 2009. The impact of supply chain complexity on manufacturing plant performance. Journal of Operations Management 27[1]: 78-93. http://doi.org/10.1016/j.jom.2008.07.003

Burt R.S., 2001. Structural holes versus network closure as social capital. Social capital: Theory and research: 31-56.

Burt R.S., 2017. Structural Holes versus Network Closure as Social Capital [in Social Capital Theory and Research by Rene Dubos], Taylor & Francis Group

Choi, Kim, 2008. Structural Embeddedness and Supplier Management: A Network Perspective. Journal of Supply Chain Management 44[4]: 5-13. http://doi.org/10.1111/j.1745-493X.2008.00069.x

Choi T.Y., Krause D.R., 2006. The supply base and its complexity: Implications for transaction costs, risks, responsiveness, and innovation. Journal of Operations Management 24[5]: 637-652. http://doi.org/10.1016/j.jom.2005.07.002

Cousins P.D., Handfield R.B., Lawson B., Petersen K.J., 2006. Creating supply chain relational capital: The impact of formal and informal socialization processes. Journal of Operations Management 24[6]: 851-863. http://doi.org/10.1016/j.jom.2005.08.007

Cross R., Borgatii S.P., Parker A., 2002. Making invisible work visible: Using social network analysis to support strategic collaboration. California management review 44[2]: 25-46. http://doi.org/10.2307/41166121

Diani M., 2002. Network analysis. Methods of social movement research: 173-200.

Doney P.M., Cannon J.P., 1997. An examination of the nature of trust in buyer-seller relationships., the Journal of Marketing: 35-51. http://doi.org/10.1177/002224299706100203

Dubey R., et al., 2017. Upstream supply chain visibility and complexity effect on focal companyâ ™s sustainable performance: Indian manufacturersâ ™ perspective. Annals of Operations Research: 1-25. http://doi.org/10.1007/s10479-017-2544-x

Eccles R.G., 1981. Bureaucratic versus craft administration: the relationship of market structure to the construction firm. Administrative science quarterly: 449-469. http://doi.org/10.2307/2392517

Freeman L.C., 1979. Centrality in social networks conceptual clarification. Social Networks 1[3]: 215-239. http://doi.org/10.1016/0378-8733(78)90021-7

Galaskiewicz J., 2011. Studying Supply Chains From a Social Network Perspective. Journal of Supply Chain Management 47[1]: 4-8. http://doi.org/10.1111/j.1745-493X.2010.03209.x

Gell-Mann M., 1995. Complex adaptive systems, Addison-Wesley Publishing Co.

Giannoccaro I., 2018. Centralized vs. decentralized supply chains: The importance of decision maker's cognitive ability and resistance to change. Industrial Marketing Management 73: 59-69. http://doi.org/10.1016/j.indmarman.2018.01.034

Granovetter M., 1985. Economic Action and Social Structure: The Problem of Embeddedness. American Journal of Sociology 91[3]: 481-510. http://doi.org/10.1086/228311

Gulati R., 1998. Alliances and networks. Strategic Management Journal 19[4]: 293-317. http://doi.org/10.1002/(SICI)1097-0266(199804)19:4<293::AID-SMJ982>3.0.CO;2-M

Idris B., Saridakis G., 2018. Local formal interpersonal networks and SMEs internationalisation: Empirical evidence from the UK. International Business Review 27[3]: 610-624. http://doi.org/10.1016/j.ibusrev.2017.10.010

Jiang C.X., et al. 2011. Effects of cultural ethnicity, firm size, and firm age on senior executives™ trust in their overseas business partners: Evidence from China. Journal of International Business Studies 42[9]: 1150-1173. http://doi.org/10.1057/jibs.2011.35

Kim et al., 2010. Structural Investigation of Supply Networks:; A Social Network Analysis Approach. Journal of Operations Management 2010. http://doi.org/10.1016/j.jom.2010.11.001

Kim Y., et al., 2015. Supply network disruption and resilience: A network structural perspective. Journal of Operations Management 33: 43-59. http://doi.org/10.1016/j.jom.2014.10.006

Knoke D., Kuklinski J., 1982. Network analysis, Sage Publications, Inc., https://trove.nla.gov.au/work/27222052?q&versionId=45734216

Krackhardt D., 1999. The ties that torture: Simmelian tie analysis in organizations. Research in the Sociology of Organizations 16[1999]: 183-210

Laaksonen T., et al., 2009. Cooperative strategies in customer-supplier relationships: The role of interfirm trust. International Journal of Production Economics 120[1]: 79-87. http://doi.org/10.1016/j.ijpe.2008.07.029

Lambert D., Cooper M., 2000. Issues in supply chain management. Industrial Marketing Management 29[1]: 65-83. http://doi.org/10.1016/S0019-8501(99)00113-3

Lazzarini S., et al. 2001. Integrating supply chain and network analyses: The study of netchains. Journal on chain and network science 1[1]: 7-22.

http://doi.org/10.3920/JCNS2001.x002

Lee H., et al., 1997. Information distortion in a supply chain: the bullwhip effect. Management science 43[4]: 546-558.

Lee R., et al., 2019. Effects of structural, relational and cognitive social capital on resource acquisition: a study of entrepreneurs residing in multiply deprived areas. Entrepreneurship & Regional Development 31[5-6]: 534-554.

Lee R., Tuselmann H., Jayawarna D., Rouse J., 2019. Effects of structural, relational and cognitive social capital on resource acquisition: a study of entrepreneurs residing in multiply deprived areas, Entrepreneurship & Regional Development, 31:5-6, 534-554, http://doi.org/10.1080/08985626.2018.1545873

Li G., Sun H.Y. L., Ping Ji, Feng L., 2010. The evolutionary complexity of complex adaptive supply networks: A simulation and case study. International Journal of Production Economics 124[2]: 310. http://doi.org/10.1016/j.ijpe.2009.11.027

Lin Q., Su X., Peng Y., 2018. Supply chain coordination in confirming warehouse financing. Computers & Industrial Engineering 118: 104-111. http://doi.org/10.1016/j.cie.2018.02.029

Lincoln J., Sargent M. 2018. Business groups as networks.

Luoma-aho V., 2007. Neutral reputation and public sector organizations. Corporate Reputation Review 10[2]: 124-143. http://doi.org/10.1057/palgrave.crr.1550043

Lusher D., 2011. Masculinity, educational achievement and social status: a social network analysis. Gender and Education 23[6]: 655-675. http://doi.org/10.1080/09540253.2010.527825

Lusher D., Ackland R., 2010. A relational hyperlink analysis of an online social movement. Journal of Social Structure 11[1].

Lusher D., Robins G., Kremer P., 2010. The application of social network analysis to team sports. Measurement in physical education and exercise science 14[4]: 211-224. http://doi.org/10.1080/1091367X.2010.495559

Lusher D., Robins G., PattisonP.E., Lomi A., 2012. Trust Me: Differences in expressed and perceived trust relations in an organization. Social Networks. http://doi.org/10.1016/j.socnet.2012.01.004

Moran P., 2005. Structural vs. relational embeddedness: social capital and managerial performance. Strategic Management Journal 26[12]: 1129-1151. http://doi.org/10.1002/smj.486

Nahapiet J., Ghoshal S., 1998. Social capital, intellectual capital, and the organizational advantage. Academy of Management Review 23[2]: 242-266. http://doi.org/10.5465/amr.1998.533225

Nayak, S., Bhatnagar J., Budhwar P., 2018. Leveraging social networking for talent management: an exploratory study of Indian firms. Thunderbird International Business Review 60[1]: 21-37. https://doi.org/10.1002/tie.21911

Osman L.H., 2017. The Pattern of Inter-Organizational Level of Connectivity, Formal Versus Informal Ties. Jurnal Komunikasi: Malaysian Journal of Communication 33[1]

Osman L.H., 2018. Embeddedness Configuration and itsâ ™ Relations to Inter-Firm connectivity in Supply Network: A Social Network Analysis Approach. Journal of International Trade, Logistics and Law 4[1]: 31

Pathak S., et al., 2007. Complexity and Adaptivity in Supply Networks: Building Supply Network Theory Using a Complex Adaptive Systems Perspective. Decision Sciences 38[4]: 547-580. http://doi.org/10.1111/j.1540-5915.2007.00170.x

Polyviou M., Croxton K.L., Knemeyer A.M., 2019. Resilience of medium-sized firms to supply chain disruptions: the role of internal social capital. International Journal of Operations & Production Management.

http://doi.org/10.1108/IJOPM-09-2017-0530

Poppo L., Zenger T., 2002. Do formal contracts and relational governance function as substitutes or complements? Strategic Management Journal 23[8]: 707-725. http://doi.org/10.1002/smj.249

Powell W., 2003. Neither market nor hierarchy. The sociology of organizations: classic, contemporary, and critical readings: 315.

Putnam RD. The Prosperous Community: Social Capital and Public Life. The American Prospect [Internet]. 1993;(13) :35-42.

Robins G., Elliott P., Pattison P., 2001. Network models for social selection processes. Social Networks 23[1]: 1-30. http://doi.org/10.1016/S0378-8733(01)00029-6

Robins, G., Lewis J.M., Wang P., 2012. Statistical Network Analysis for Analyzing Policy Networks. Policy Studies Journal 40[3]: 375-401. http://doi.org/10.1111/j.1541-0072.2012.00458.x

Robins, G., Pattison P., Wang P., 2009. Closure, connectivity and degree distributions: Exponential random graph [p*] models for directed social networks. Social Networks 31[2]: 105-117. http://doi.org/10.1016/j.socnet.2008.10.006

Romo F.P., Schwartz M., 1995. The Structural Embeddedness of Business Decisions: The Migration of Manufacturing Plants in New York State, 1960 to 1985. American sociological review 60[6]: 874-907. http://doi.org/10.2307/2096431

Rowley T., Behrens D., Krackhardt D., 2000. Redundant governance structures: an analysis of structural and relational embeddedness in the steel and semiconductor industries. Strategic Management Journal 21[3]: 369-386. http://doi.org/10.1002/(SICI)1097-0266(200003)21:3<369::AID-SMJ93>3.0.CO;2-M

Schell, S., Hiepler M., Moog P., 2018. It's all about who you know: The role of social networks in intra-family succession in small and medium-sized firms. Journal of Family Business Strategy 9[4]: 311-325. http://doi.org/10.1016/j.jfbs.2018.08.003

Scott J., 1988. Social network analysis. Sociology 22[1]: 109. http://doi.org/10.1177/003803858802201007

Shumate M., Palazzolo E.T., 2010. Exponential Random Graph [p*] models as a method for social network analysis in communication research. Communication Methods and Measures 4[4]: 341-371. http://doi.org/10.1080/19312458.2010.527869

Sivadasan, Smart J., Huatuco L.H., Calinescu A., 2010. Operational complexity and supplier-customer integration: case study insights and complexity rebound. The Journal of the Operational Research Society 61[12]: 1709. http://doi.org/10.1057/jors.2009.138

Snijders T.A.B., Pattison P.E., Robins G.L., Handcock M.S., 2006. New specifications for exponential random graph models. Sociological Methodology 36[1]: 99-153. http://doi.org/10.1111/j.1467-9531.2006.00176.x

Starovic D., Marr B., 2003. Understanding corporate value: managing and reporting intellectual capital, CIMA.

Starovic D., Marr B., 2004. Understanding Corporate Value: Managing and Reporting Intellectual Capital. The Chartered Institute of Management Accountants (CIMA) and Cranfield University, London. http://www.cimaglobal.com/Documents/ImportedDocuments/intellectualcapital.pdf

Uzzi B., 1996. The sources and consequences of embeddedness for the economic performance of organizations: The network effect. American sociological review 61[4]: 674-698. https://www.jstor.org/stable/2096399

Uzzi B., 1997. Social structure and competition in interfirm networks: The paradox of embeddedness. Administrative science quarterly 42[1]: 35-67. http://doi.org/10.2307/2393808

Wang P., et al., 2006. PNet: Program for the estimation and simulation of p* exponential random graph models, User Manual. Department of Psychology, University of Melbourne.

Wasserman S., Galaskiewicz J., 1994. Advances in social network analysis: Research in the social and behavioral sciences, Sage Publications, Inc. http://dx.doi.org/10.4135/9781452243528

Wegner D., Faccin K., Dolci P.C., 2018. Opening the black box of small-firm networks: governance mechanisms and their impact on social capital. International Journal of Entrepreneurship and Small Business 35[4]: 559-578.

Wilding R., 1998. The supply chain complexity triangle. Management 28[8]: 599-616. http://doi.org/10.1108/09600039810247524

Yan Y., Guan J., Zhang J., 2019. Network Embeddedness and Innovation: Evidence From the Alternative Energy Field. IEEE Transactions on Engineering Management. http://doi.org/10.1109/TEM.2018.2885462

Zaheer A., Bell G.G., 2005. Benefiting from network position: firm capabilities, structural holes, and performance. Strategic Management Journal 26[9]: 809. http://doi.org/10.1002/smj.482

CZY ZAJMOWANIE CENTRALNEJ POZYCJI W FORMALNEJ SIECI POPRAWIA ZDOBYCIE ZAUFANIA? ANALIZA SIECI SOCJALNYCH ISTNIEJĄCYCH W STRUKTURACH ŁAŃCUCHA DOSTAW

STRESZCZENIE. **Wstęp:** Praca ma celu rozszerzenie znaczenia i stosowania poza strukturę sieci teorii zależności aktywności ekonomicznych od czynników socjalnych. Wcześniejsze badania dotyczące analizy sieci w dużej mierze koncentrowały się na zagadnieniu decentralizacji struktury sieci i wpływu tego procesu na działanie poszczególnych jej członków. Niemniej każdy członek łańcucha dostaw jest elementem zcentralizowanej struktury sieci. Zcentralizowana firma odgrywa przywódcza rolę w całej takiej strukturze. Dlatego też łańcuch dostaw jest siecią zcentralizowaną z powodu istnienia firmy przywódczej. Istnieje takiego typu firmy w sieci ma wpływ na wyniki działalności.
Celem tej pracy jest określenie wpływu formalizmu, będącego wynikiem zcentralizowania łańcucha dostaw, ba poziom zaufania w obrębie tego łańcucha oraz możliwości organizacji wykorzystania zasobów tego łańcucha do uzyskania wykorzystania optimum zasobów.
Metody: W oparciu o wcześniej stosowane podejście używające analizy sieci socjalnych, zastosowano metodologię analizy sieci socjalnych do zgromadzenia danych dotyczących połączeń i relacji w obrębie łańcucha dostaw. Przy użyciu modelu Exponential Random Graph Model [ERGM] opracowano losowo szukający algorytm dla rozwiązywani problemu optymalizacji relacji sieci. Exponential Random Graph Modeling [ERGM] to metoda statystyczna służąca kształtowaniu procesów generatywnych, tworzących sieci socjalne. W metodzie tej, zarówno połączenia nieparzyste jak i dwójki węzłów sieci są modelowane poprzez użycie postaci wykładniczej analogicznej do regresji logistycznej.
Wyniki: Uzyskane wyniki badań wskazują, że centralizacja ma negatywny wpływ na poziom zaufania w łańcuchu dostaw. Firmy umieszczone w różnych częściach łańcucha dostaw zyskują w różny sposób z relacji socjalnych w obrębie tego łańcucha. Zasoby firmy musiałyby być przesunięte, aby uzyskiwać benefity wynikające z różnej pozycji w strukturze sieci.

Wnioski: Wyniki uzyskane na podstawie analizy statystycznej sieci wskazują na ciekawe zależności w obrębie strukturalnych form, mający wpływ na zaangażowanie w formalnej strukturze łańcucha dostaw. Im dana firma znajduje się wyżej w sieci łańcucha dostaw w odniesieniu do formalnych połączeń i relacji, tym jest mniejsze prawdopodobieństwa, że będzie traktowana z zaufaniem przez innych członków danej sieci. W konsekwencji, należy wysunąć wniosek, że ze wzrostem pozycji w zcentralizowanej sieci, zaufanie do danej firmy maleje.

Słowa kluczowe: analiza sieci, dzielenie się informacją, zasoby socjalne

Lokhman Hakim Osman, ORCID ID: https://orcid.org/0000-0001-6630-5067
School of Management
Faculty of Economic and Management
Universiti Kebangsaan **Malaysia**
43600, Bangi, Selangor, Malaysia
e-mail: lokhman@ukm.edu.my

Abdullah Sanusi Othman
School of Management
Faculty of Economic and Management
Universiti Kebangsaan Malaysia
43600, Bangi, Selangor, **Malaysia**

Mohd Rizal Palil
School of Management
Faculty of Economic and Management
Universiti Kebangsaan Malaysia
43600, Bangi, Selangor, **Malaysia**

LogForum

> Scientific Journal of Logistics <

2020, 16 (1), 103-116

http://doi.org/10.17270/J.LOG.2020.377

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

SUPPLY CHAIN MANAGEMENT MATURITY: AN ALL-ENCOMPASSING LITERATURE REVIEW ON MODELS, DIMENSIONS AND APPROACHES

Mohsen Cheshmberah[1], Safoura Beheshtikia[2]

1) Malek Ashtar University of Technology, Isfahan, **Iran,** 2) Isfahan University of Technology, Isfahan, **Iran**

ABSTRACT. **Background:** In recent years, organizational maturity has disseminated its concepts to various management domains, for instance, Supply Chain Management (SCM). The present paper is an attempt to review the developments in the realm of SCM over the past two decades. In the domain of SCM maturity, different models, dimensions (areas) and approaches are advanced for maturity measurements.

Methods: Research studies conducted and presented in the literature, including papers on conference proceedings, articles in journals and technical reports, are reviewed; the review covers a time span from the early 1990s to the present time (2019). Also provided in this review are the previous models, dimensions (areas/ elements), and approaches for measuring SCM maturity techniques. Additionally, research gaps are identified, analysed and discussed.

Results: After reviewing, the research studies in the field and the dimensions found in the works are placed into different categories. The current study aims to present a review of the literature, ultimately providing help to researchers in realizing gaps and opportunities in the field of SCM maturity. There are also different approaches to supply chain maturity models. For example, one approach may solely focus on integration while another might concentrate on SC visibility and traceability. In more recent research studies, more attention is paid to such specific areas of supply chain as flexibility and sustainability. The results of the present paper point to gaps, which indicate that more research works are required. In addition, it is assumed that the materials presented here may help establish more comprehensive SCM maturity models.

Conclusions: It is seen that supply chain management is rapidly shifting toward e-SCM, and some other technologies like blockchain. Also, supply chain sustainability comes to the fore as a significant approach. It should be reminded that other strategic features of supply chains like leanness, agility, resilience, sustainability, integration, green and reverse logistics etc., also play their own role in the field. Combining these strategic features can be an effective idea for developing more comprehensive models for SCM maturity. To sum up, the results of the present survey indicate that the published works need more adequacy and treatment research, and that more research is called for to bridge the gaps in the realm of SCM maturity.

Key words: organizational maturity, supply chain management (SCM), SCM maturity, maturity model, literature review.

INTRODUCTION

Organizational maturity is defined as the ability to maintain or develop performance such that persistent satisfaction of the organization's stakeholders is guaranteed over time. Organizational maturity will not come about unless the organization can identify environmental changes and exploit them to update strategic goals and plans. In order to achieve the requisite maturity, the organization must continuously monitor changes in environmental issues and other relevant developments.

Organizational maturity models provide a simple yet effective way to study and improve processes and, although maturity model approaches emerged within the field of

Citation: *Cheshmberah M., Beheshtikia S., 2020. Supply chain management maturity: An All-Encompassing literature review on models, dimensions and approaches. LogForum 16 (1), 103-116, http://doi.org/10.17270/J.LOG.2020.377*

Received: 31.07.2019, Accepted: 09.10.2019, on-line: 30.12.2019.

software engineering, it quickly spread to other domains [Wendler 2012]. In particular, over the past two decades, the adoption of maturity models has been considered in most organizational milieus. Generally speaking, the maturity model is an explanation of the processes that must be implemented such that the highest level of maturity is obtained. Maturity models are rooted in the field of quality management, where Philip Crosby's Quality Management Maturity Network is considered a key element in this regard.

In the literature on the issue of maturity models, various models have been developed in such varied branches as strategic management, knowledge management, project management, process management, IT management, and related fields. As was pointed out earlier, the concept of the maturity model is commonly associated with Information Technology and software development; in this regard, a model designated as the Capability Maturity Model (CMM) was evolved [Lockamy, McCormack, 2004].

In recent years, a number of researchers have seriously focused their attention on reviewing the processes of supply chain management and tried to improve their efficiency and responsiveness through supply chain maturity approaches [Varoutsa, Scapens 2015]. Hence, supply chain management is an area where the measurement of progress requires a roadmap and a compass; maturity assessment allows a roadmap to be drawn up, based on which progress can be checked, and the continuation of the path can be guaranteed [Sun et al. 2005, Netland et al. 2007].

Supply chain management focuses on acquiring advanced information technologies and systems; best practices in business processes, including cooperative and trustworthy relationships between supply chain partners; and achieving optimum support and the highest level of managerial commitment. To that end, the realization of maturity is based on a specific model in the organization's supply chain management for accomplishing responsive and efficient performances [Sun et al. 2005, Netland et al. 2007].

Various maturity assessment models are available in the field of supply chain management – Netland et al. [2007] studied different maturity models in the realm of supply chain management [Netland et al. 2007]. These models range from simple self-assessment tests to detailed cause and effect analyses. Naturally, different maturity tests are considered for different causes, which accordingly have different designs and contents. In general, the following six criteria characterize maturity models [Netland et al. 2007]:

– They usually have a number of maturity levels
– There is a special term dedicated to each level.
– There exist certain descriptions for each level.
– The model includes a number of dimensions or areas
– There are a number of activities defined for each process area.
– There is a clear description to each activity at any maturity level.

A REVIEW OF PUBLISHED WORKS

In the domain of SCM maturity, different models and dimensions (areas) are advanced for maturity measurements; reliable research works – including conference proceeding papers, journal articles, and technical reports – published by authors as sources, are reviewed in as much detail as space allows. The following provides some of the models produced in the literature.

Hanson and Voss [1995] introduced organization and culture, logistics, manufacturing systems, lean production, concurrent engineering, and total quality as proper areas for maturity assessments [Hanson, Voss 1995]. Lambert and Cooper [2000] suggested product flow, customer relationship management, demand management, order fulfillment, production flow, logistics, product development and commercialization, as well as returning (reverse logistics) to investigate maturity levels [Lambert, Cooper 2000].

Bowersox et al. [2000] described supply chain (management) maturity in terms of the level of realization of integrated supply chain and collaborative supply chain as well. They believe ten (10) mega trends will shape the future of supply chain management (such as transition from customer service to relationship management and adversarial to collaborative relationships).

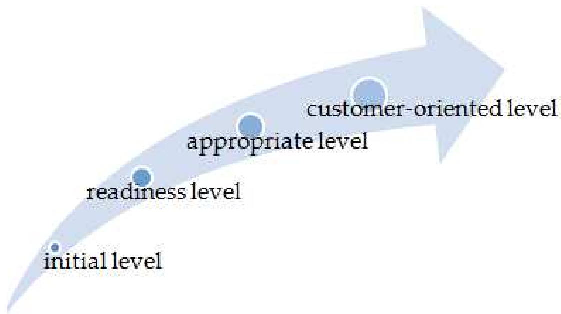
Van Landeghem and Persoons [2001] considered employees, planning and control, production and assembly, research and development (R&D), distribution, order fulfillment, purchases and suppliers, markets and service providers to audit the supply chain and logistics management.

Lockamy and McCormack [2004] examined the relationship between the supply chain management maturity processes and the overall performance of the supply chain. The result of this study, while confirming the strong relationship between the two variables, showed that metrics, such as "cycle times" and "inventory levels", depend upon the maturity of the supply chain processes. In this model, five levels of maturity are considered. They are as follows: Level 1: Ad hoc; Level 2: Defined; Level 3: Linked; Level 4: Integrated; Level 5: Extended [Lockamy, McCormack, 2013]; Figure 1 shows Lockamy & McCormack's maturity model.

Source: the author's own work

Fig. 1. Lockamy & McCormack's maturity model

Leem and Yoon [2004] developed a Customer Satisfaction Maturity model based on four levels of initial maturity (regardless of customer feedback), readiness level (generating a product / service in a general way. They also develop strategies to increase customer satisfaction), appropriate level (providing different products/services for a segmented market), and customer-oriented level (customized products/ services according to the expectations of individual customers) [Leem, Yoon 2004]; Figure 2 gives a schema of Leem and Yoon's maturity model.

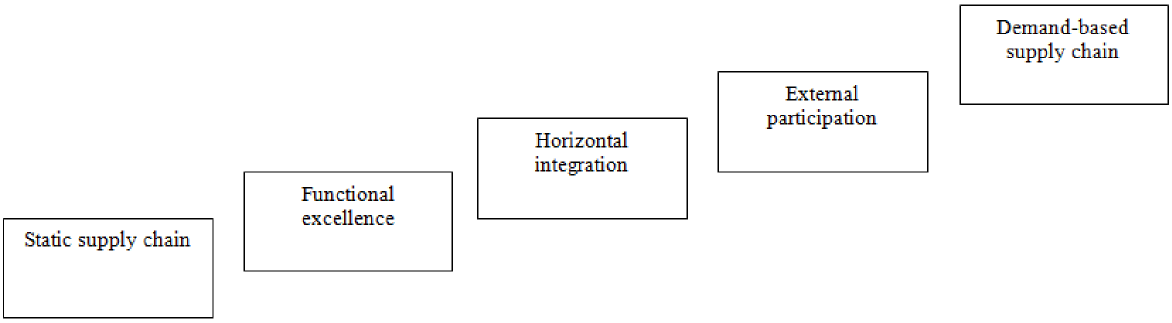


Source: the author's own work

Fig. 2. Leem & Yoon's maturity model

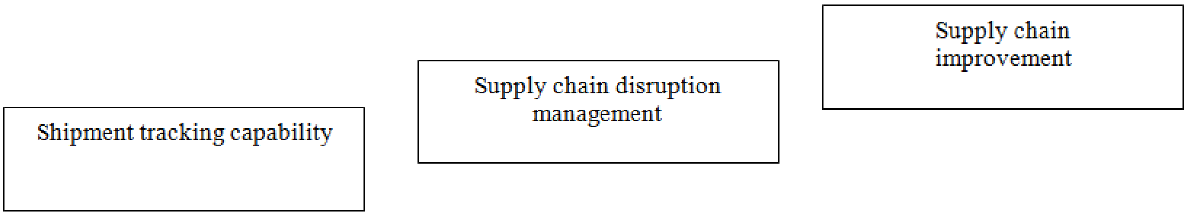
IBM [2005] has developed a model, which in conformity with the level of supply chain integration provided a basis for maturity level measurements. The five levels that characterize the model are: "Static supply chain", "functional excellence", "horizontal integration", "external participation" and "demand-based supply chain". Figure 3, presents the IBM maturity model.

The Aberdeen Group [2006] presented a model known as "Roadmap for the Visibility of Supply Chain" providing a methodology for assessing the visibility degree of the supply chain. This model examines supply chain maturity status at three levels: "Shipment tracking capability", "supply chain disruption management" and "supply chain improvement"; Figure 4 shows the roadmap developed by Aberdeen.



Source: the company's own report

Fig. 3. The maturity model of IBM



Source: the company's own report [Aberdeen Group 2006]

Fig. 4. Aberdeen Group Roadmap

Daozhi, et al. [2006] presented a three dimensional supply chain management maturity model: Environment (law and regulations, communications, industrial monopoly and so forth), resources (material, knowledge, human resource, capital and information), and management (flexibility, risk management, forecast ability et cetera).

Jaklic et al. [2006] presented a five-level maturity model for the supply chain. This model combines the SCOR framework with that of the Lockamy and McCormack model. The levels included in this model are: Level 1 (Ad hoc), Level 2 (Defined), Level 3 (Linked), Level 4 (Integrated) and Level 5 (Extended).

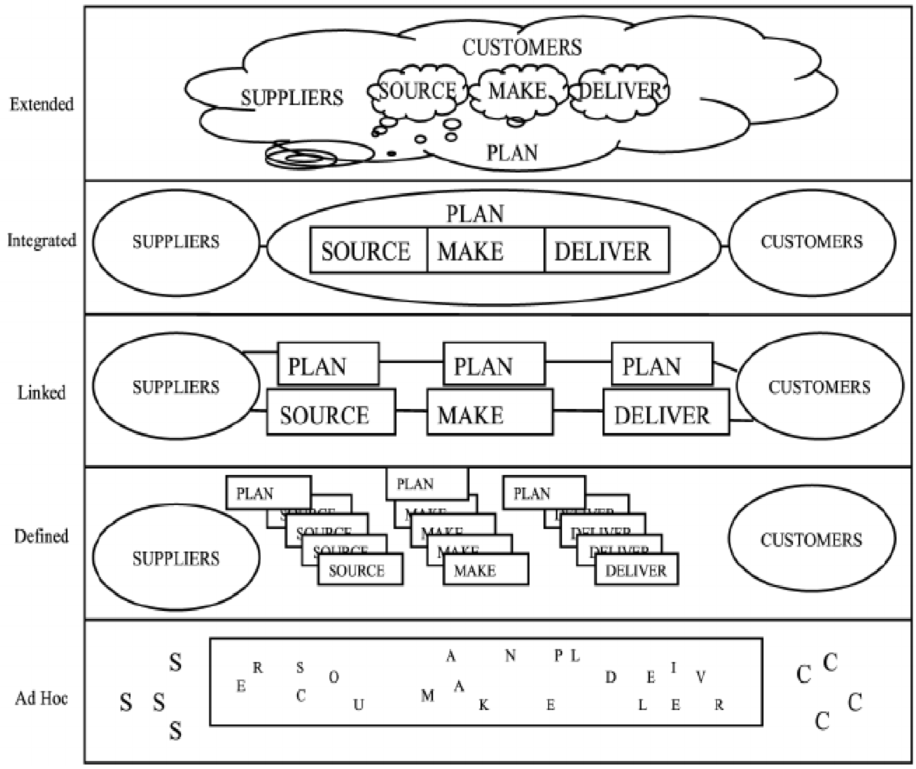
The SCOR (Supply Chain Operations Reference) [Ver.11, 2012] model provides a framework linking business process, metrics and best practices to support communication among supply chain partners which ultimately improves the effectiveness (responsiveness) of supply chain management; the maturity model presented by Jaklic et al. is exhibited in Figure 5.

Pache and Spalanzani [2007] suggested five maturity levels shaping the inter-organizational relationships in terms of intra-organizational level, inter-organizational level, extended inter-organizational level, multi-chain level, and social level. Figure 6 displays their model.

Netland et al. [2007] suggested exploiting the EFQM Excellence Model for measuring supply chain maturity level. Still another model proposed in the field of SCM maturity is that of the SCM-CMM [2010], which follows the CMM model approach. It is worth noting that the CMM model was developed by Carnegie Melon. Five maturity levels are defined for the SCM-CMM model: Ad hoc (contingency), primary, defined, extended, and networked [Sun et al. 2005].

Garcia [2008] developed a model of SC capability maturity. The model provides a roadmap for enterprise improvement, covering multiple dimensions (suppliers, production, inventories, customers, human resources, information systems & technology, and performance measurement systems) as well as abstraction levels of the supply chain (undefined, defined, manageable, collaborative and leading). In general, it provides useful tools for bringing about improvements in businesses.

Lahti, et al. [2009] considered a four-stage SCM maturity model for implementation as developed by ABB – a corporate research center in Finland. The model included four stages designated as functional focus, internal integration, external integration and cross-enterprise collaboration. This research designed a questionnaire to assess both the maturity of different supply chain process areas and the maturity of the practices of the supply chain participants. Figure 7 illustrates the ABB's SCM maturity model.

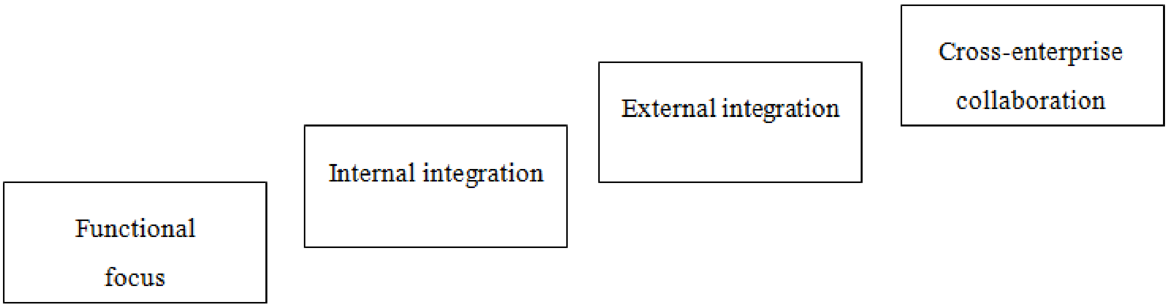


Source: the author's own work

Fig. 5. Maturity model by Jaklic et al. [2006]

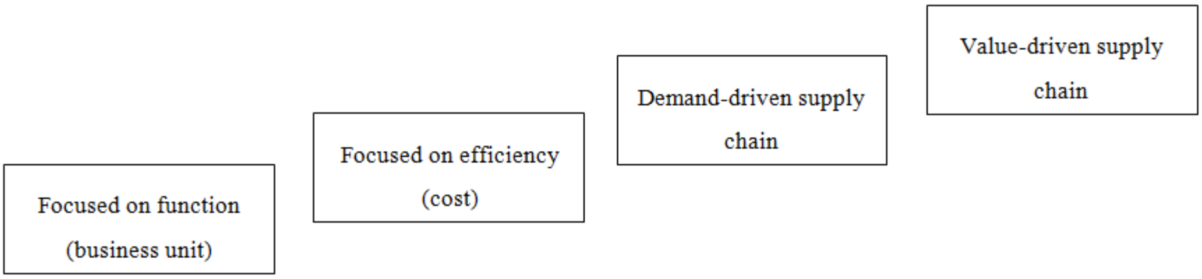
Source: the author's own work

Fig. 6. Pache and Spalanzani's maturity model



Source: the author's own work

Fig. 7. ABB's SCM maturity model



Source: the author's own work

Fig. 8. Accenture maturity model

Accenture Company [2012] sets four stages for supply chain maturity starting with discrete decision-making in the chain and ending with value-driven supply chain. These steps include supply chains focused on tasks and business units, supply chains focused on efficiency and cost, demand-driven supply chains, and value-driven supply chains [Goblet 2012]. Figure 8 shows the Accenture maturity level.

Hameri, et al. [2013] proposed a model of six phases as regards SCM maturity. The model is based on six steps, the first three of which are regional, dealing with initial sourcing, chain organization, and chain expansion. The next three steps concern the international and global operations with chain restructuring, chain redesign, and lean supply chain management.

Huang and Handfield [2015] investigated the effects of implementing enterprise resource planning (ERP) systems on supply management performance. The results of their analysis suggest that ERP users are more mature than non-ERP users considering three key indicators: strategic sourcing, category management, and supplier relationship management.

Fischera et al. [2016] have focused on assessing the maturity of Supply Chain Flexibility (SCF). The researchers identified three maturity levels of SCF: reactive, proactive, and paradigmatic supply chain levels, in the order stated. Each level includes five (5) dimensions: collaboration, information technology, information flow, internal flexibility and performance measurement.

Ho et al. [2016] considered a framework based on a Capability Maturity Model Integration (CMMI) approach as a diagnostic tool for analyzing current collaboration practices in organizations as well as a roadmap to guide organizations toward advancement levels in supply chain collaboration.

Radosavljevic et al. [2016] studied SCM maturity in several Serbian companies. The results obtained indicate that best practice elements are not very popular in enterprises in Serbia.

Sarkar et al. [2016] consider carbon emission costs in a three-echelon supply chain (supplier, manufacturer and retailer). Their model aims to reduce supply chain costs, including variable transportation and carbon emission costs arising from shipment problems.

Sartori and Frederico [2017] discussed and identified three categories as regards the maturity of supply chain management. These include management components (processes management, technology and tools, performance measurement and risk and project management), supply chain structure (collaboration, strategic focus, responsiveness and environmental resources), and business process. Baraniecka et al. [2017] examined the maturity of supply chain management based on a classification tree and its respective levels.

Reefke and Sundaram [2018], drawing upon the Delphi method, studied the design and validation of models for sustainable supply chain management at the ongoing maturity development of sustainability. In another study, Asdecker and Felch [2018] developed a model to apply Industry 4.0 maturity models to outbound logistics to the already researched manufacturing processes.

In recent developments, blockchain technology has emerged as the new information technology. The application of this technology to supply chain management has become a recent topic of discussions among researchers in the field. Schniederjans et al. [2019] believe that the digitization of industry (Industry 4.0), is a newly emerging trend in supply chain management. In their study, they consider how to enhance the supply chain digitization research paradigm in future research projects.

Kamilaris, et al. [2019] examined the impact of blockchain technology in ongoing projects of the agriculture and food supply chain sector discussing overall implications as well as challenges facing the maturity of the latter projects. Indeed, blockchain is an emerging digital technology permitting ubiquitous financial transactions among parties while needing no intermediaries.

Their study approach is novel in the supply chain context, where visibility and transparency of product flows are the major challenges [Azzi et al. 2019]. In other words, blockchain is a distributed and immutable database using cryptography, thus enabling more efficient and transparent transactions [Schmidt and Wagner, 2019].

Azzi et al. [2019] attempted to describe the way blockchain can be integrated into the supply chain architecture so that a trustworthy, transparent, reliable and secure system is established.

Gustafsson et al. [2019] developed a maturity model in retail supply chains of product fitting where three levels of digitalization and potential outcomes for each level are specified. As a matter of fact, digital product fitting is an emerging operational practice in the retail domain implementing digital models of products and customers for matching the product supply to the customer's requirements. The three levels referred to are: corpus, virtusize and volumental.

Researches and models: An analysis

After reviewing, the research studies referred to above and classifying the dimensions which appear in the literature, the most striking areas (dimensions) to be expressed are given in Table 1. These areas (dimensions) are:

- Planning and policy making
- Demand and customer management
- Make (internal) or ISCM (internal supply chain management)
- Logistics
- Supply
- IT/ IS (information technology/ information systems)
- Collaboration
- Cost
- Product design and commercialization
- Reverse logistics/ closed loop supply chain
- Focus on processes
- Human resources

Table 1. Categorizing dimensions (areas) of the SCM maturity in researches issued to this time

	Human resource	Process view	Reverse logistics/ closed loop SC	Design/Commercialization product	Cost	Environment	Social responsibility	collaboration and inter-organizational relationships	IT/IS	Supply	Logistics	Make (Internal)	Demand/ customer	Planning (policy making)
Hanson, Voss (1995)					*					*	*	*	*	*
Lambert, Cooper (2000)			*	*						*	*	*	*	*
Van Landeghem, Persoons (2001)	*			*						*	*	*	*	*
Lockamy, McCormack (2004)										*	*	*	*	
Leem, Yoon (2004)													*	
IBM (2005)								*						*
Aberdeen Group (2006)											*		*	
Daozhi et al. (2006)	*					*			*					*
Jaklic et al. (2006)					*			*		*	*	*	*	
Pache, Spalanzani (2007)							*	*						
Netland et al. (2007)	*	*								*			*	*
Garcia (2008)	*							*	*					*
SCM-CMM (2010)	*	*											*	
Accenture (2012)								*					*	*
Hameri et al. (2013)								*		*				
Fischer et al. (2016)		*						*	*					
Sarkar et al. (2016)					*	*								
Sartori, Frederico (2017)		*				*		*						*
Reefke, Sundaram (2018)					*	*	*							
Asdecker, Felch (2018)									*					
Schniederjans et al. (2019)									*					
Kamilaris, et al. (2019)									*					
Azzi et al. (2019)									*					
Gustafsson et al. (2019)									*					

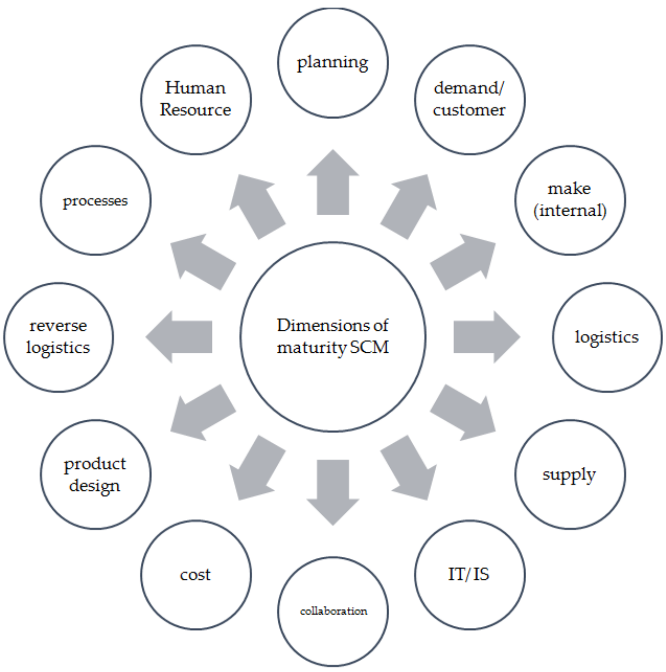


Fig. 9. Categories of SCM maturity dimensions (areas)

Table 2 shows the relevance of each dimension (areas) to the investigated works in the literature. Figure 10 further illuminates the most crucial dimensions raised in the published works. The dimensions brought up in Figure 9 can provide a basis for the development of more powerful and comprehensive maturity models in supply chain management. These dimensions provide an all-embracing prospect for supply chain management. By defining the appropriate levels for each dimension, it is possible to draw up an appropriate roadmap for SCM maturity.

In depth and accurate examinations reveal that there are various approaches to the assessment of SCM maturity. Certain studies, by introducing the dimensions (areas), measure the so make the organizational managers aware of the organization's situation as regards supply chain management and its maturity level.

In some other studies, supply chain integration levels are considered, and in others serious attention is given to the customer. The level of technology deployment, especially information technology, is a conspicuous approach in some particular studies. In more recent research studies, focus is directed towards such specific areas of the supply chain as flexibility and sustainability. Table 2 displays the approaches on SCM maturity issues, as can be observed in the literature.

Table 2. Approaches to SCM maturity identified in previous researches

Approaches **Researches**	dimensions (criteria)	integration (collaboration)	Excellence approach	Supply chain sustainability	Supply chain flexibility	Customer orientation	Application of technology (IT/IS/ERP)	shipment tracking	Environment considerations in	Mega Trend(s)
Hanson, Voss (1995)	*									
Lambert, Cooper (2000)	*									
Bowersox et al. (2000)										*
Van Landeghem, Persoons (2001)	*									
Lockamy, McCormack (2004)		*								
Leem, Yoon (2004)						*				
IBM (2005)		*								
Daozhi et al. (2006)	*									
Aberdeen Group (2006)						*	*	*		
Jaklic et al. (2006)	*	*								
Pache, Spalanzani (2007)		*		*						
Netland et al. (2007)			*							
Garcia (2008)	*	*								
Lahti et al. (2009)	*									
SCM-CMM (2010)	*									
Accenture (2012)						*				
Hameri et al. (2013)	*	*	*							
Huang, Handfield (2015)							*			
Fischer et al. (2016)	*				*					
Ho et al. (2016)		*								
Sarkar et al. (2016)									*	
Sartori, Frederico (2017)	*									
Reefke, Sundaram (2018)				*						
Asdecker, Felch (2018)							*			
Schniederjans et al. (2019)							*			
Kamilaris, et al. (2019)							*			
Azzi et al. (2019)							*			
Gustafsson et al. (2019)							*			

Some models have contemplated specific approaches, for example, tracking and visibility capabilities in the supply chain (especially from the shipment point of view). That is, if the supply chain performance is more transparent and in case tracing is facilitated, Supply Chain Management develops in a more mature manner.

Besides investigating the dimensions of the maturity of supply chain management and the relevant approaches in the field under investigation, there are different designations employed by maturity models for maturity levels. Table 3 shows the diverse terminologies used for maturity levels.

Table 3. Levels nomenclature in maturity SCM models

Author(s)	Number of levels	Names of levels
Lockamy, McCormack (2004)	Five (5)	Ad Hoc, Defined, Linked, Integrated, Extended
Leem, Yoon (2004)	Four (4)	Initial, Readiness, Appropriate, Customer-Oriented
IBM (2005)	Five (5)	Static supply chain, Functional excellence, Horizontal integration, External collaboration, On-demand supply chain
Aberdeen Group (2006)	Three (3)	"shipment tracking capability", "supply chain disruption management" and "supply chain improvement"
Jaklic et al. (2006)	Five (5)	Ad hoc, Defined, Linked, Integrated, Extended
Pache, Spalanzani (2007)	Five (5)	intra-organizational, inter-company collaboration, extended inter-organizational, multi-chain, social
Garcia (2008)	Five (5)	Undefined, Defined, Manageable, Collaborative and Leading
SCM-CMM (2010)	Five (5)	Ad Hoc, Initial, Defined, Extended, and Network
Accenture (2012)	Four (4)	focused on tasks & business units, focused on efficiency (cost), demand-driven, value-driven
Fischer et al. (2016)	Three (3)	SC reactive, proactive, and paradigmatic
Gustafsson et al. (2019)	Three (3)	corpus, virtusize and volumental

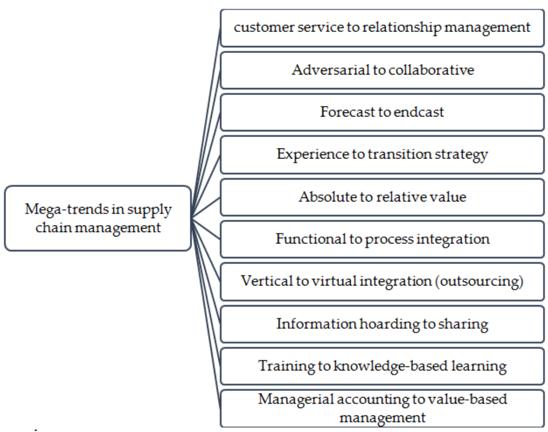
Executive and managerial considerations

The results of this study might provide assistance in directing students' research programs and improving managers' insights. In their practices, by studying and analyzing the maturity models of supply chain management, certain topics are highlighted. There are different targets set in the field. Some of these targets are cost reduction, supply chain integration, increasing customer satisfaction, enhancing flexibility/agility, embedding sustainability into supply chains, removing waste from supply chains (Leanness), and upgrading supply chain technologies. Further, the results of the present survey indicate that the published works are not sufficiently rich and more robust research is called for to bridge the gaps in the realm of SCM maturity.

The following mega-trends might prove useful to practicing and would-be managers. They need transitions from Bowersox et al. [2000]:

- Customer service to relationship management
- Adversarial to collaborative relationships (arm's length to partnership)
- Forecasting to endcasting in demand management
- Experience to transition strategy
- Absolute to relative value
- Functional to process integration
- Vertical to virtual integration (outsourcing and e-SCM)
- Information hoarding to sharing
- To knowledge-based learning
- Managerial accounting to value-based management

Figure 10 provides a schematic impression of these mega trends.



Source: the author's own work

Fig. 10. Mega trends in SCM

GAP ANALYSIS IN THE EXAMINED WORKS AND CONCLUDING REMARKS

Besides the prospective research work trends referred to above, other areas in the field of SCM, e.g. supply management and distribution management, will witness a plethora of published work. Moreover, strategic characteristics of the supply chain, like leanness, agility and resilience, will be the pivotal issues in future research work on the maturity of supply chain management. In this regard, Fischera et al. [2016] can be cited as an example of research specifically aiming to investigate the maturity of supply chain flexibility. Table 4 shows a gap analysis in the research works explored.

It should be remembered that there exist many gaps in research works in the field under study. That is, more investigation is required on the issue of supply chain management in order to achieve the desired goals; the present era is characterized by chaotic conditions and a turbulent environment, and so organizations should set high levels of maturity as the defined targets in their supply chain management.

Table 4. Gap analysis in works surveyed

Focus Areas / Researches	Cost reduction	SC FLEXIBILITY	SC integration - Collaboration (SRM)	SC integration (CRM)- customer satisfaction	SC agility	SC visibility & traceability	Value driven SC	SC sustainability	SC leanness	ERP - IT-based SCM	Inventory management	Return (reverse logistics)	Concurrent engineering	Environmental protection
Hanson, Voss (1995)									*				*	
Lambert, Cooper (2000)				*								*	*	
Bowersox et al. (2000)			*	*										
Van Landeghem, Persoons (2001)			*										*	
Lockamy, McCormack (2004)											*			
Leem, Yoon (2004)				*										
IBM (2005)			*	*										
Daozhi et al. (2006)		*												
Aberdeen Group (2006)						*								
Jaklic et al. (2006)			*	*										
Pache, Spalanzani (2007)			*	*										
Lahti et al. (2009)			*	*										
Accenture (2012)							*							
Hameri et al. (2013)									*					
Huang, Handfield (2015)			*	*						*				
Fischer et al. (2016)		*												
Ho et al. (2016)			*											
Sarkar et al. (2016)	*													*
SARTORI, FREDERICO (2017)		*												*
REEFKE, SUNDARAM (2018)								*						*
ASDECKER, FELCH (2018)						*				*				
SCHNIEDERJANS ET AL. (2019)						*				*				
KAMILARIS, ET AL. (2019)						*				*				
AZZI ET AL. (2019)						*				*				
Gustafsson et al. (2019)						*				*				

As can be seen, supply chain management is rapidly shifting toward e-SCM. In fact, new and advanced information and communication technologies such as blockchain are expected to play an important role in future developments [Asdecker, Felch 2018, Schniederjans et al. 2019, Kamilaris et al. 2019, Azzi et al. 2019].

Also, more serious attention will be paid to the issue of supply chain sustainability. As there are severe constraints in available resources (from an economic viewpoint), social responsibilities are becoming more important and there is a need to safeguard the living environment, supply chain sustainability is expected to be the key approach in future research work [Reefke, Sundaram 2018].

As a final word, supply chains might need to provide a combination of such strategic features as leanness, agility, resilience, sustainability, integration, greater and more effective use of information and communication technologies (ICTs), a movement toward e-SCM, green and reverse logistics and other such relevant issues. Combining these strategic features may provide an effective idea/solution for developing a comprehensive paradigm for supply chain management maturity models.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Asdecker B., Felch V., 2018. Development of an Industry 4.0 maturity model for the delivery process in supply chains, Journal of Modelling in Management, 13, 4, 840-883, http://doi.org/10.1007/978-3-319-67383-7-10

Azzi R., Chamouna R.K., Sokhn M. 2019. The power of a blockchain-based supply chain, Computers & Industrial Engineering, 135, 582-592, http://doi.org/10.1016/j.cie.2019.06.042

Baraniecka A., Jajko-Siwek A., Szuster M., Szymczak M., Wieteska G. 2017. Relativism in the Approach to Managing Supply Chain Maturity, Procedia Engineering, 182, 50-57, http://doi.org/10.1016/j.proeng.2017.03.113

Bowersox D.J., Closs D.J., Stank T.P., 2000. Ten mega trends that will revolutionize supply chain logistics, Journal of business logistics, 21, 2, 1-16.

Daozhi Z., Liang Z., Xin L., Jianyong S., 2006. A New Supply Chain Maturity Model With 3-Dimension Perspective. Information Technology and Innovation Conference, Hangzhou, http://doi.org/10.1049/cp:20061046

Fischer J., Thomé A., Scavarda L.F., Hellingrath B., Martins R. 2016. Development and application of a maturity measurement framework for supply chain flexibility. Fischera J., Thoméb A., Scavardab L.F., Hellingratha B., Martinsc R., Procedia CIRP, 41, 514-519, http://doi.org/10.1108/14637159510798220

Garcia H., 2008. A Capability Maturity Model to Assess Supply Chain Performance, Florida Int. University (Dissertation).

Garcia H., 2008. A Capability Maturity Model to Assess Supply Chain Performance. FIU Electronic Theses and Dissertations.191 http://digitalcommons.fiu.edu/etd/191

Goblet Ch., 2012. How to understand and use the key drivers and trends in today's pharmaceutical market? Accenture Management Consulting.

Aberdeen Group, 2006. The supply chain visibility roadmap – Moving from vision true business value.

Gustafsson E., Jonsson P., Holmström J. 2019. Digital product fitting in retail supply chains: maturity levels and potential outcomes, Supply Chain Management: An Int. Journal, http://doi.org/10.1108/SCM-07-2018-0247

Hameri A.P., McKay K.N., Wiers V.C., 2013. A maturity model for industrial supply chains, Supply Chain Forum: An Int. Journal, l, 14, 3, 2-15, http://doi.org/10.1080/16258312.2013.11517317

Hanson P., Voss C., 1995. Benchmarking best practice in Euopean manufacturing sites, Business Process Re-Engineering & Mangament journal, 1, 1, http://doi.org/10.1108/14637159510798220

Ho D., Kumar A., Shiwakoti N. 2016. Maturity model for supply chain collaboration: CMMI approach, Int. Conference on Industrial Engineering and Engineering Management, http://doi.org/10.1109/IEEM.2016.7797996

Huang Y., Handfield Robert. 2015. Measuring the benefits of ERP on supply management maturity model: a big data method, Int. Journal of Operations & Production Management, 35, 2 – 25, http://doi.org/10.1108/IJOPM-07-2013-0341

Jaklic J., Trkman P., Groznik A. 2006. Enhancing lean supply chain maturity with business process management, Journal of information and organizational sciences, 30, 2

Kamilaris A., Fonts A., Prenafeta-Boldú F.X., 2019. The Rise of Blockchain Technology in Agriculture and Food Supply Chains, Trends in Food Science & Technology, http://doi.org/10.1016/j.tifs.2019.07.034

Lahti M., Shamsuzzoha A.H.M., Helo P., 2009. Developing a maturity model for Supply Chain Management, Int. J. Logistics Systems and Management, 5, 6, 654–678, http://doi.org/10.1504/IJLSM.2009.024796

Lambert D.M., Cooper M.C., 2000. Issues in supply chain management, Industrial Marketing Management, 29, http://doi.org/10.1016/S0019-8501(99)00113-3

Leem C., Yoon Y., 2004. A maturity model and an evaluation system of software customer, Industrial Management & Data Systems, 104, 4, 347-354, http://doi.org/10.1108/02635570410530757

Lockamy A., McCormack K., 2004. The Development of a Supply Chain Management Process Maturity Model Using the Concepts of Business Process Orientation, Supply Chain Management: An Int. Journal, 9, 4, http://doi.org/10.1108/13598540410550019

Lockamy A., McCormack K., 2013. The Effect of on Supply Chain Performance: An Empirical Study, 1st Annual Int. Interdisciplinary Conference (Aiic), Azores, Portugal.

Netland T.H., Alfnes A., Fauske H., 2007. How Mature Is Your Supply Chain?– A Supply Chain Maturity Assessment Test, EurOMA Conference, Ankara, Turkey.

Pache G., Spalanzani A., 2007. La gestion des chaines logistiques multi-acteurs: perspectives strategiques, Ed. PUG. [Management of logistics chains by multistakeholders, strategic perspective].

Radosavljevic M., Barac N., Jankovic-Milic V. 2016. Supply chain management maturity assessment: challenges of the enterprises in Serbia, Journal of Business Economics and Management, http://doi.org/10.3846/16111699.2016.1191038

Reefke H., Sundaram D., 2018. Sustainable Supply Chain Management: Decision Models for Transformation and Maturity, Decision Support Systems, http://doi.org/10.1016/j.dss.2018.07.002

Sarkar B., Ganguly B., Sarkar M., Sarla P., 2016. Effect of variable transportation and carbon emission in a three-echelon supply chain model, Transportation Research Part E, 91, 112–128, http://doi.org/10.1016/j.tre.2016.03.018

Sartori J., Frederico G., 2017. Maturity and Conceptual Dimensions of Supply Chain Management: Establishing a Structural Model, Global Journal of Management and Business Research.

Schmidt C.G., Wagner S.M.. 2019. Blockchain and supply chain relations: A transaction cost theory perspective, Journal of Purchasing and Supply Management, http://doi.org/10.1016/j.pursup.2019.100552

Schniederjans D.G., Curado C., Khalajhedayati M., 2019. Supply chain digitisation trends: An integration of knowledge management, Int. Journal of Production Economics, http://doi.org/10.1016/j.ijpe.2019.07.012

IBM Business Consulting. 2005. Follow the leaders – Scoring high on the supply chain maturity model, IBM.

Sun H., Ren Y., Yeo K., 2005. Capability Maturity Model for Supply Chain Management, Int. conference on Management Science and Applications, Chengdu, China.

Supply Chain Council (SCC), 2012. The Supply Chain Operations Reference (SCOR)-Ver.11, Texas.

Van Landeghem R., Persoons K., 2001. Benchmarking of logistical operations based on a causal model, Int. Journal of Operations & Production Management, 21, 1/2, 254-267, http://doi.org/10.1108/01443570110358576

Varoutsa E., Scapens R.W., 2015. The governance of inter-organisational relationships during different supply chain maturity phases, Industrial Marketing Management, http://doi.org/10.1016/j.indmarman.2015.01.006

Wendler R., 2012. The maturity of maturity model research: A systematic mapping study, Information and Software Technology, http://doi.org/10.1016/j.infsof.2012.07.007

DOJRZAŁOŚĆ ZARZĄDZANIA ŁAŃCUCHEM DOSTAW: PRZEGLĄD LITERATURY W KONTEKŚCIE MODELI, WYMIARÓW ORAZ UJĘCIA TEMATYKI

STRESZCZENIE. **Wstęp:** Ostatnio zagadnienie dojrzałości organizacji pojawia się jako koncepcja w wielu różnych obszarach tematycznych, np. w obszarze zarządzania łańcuchem dostaw (SCM). Prezentowana praca jest próbą przeglądu rozwiązań w zakresie zarządzania łańcuchem dostaw w okresie ostatnich dwudziestu lat. W obszarze dojrzałości SCM istnieje wiele modeli, wymiarów oraz podejść stosowanych dla pomiary tej dojrzałości.

Metody: W prezentowanej pracy poddano analizie różne materiały naukowe, obejmujące artykuły z konferencji naukowych, artykuły publikowane w czasopismach naukowych jak i raporty techniczne. Dokumenty, które poddano analizie, pochodzą z okresu od wczesnych lat 90-tych zeszłego stulecia do chwili obecnej (2019). W pracy zaprezentowano również metody, wymiary oraz podejścia stosowane wcześniej dla pomiaru dojrzałości SCM. Zidentyfikowano luki w prowadzonych wcześniej badaniach, poddano je analizie i dyskusji.

Wyniki: W wyniku przeprowadzone analizy, uszeregowano różne wymiary w odpowiednie kategorie. Praca ma na celu zaprezentowanie przeglądu literatury w celu wykrycia luk badawczych i dostarczenie w ten sposób pomocy naukowcom dla dalszych badań w obszarze dojrzałości SCM. Istnieje wiele różnych podejść do modeli dojrzałości łańcucha dostaw. Jedne modele koncentrują się na jego spójności, podczas gdy inne na przejrzystości łańcucha dostaw i możliwości śledzenia poszczególnych operacji. W najnowszych badaniach, więcej uwagi jest poświęcone takim obszarom łańcucha dostaw jak elastyczność i zrównoważony rozwój. Wyniki pracy wskazują na luki badawcze w określonych obszarach, które wymagają dalszych badań. Dodatkowo, materiały prezentowane w pracy pozwalają na stworzenie bardziej wszechstronnych modeli dojrzałości SCM.

Wnioski: Na podstawie uzyskanych wyników można wyraźnie zaobserwować trend w zarządzaniu łańcuchem dostaw w kierunku e-SCM oraz innych technologii jak blockchain. Równie istotny jest zrównoważony rozwój organizacji. Należy też wspomnieć, że także inne strategiczne cechy łańcuchów dostaw, jak szczupłość, zwinność, odporność, zintegrowanie, zielona logistyka, itd., odgrywają istotną rolę w tym obszarze. Połączenie tych strategicznych cech może być efektywną ideą stworzenia bardziej wszechstronnych modeli dojrzałości SCM. Uzyskane wyniki wskazują, że pożądane są dalsze badania w celu pokrycia istniejących luk w obszarze dojrzałości SCM.

Słowa kluczowe: dojrzałość organizacji, zarządzanie łańcuchem dostaw, dojrzałość łańcucha dostaw, model dojrzałości, przegląd literatury

Mohsen Cheshmberah ORCID ID: https://orcid.org/0000-0003-3282-1527
Malek Ashtar University of Technology
Faculty of Industrial Engineering
Department of Industrial Engineering
Isfahan, **Iran**
e-mail: mcheshmberah@mut.ac.ir
e-mail: mcheshmberah66@gmail.com

Safoura Beheshtikia ORCID ID: https://orcid.org/0000-0002-5863-7974
Isfahan University of Technology
Researcher in Management Field
Isfahan, **Iran**
e-mail: sbeheshtikia@gmail.com

LogForum

> Scientific Journal of Logistics <

2020, 16 (1), 117-127

http://doi.org/10.17270/J.LOG.2020.343

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

EFFICIENCY OF SALES LOGISTICS IN OWN AND PARTNER NETWORKS

Łukasz Brzeziński[1], Piotr Cyplik[2]

1) Poznań School of Logistics, Poznań, **Poland**, 2) Poznan University of Technology, Poznań, **Poland**

ABSTRACT. **Background:** Sales plays an important and simultaneously specific role in an organization's logistics system. It can be pointed out that it is the connective tissue between the supply and distribution subsystems of a business entity. Sales logistics encompasses all the activities whose core tenet is to provide the customer with the ordered product within the required time, at a satisfactory cost and quality. Additionally, it should be pointed out that sales networks in the telecommunications industry are actively involved especially in distribution. There are three types of sales networks in telecommunications companies. These are own sales networks, partner sales networks - also called external or dealerships, and mixed networks - where both previously enumerated solutions work simultaneously. The conditions for the proper functioning of own and partner sales networks differ significantly in terms of both the formal-legal side and remuneration. The purpose of the article is to analyze the impact of using sales network partners on the effectiveness of sales logistics.

Methods: The comparative analysis dealt with four entities constituting the telecommunications industry in Poland, considering such parameters as: number of employees, average number of activations per employee, average cost per one employee, average income per one employee, sales profitability, The analysis period covered the years in which the surveyed entities used own and partner sales networks in parallel (1999-2016).

Results: When comparing the functioning of own and partner sales networks based on the studied parameters, it should be noted that the latter is characterized by a much higher number of employees (by 73.19%). Besides, the profitability of sales in the partner network is much higher than in the case of own network - by 141.69 percentage points.

Conclusions: Partner sales networks are characterized by a higher average sales value and profitability than own networks. At the same time, there are a larger number of employees employed in partner sales networks. It should be noted that in respect of market penetration and income generation by organizations, this solution is more advantageous. The added value of the research is determining the level of sales logistics effectiveness of own and partner sales networks in terms of the telecommunications industry.

Key words: sales logistics, comparative analysis of sales networks, telecommunications industry, sales effectiveness of own and partner networks.

INTRODUCTION

Sales logistics is an area covering all the activities whose basic assumption is to deliver the ordered goods to the customer within the time set by him. In this aspect, it is vital to maintain a rational cost, and even minimize it as in the case of intensifying competitive fights [Mellat-Parast, Spillan 2014, Kampf, Ližbetinová, Tišlerová 2017].

When looking at a slightly broader approach related to the entire supply chain of the telecommunications market, in terms of phases it consists of a supply (suppliers), sales (telecommunications operators, sales networks) and distribution (sales networks, courier companies). The supply concerns entities providing products offered by

Citation: Brzeziński Ł., Cyplik P., 2020. Efficiency of sales logistics in own and partner networks. LogForum 16 (1), 117-127
http://doi.org/10.17270/J.LOG.2020.343

Received: 12.03.2019, Accepted: 08.11.2019, on-line: 30.12.2019.

telecommunications operators (telephones, smartphones, laptops, netbooks, modems, tablets and other devices). Sales of telecommunications services and products are carried out by sales networks (own and partner) of telecommunications operators. On the other hand, the distribution of products and services is carried out by courier companies, as well as by sales networks - including partner networks. Also, it should be noted that sales networks actively participate in both the sales and distribution phase [Brzeziński, Wyrwicka 2018].

Distribution logistics is the total of actions taken to achieve effective product movement from the end of the process on the production line to the consumer. It covers all tasks related to supplying the customer with products directly from production, from sales warehouses or possibly from other regional shipping centres. Typically, this stage of flows already concerns final products, but examples of different situations include the takeover by a specialized logistics distribution service provider along with the previous final assembly of the product adapting its features to the needs of the final recipient [Jazairy, Lenhardt, von Haartman, 2017].

When taking appropriate actions to place goods at the buyer's disposal, it is necessary to take into account, above all, his expectations, especially in terms of quantity and quality of products, delivery times and the scope of after-sales services, as well as the division of tasks related to the flow of goods between the supplier and the recipient. The development of service standards plays an important role in this respect.

Distribution stands for all the activities related to the movement of materials, usually products and components for the needs of the service, from the producer to the consumer. These include transport, storage, inventory management, material handling, order processing, location analysis, packaging management, information processing and communication necessary for effective coordination of all activities [Thompson, Richardson 1996, Lechner, Dowling, Welpe, 2006, Gino, Melacini, Sassi, Tappia 2017].

However, despite the complexity of sales logistics and its links with aspects of distribution, the implementation of effective commercial processes seems to be more difficult and somewhat initiating activity for others - because it provides the organization with financial resources in the form of revenues. A characteristic feature of sales in the telecommunications industry is that it takes the form of a network [Fabbe-Costes, Jahre, 2008, Kościelniak 2014, Bang-Ning, Chen, Lin, 2016, Jens, Teuteberg, 2016, Urciuoli, Hintsa, 2017].

Cooperation has always existed in the economy resulting from the adopted tactics of the enterprise or operational needs. Contemporary cooperation relations are developed and supported by technology. They now penetrate life so strongly that the metaphor of the network becomes ubiquitous, and the characteristics describing the connections indicate that it is global [Bengtsson, Kock, 2000, Agndal, Nilsson 2009; da Mota Pedrosa, Blazevic, Jasmand, 2015].

The creation of network forms of sales processes results from the search for new forms of task implementation. Important features of networking include: goal - creating a sense of identity that allows effective management of resources, participants, their activities in a way that enables the implementation of the assumed strategy; high degree of specialization; network structure often determined depending on the goal or problem being solved; coordination based on self-organization, problem solving, employee involvement; spontaneity [Peterson, Zimmerman 2004]; low formalization - few written rules, information flow through the network of connections, knowledge resources perceived as a common good, available to everyone [Hadas, Stachowiak, Cyplik, 2011; Oláh,Karmazin, Pető, Popp, 2018].

The development of network forms means that new forms of work organization are used. An employee can be used to create value in an enterprise. In sales networks, employees increasingly have a relatively wide range of rights and responsibilities. The model of self-managing teams and time forms - e.g. task-based (e.g. partner sales networks) is becoming more common [Hakansson, Havila, Pedersen 2000, Cachon, Swinney, 2009, Metcalfe 2010, Manuj, Sahin, 2011, Tereyağoğlu, Veeraraghavan, 2012, Wudhikarn, Chakpitak, Neubert, 2018, Solakivi, Hofmann, Töyli, Ojala 2018].

CHARACTERISTICS OF OWN AND PARTNER SALES NETWORKS IN THE TELECOMMUNICATION INDUSTRY

A network is an organizationally related structure that occurs inside and / or outside an enterprise with its separate resources and tasks. This structure is also a link between the market and the enterprise, through which, for example, the sale of goods takes place [Bradford, et. al., 2019, Agnihotri, et. al. 2017, Gustafson, et. al, 2018, Palmatier, et. al., 2018].

There are three types of sales networks in telecommunications companies. These are own sales network and partner sales network - also called external or dealerships, and mixed networks - where both previously mentioned solutions work simultaneously. The functioning of your own sales network depends entirely on the company's resources: employees are employed under employment contracts. On the other hand, partner sales networks are usually based on commercial contracts, and most of the operating costs are passed on to entities operating in this type of network. [Davis-Blake, Broschak 2009, Smith, 2015].

Entities forming a partner sales network are enterprises. Thus, the leading entity - the parent enterprise (forming the network) establishes cooperation based on commercial contracts (cooperation agreements) with partners who are to implement the processes of selling products and services for the parent enterprise. The partners, in turn, further shape their own sales structures.

The functioning of the sales network depends on many elements, which include, in particular, the persons employed in them, providing an appropriate offer to recipients, providing support for employees in the form of IT tools, allocation of material resources in the form of e.g. offices and their equipment. Also, the distribution of structures in the area covered by sales activities should be based on current needs and market trends [Davis-Blake, Broschak 2009, Smith 2015].

When examining the context of sales logistics in the aspect of own and partner network forms, it is worth pointing to an interesting level of functioning, primarily of the second type of network. An affiliate sales network is an alternative or joint solution (in the case of mixed networks) concerning own sales networks. It is a structure composed of entities performing sales activities for the commissioning company, which use its resources, but do not fall directly into the organizational scope of the entity - the ordering party [Lin, Shi, Zhou 2010].

Therefore, one can indicate several leading concepts that shape the essence of partner sales networks. These include, among others, strategic alliances, contracting, cooperation, partnering and shared resources (Fig. 1). Sometimes the functioning of partner sales networks can be based on organizational cooperation of partners.

Source: own work

Fig. 1. Potential ideas for the functioning of partner sales networks

Essentially, outsourcing consists of entrusting the performance of the function of an enterprise to an external entity or a unit established for this purpose, e.g. a daughter company. The concept, scope and purpose of outsourcing have changed over time. Initially, it was a way to reduce costs, then the possibility of reducing exposure to the risk of technological changes, reducing the scope of operations, as well as a strategic orientation. Therefore, outsourcing can be considered the initial element based on which subsequent elements were created [Davis-Blake, Broschak 2009, Smith 2015].

The Alliance is a union of several enterprises that are competitors and operate on the same market, usually of a long-term nature, whose goal is to implement a joint venture. In comparison to typical cooperation relations between enterprises, strategic alliances are distinguished by a broader scope that may apply to the entire market, and potential directions of activity, a small number of partners [Dziaduch, Knokol 2009]. Contracting - instead of an employment contract, an agreement is concluded between the cooperating entities under which the terms of cooperation are established. Cooperation is the cooperation of many entities aimed at achieving a common goal, and individual entities mutually support each other in achieving it. This applies to cooperation, e.g. in the provision of services, i.e. the scope covers all types of relationships between enterprises. Cooperation stands out in relation to outsourcing: joint implementation of partial tasks, the contractual nature of cooperation, freedom in determining the form of cooperation. Partnering is associated with the identification of mutual relations between the customer and the supplier as a result of which both parties gain benefits. Partnering is focused on developing high-quality contacts with the recipient of products or services. In a sense, this concept is synonymous with outsourcing, but in this approach, the most important are relations between partners. Shared resources concern the joint use of enterprise infrastructure, e.g. computer network, provision of computer programs, data, mass storage devices, printers [Inkpen, Tank 2005, Davis-Blake, Broschak 2009, Smith 2015].

Entities forming a partner sales network are enterprises. Thus, the leading entity - the parent enterprise (forming the network) establishes cooperation based on commercial contracts (cooperation agreements) with partners who are to implement the processes of selling products and services for the parent enterprise. The partners, in turn, further shape their own sales structures. Operating costs result from the workload of tasks. Therefore, the remuneration for the provision of sales processes to the parent enterprise by the partner is based on the commission, which is specified in the contract. This is due to the allocation of tasks between individual entities. Similar relationships occur between the partner and sales representatives employed in the partner sales network. All operating costs are "passed on" to sales representatives.

Own and partner sales networks, despite a certain convergence in the very purpose of their operation, which can be synthetically described as the highest possible efficiency of sales processes, in the very operation and integration into the company structure differ significantly. Therefore, it seems reasonable to compare them.

Common features and differences between own sales networks and partner sales networks will be compiled in the following categories: employees, sales plans, organization, costs, salaries, entitlements and responsibility, assets, and control and supervision. The comparison is presented in Table 1.

The main difference between the two types of sales network considered here is the contract with a sales representative, based on which employees are employed. In the case of own sales networks, this is an employment contract (in principle), while partner networks have cooperation agreements (which is a reference to contracting). The differences are also manifested in the organization because own sales networks are included in the structures of the leading enterprise. The partner network has no such connection, the only link is the person of the director of the partner network who is employed in the contracting enterprise. Own networks are characterized by significantly higher operating costs. In partner networks, remuneration is based on commission, if the people employed there will not finalize sales transactions, there will be no basis for payment for the work done. In the case of their own sales network, the company's management or board of directors can fully control and interfere in operations.

Table 1. Features of own sales networks and partner sales networks – comparison

Specification	Own sales networks	Partner sales networks
Employees	Employed on the basis of an employment contract	The cooperation between the parent company and the partner is based on a cooperation agreement. The partner also employs employees based on a cooperation agreement (contracting)
Sales plans	Monthly, quarterly, semi-annual and annual sales goals are set for the employees	In the case of a partner, an overall sales goal (for the entire entity) is set, as well as individual goals for individual employees - sales representatives and sales managers
Organisation	The sales network is included in the company structure as part of the Sales Department or Division and is managed by the Sales Director in accordance with the objectives set by the Management Board	Partner networks operate outside the enterprise structure and in addition, the entity implements its own organizational solutions. However, contractual subordination remains with respect to the parent enterprise, and the supervision of the partner network is usually performed by the Partner Network Director employed in the parent enterprise.
Costs	All operating costs of the company's own sales network are borne by the home company, you can distinguish, inter alia, the costs of remuneration (along with mark-ups, bonuses, premiums, etc.), training, work tools (e.g. company cars, fuel costs, cell phones, laptops, tablets, computer software, customer database, etc.) and promotional activities (advertising materials, promotional campaigns, customer bonuses).	All costs of the partner sales network are borne by the partner and his employees, including training, work tools (e.g. mobile phones, laptops, tablets, computer software, customer database, etc.) and promotional activities (advertising materials, promotional campaigns, bonuses for customers).
Earnings (revenue - for partner networks)	Borne by the parent company based on the employment contract, bonus and other extra regulations	The partner as an institution receives remuneration for services rendered, and then pays them to employees based on sales volume and commission rates
Entitlements, responsibility	Employees of own sales network have proxies and full rights to sell services and products	The independent entity has full authority and responsibility for the performance of the function
Assets	Fixed assets such as real estate, e.g. land, buildings, structures, premises constituting a separate real estate, their parts or shares; machinery and equipment as well as means of transport belong to the parent enterprise	Fixed assets such as real estate, e.g. land, buildings, structures, premises constituting a separate real estate, their parts or shares; machines and equipment as well as means of transport belong to a partner or sales representatives and it is private property. Partial use of the leading enterprise infrastructure
Control and supervision	The management board and management of the parent enterprise are free to control the activities of an own sales network, have full market access, and possibility of ongoing implementation of changes and modifying the specifics of operations	From the perspective of the parent company, there is a limited possibility of controlling the functioning of the partner network, the modifications are difficult and more time is needed for them to start functioning, the partner has full control and supervision, implementing changes in current operations and others

Source: own work

Referring to certain similarities in the activities of own and partner networks, one should indicate the rights - employees in both cases have the power of attorney to conclude contracts, sell products and services. The next element is assets (enterprise resources), which are jointly used to a certain extent.

The functioning of the sales network depends on many elements, which include, in particular, the persons employed in them, providing an appropriate offer to recipients, providing support for employees in the form of IT tools, allocation of material resources in the form of e.g. offices and their equipment. Also, the distribution of structures in the area covered by sales activities should be based on current needs and market trends.

METHODOLOGY OF OWN STUDY

In the research process, inferences were made about the entire statistical population based on information collected during the statistical (representative) sample survey.

The research sample consisted of all (four) enterprises, which at the same time, per the adopted baseline criteria, simultaneously created the entire telecommunications market in Poland. Based on the data from the Office of Electronic Communications, it can be concluded that in 2015, 23 business entities operated on the telecommunications market in Poland. However, only four entities meet the following criteria:

- enterprises operate on the territory of the Republic of Poland
- enterprises operate in the mobile telephony segment in particular,
- enterprises covered by the survey use partner networks,
- partner networks operate on behalf of enterprises in the telecommunications industry in Poland realize sales both on the business market and the individual customer market (sales to other natural persons),
- enterprises offer post-paid services, i.e. subscription services.

The research activities undertaken were utilitarian and in particular, referred to business practice. The research assumption was to confront the effectiveness of sales logistics obtained by own and partner sales networks in the telecommunications industry in Poland.

The purpose of the article is to analyze the impact of using sales network partners on the effectiveness of sales Logistics.

On this basis, the following research problems were formulated:

Are partner sales networks more efficient than own sales networks (in terms of sales logistics)?

P1: What is the average cost per employee in own and partner networks?

P2: What is the average income per employee in own and partner networks?

P3: What is the average number of activations per employee in own and partner networks?

P4: What is the profitability of sales logistics of own and partner sales networks?

The effectiveness was analysed based on values: number of employees, average number of activations per employee (activation of the customer's SIM card in the telecommunications network of the telecommunications operator), average cost per one employee, average income per one employee, sales profitability.

Variables selected in this way, used in the operation, perform sales logistics effectiveness assessments. On the one hand, they include the cost side. In the case of employees belonging to the sales network, gross remuneration, costs associated with reaching the customer and the costs of providing telecommunications equipment, as well as the revenues generated by these employees (average number of activations based on). In turn, in the case of partners in the sales network, costs related to the payment of commission are included. It is also irrelevant to indicate the number of employees to indicate the scale of activity. On this basis, you can assess the logistics efficiency and compare the effectiveness of sales logistics.

The leading research method was comparative analysis, which services identify the type of elements forming a given whole based on their features and assess the efficiency of the whole functioning against the background of the adopted pattern. The comparative analysis concerns a specific object, which is usually complex and differs from others, therefore it is a set of its proper features with different potential information. The study of complex objects or phenomena means that comparative analysis has many dimensions [Reynolds 2000, Zimmerman and Szenberg 2000].

COMPARATIVE ANALYSIS OF SALES LOGISTICS EFFICIENCY OF TELECOMMUNICATIONS ENTERPRISES IN POLAND

The following entities will be subject to comparative analysis: Enterprise A, Enterprise B, Enterprise C, Enterprise D.

Enterprise A has been using partner networks since 2008 when it employed 33 people in its own sales network and 70 in the partner sales network. In 2016, 956 people were employed in the enterprise, whose daily duties were directly related to sales in their own sales network (showrooms and sales representatives), and 1356 people in the partner network. It is worth noting that until 2012 there was a significant increase in sales and employment outlets in both own and partner networks. In subsequent years, there was a systematic decrease in the number of showrooms and employment in both types of sales networks.

Enterprise B has been using partner networks since 1999. In 2016, the total number of employees of the own network was 665. However, in the case of the partner network, it was 1340 people. The number of own showrooms in 2016 was 220, and there were 530 in the partner network. Also, the number of sales representatives in the partner network in 2016 was much higher (420 people) than in the case of own sales network (225 people).

Enterprise C launched a partner sales network in 2001. This entity has the most extensive sales structures compared to enterprises A, B and D. In 2016, there were 270 own and 850 partner showrooms. The total number of employees in the own network was 1000 and the partner network 2130.

Enterprise D launched a partner sales network in 2002. In the same year, 200 employees were employed in their own sales network. In 2016, this number was 1095. 190 people were employed in the partner network in 2002, and in 2016, 950.

The analyses carried out were based on three main values: the average annual number of activations per employee (activation of the customer's SIM card in the telecommunications network of the telecommunications operator), then the average annual cost per employee, which in the case of employees of the own network consists of remuneration with mark-ups, bonuses, business trips, fuel costs, the purchase of a car fleet, business phones, business laptops and other items necessary for work. However, in relation to employees of the partner network, it is the cost of commission and possible bonuses for obtaining high sales results. The average income per employee is the inflow of funds resulting from all activations. These are subscription services, i.e. the customer bears the monthly costs of using a specific SIM card, plus one-time activations and the purchase of additional paid services.

The average number of employees of own sales network in all enterprises covered by the survey was 877.00 (median 887.00). The average number of activations sold by one employee was 148.47. The average employer's cost per employee was PLN 90,575.70. The average income per employee was PLN 19,118.10. The profitability of sales was at 125.12%.

The average number of employees of the partner networks of all the analysed enterprises was 1517.00 people, besides, the average sales of activations per employee were 176.56. The average cost of one employee was PLN 62,744.46, and the average income per employee was PLN 22,702.10. Sales profitability was 266.71% (Table 9).

Comparing the calculated parameters for own and partner sales networks, it should be noted that the latter employs significantly more employees (by 73.19%). Concerning the average number of activations in the annual average, the employees of the partner network sold 18.92% more. Costs per employee in the content network were 30.73% lower than in the case of the own network. The average revenue per employee of the partner network was higher by 18.91% compared to own sales networks. The profitability of sales in the content network was much higher than in the case of own network - by 141.69 percentage points. A comparison of the values of own and partner networks is presented in Table 2.

Summing up the analysis carried out in terms of the average number of activations per employee, average income and cost per employee and sales profitability, in each of the examined elements the partner networks achieved better results.

Table 2. Number of regular destinations and passenger traffic in 2013

Specification	Element of descriptive statistics	Own sales network	Partner sales network
Number of employees [pers.]	Average	875,71	1516,67
	Median	878,90	1320,75
	Minimum value	708,33	1197,67
	Maximum value	1036,67	2227,5
Average number of activations per employee [PLN]	Average	148,47	176,56
	Median	146,82	179,08
	Minimum value	137,44	163,06
	Maximum value	162,80	185,00
Average cost per one employee [PLN]	Average	90575,70	62744,46
	Median	90663,83	62991,34
	Minimum value	77202,22	59551,88
	Maximum value	103772,90	65443,28
Average income per one employee [PLN]	Average	191148,10	227302,10
	Mediana	18985,30	224325,90
	Minimum value	169851,10	212447,80
	Maximum value	214874,20	248108,70
Sales profitability [%]	Average	125,12%	266,81%
	Median	122,43%	265,69%
	Minimum value	91,55%	245,27%
	Maximum value	164,06%	290,58%

Source: own work

CONCLUSIVE REMARKS

The goal of the research - to analyze the impact of using sales network partners on the effectiveness of sales logistics - has been executed.

While partner sales networks are, in principle, more effective than own sales networks, the added value of this research is to determine the scale of this phenomenon in terms of the entire telecommunications industry. There are no similar studies of this type in Poland - conducted on such a scale. The authors also failed to find this in foreign literature, even in relation to other industries. Therefore, it should be pointed out that the authors have made a significant contribution to acquiring new knowledge.

Employees of partner sales networks generate higher sales (recognized as the average annual number of activations per employee - by 18.92%, with lower costs per employee by 30.73%). This shows the significant advantage and legitimacy of creating partner sales networks. On this basis, the research hypothesis - partner networks are characterized by better sales efficiency than own sales networks - should be verified positively.

It seems that employees of partner networks - from the perspective of the due commission are motivated to more active sales activities and showing greater initiative - which also translates into remuneration. Besides, taking into account the context of the parent enterprise - lower costs resulting from the specificity of the operation of partner networks are an additional factor prompting management to create such structures. Therefore, in the context of sales logistics, the creation of partner structures is a more beneficial solution for an economic entity, where reaching the client with the offer and closing the sale takes place at a lower cost, also, a higher level of transactional efficiency is not without significance.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This paper has been the result of the study conducted within the projects pursued at the Poznan University of Technology, Faculty of Engineering Management [project number: 11/140/SBAD/4168] and Poznan School of Logistics [project number KSL 2/17].

REFERENCES

Agndal H., Nilsson U., 2009. Interorganizational cost management in the exchange process, Management Accounting Research, 20, 2, http://doi.org/10.1016/j.mar.2008.07.001.

Agnihotri, R., Colin B.G., Itani O.S., Jaramillo F., Krush M.T., 2017, Salesperson Ambidexterity and Customer Satisfaction: Examining the Role of Customer Demandingness, Adaptive Selling, and Role Conflict, Journal of Personal Selling & Sales Management 37 (1):27–41. http://doi.org/10.1080/08853134.2016.1272053.

Bang-Ning H., Chen T.T., Lin J.T., 2016. 3PL Selection Criteria in Integrated Circuit Manufacturing Industry in Taiwan, Supply Chain Management: An International Journal, 21, 1, 103–124. http://doi.org/10.1108/SCM-03-2014-0089.

Bengtsson M., Kock S., 2000. Coopetition in Business Networks – Cooperate and Compete Simultaneously, Industrial Marketing Management, 29, 411-426.

Bradford K.D., Yongmei L., Yuying S., Weitz B.A., Xu J., 2019. Harnessing Internal Support to Enhance Customer Relationships: The Role of Networking, Helping, and Allocentrism, Journal of Marketing Theory and Practice, 27, 2, 140-158.

Brzeziński Ł., Wyrwicka M.K., 2018. Development factors of partnership sales networks in the supply chain of a telecom - case study, Research in Logistics & Production, 8, 4, 329-339, http://doi.org/10.21008/j.2083-4950.2018.8.4.4.

Cachon G.P., Swinney R., 2009, Purchasing, pricing, and quick response in the presence of strategic consumers, Management Science, 55, 3, 497-511.

da Mota Pedrosa A., Blazevic V., Jasmand C., 2015. Logistics innovation development: a micro-level perspective, International Journal of Physical Distribution & Logistics Management, 45, 4, 313-332. http://doi.org/10.1108/IJPDLM-12-2014-0289.

Davis-Blake A., Broschak J.P. 2009. Outsourcing and the Changing Nature of Work, Annual Review of Sociology, 35, 321-340. http://doi.org/10.1146/annurev.soc.34.040507.134641.

Fabbe-Costes N., Jahre M., 2008. Supply chain integration and performance: A review of the evidence. International Journal of Logistics Management 19, 2.

Gino M., Melacini M., Sassi C., Tappia E., 2017. Assessing Efficiency and Innovation in the 3PL Industry: An Empirical Analysis, International Journal of Logistics Research and Applications 20 (1): 53–72. http://doi.org/10.1080/13675567.2016.1226789.

Gustafson B.M., Pomirleanu N., Mariadoss B.J., 2018. A Review of Climate and Culture Research in Selling and Sales Management, Journal of Personal Selling & Sales Management 38 (1):144–167. http://doi.org/10.1080/08853134.2018.1426992.

Hadas L., Stachowiak A., Cyplik P., 2011. Decision Making Model in Integrated Assessment of Business-Environment System: a Case Study, in: Golinska P. (Ed.), Fertsch M. (Ed.), Marx-Gómez J. (Ed.), Information Technologies in Environmental Engineering. Environmental Science and Engineering, 3. Springer, Berlin, Heidelberg.

Hakansson H., Havila V., Pedersen A., 2000. Learning in Networks, Industrial Marketing Management, 28, 5, 443-452, http://doi.org/10.1016/S0019-8501(99)00080-2.

Inkpen, A.C., Tang, E.W.K., 2005. Social capital, networks and knowledge transfer. Academy of Management Review, 30, 148.

Jazairy A., Lenhardt J., von Haartman R., 2017, Improving logistics performance in cross-border 3PL relationships, International Journal of Logistics Research and Applications, 20:5, 491-513, http://doi.org/10.1080/13675567.2017.1306036.

Jens M., Teuteberg F., 2016, Understanding the 4PL Approach Within an Agricultural Supply Chain Using Matrix Model and Cross-Case Analysis, International Journal of Logistics Research and Applications, 19 (5): 333–350. http://doi.org/10.1080/13675567.2015.1107533.

Kampf R., Ližbetinová L., Tišlerová K., 2017. Management of Customer Service in Terms of Logistics Information Systems, Open Engineering, 7, 1, 26-30. http://doi.org/10.1515/eng-2017-0006.

Kościelniak H., 2014. An improvement of information processes in enterprises –the analysis of sales profitability in the manufacturing company using ERP systems.Polish Journal of Management Studies 2014; 10, 2, 65-72.

Lechner Ch., Dowling M., Welpe I., 2006. Firm Networks and Firm Development: The Role of The Relational Mix, Journal of Business Venturing, 21, 514-540.

Lin Y., Shi Y. Zhou L., 2010. Service supply chain: nature, evolution, and operational implications, in: Huang G.Q. (Ed.), Mak K.L. (Ed.), Maropoulos P.G. (Ed.), Advances in Intelli-gent and Soft Computing, Vol. 66, Springer-Verlag, Berlin/Heidelberg, 1189-1204.

Manuj I., Sahin F., 2011. A model of supply chain and supply chain decision-making complexity, International Journal of Physical Distribution and Logistics Management, 41, 5, 511-549.

Mellat-Parast M., Spillan J.E., 2014. Logistics and supply chain process integration as a source of competitive advantage, International Journal of Logistics Management, 25, 2, 289-314.

Metcalfe, A.S., 2010. Examining the Trilateral Networks of the Triple Helix: Intermediating Organizations and Academy-Industry-Government Relations. Critical Sociology, 36, 4, 503–519, http://doi.org/10.1177/0896920510365920.

Oláh J., Karmazin G., Pető K., Popp J., 2018. Information technology developments of logistics service providers in Hungary, International Journal of Logistics Research and Applications, 21:3, 332-344, http://doi.org/10.1080/13675567.2017.1393506.

Palmatier R.W., Houston M.B., Hulland J., 2018. Review Articles: Purpose, Process, and Structure, Journal of the Academy of Marketing Science 46, 1, 1-5.

Peterson N.A., Zimmerman M.A., 2004. Beyond the individual: Toward a nomo-logical network od organizational empowerment, American Journal of Community Psychology, 34, 1-2, http://doi.org/10.1023/B:AJCP.0000040151.77047.58

Reynolds N.L., 2000, Benchmarking Interna-tional Marketing Research in Practice in UK Agencies Preliminary Evidence, Benchmarking: An International Journal, 7, 5.

Smith D.R., 2015. The outsourcing and comer-cialization of science, Science & Society, 16(1), 14-16. http://doi.org/10.15252/embr.201439672.

Solakivi T., Hofmann E., Töyli J., Ojala L., 2018. The performance of logistics service providers and the logistics costs of shippers: a comparative study of Finland and Switzerland, International Journal of Logistics Research and Applications, 21:4, 444-463, http://doi.org/10.1080/13675567.2018.1439906.

Tereyağoğlu N., Veeraraghavan S., 2012. Selling to conspicuous consumers: pricing, production, and sourcing decisions, Management Science, 58, 12, 2168-2189.

Thompson J.L., Richardson B., 1996. Strategic and Competitive Success: Towards a Model of the Comprehensively Competent Organization, Management Decision, 34. 5-19.

Urciuoli L., Hintsa J., 2017. Adapting Supply Chain Management Strategies to Security– an Analysis of Existing Gaps and Recommendations for Improvement, International Journal of Logistics Research and Applications, 20, 3, 276–295. http://doi.org/10.1080/13675567.2016.1219703.

Wudhikarn R., Chakpitak N., Neubert G., 2018. A literature review on performance measures of logistics management: an intellectual capital perspective, International Journal of Production Research, 56:13, 4490-4520, http://doi.org/10.1080/00207543.2018.1431414.

Zimmerman A.S., Szenberg M., 2000. Implementing International Qualitative Research: Techniques and Obstacles, Qualitative Market Research An International Journal, 3, 3, http://doi.org/10.1108/13522750010333906

EFEKTYWNOŚĆ LOGISTYKI SPRZEDAŻY WŁASNYCH I PARTNERSKICH SIECI SPRZEDAŻY

STRESZCZENIE. **Wstęp:** Sprzedaż pełni istotną i jednocześnie specyficzną rolę w systemie logistycznym organizacji. Można wskazać, że jest spójnikiem pomiędzy podsystem zaopatrzenia i dystrybucji podmiotu gospodarczego. Logistyka sprzedaży obejmuje swoim zakresem ogół działań, których podstawowym założeniem jest dostarczenie klientowi zamawianego produktu, w wymaganym czasie, przy zadowalającym koszcie i jakości. Dodatkowo należy wskazać, że sieci sprzedaży w branży telekomunikacyjnej, uczestniczą aktywnie w szczególności w dystrybucji. W przedsiębiorstwach telekomunikacyjnych spotyka się trzy rodzaje sieci sprzedaży. Są to: własna sieć sprzedaży i partnerska sieć sprzedaży - nazywana również zewnętrzną lub dealerską oraz sieci mieszane - gdzie oba wymienione uprzednio rozwiązania działają jednocześnie. Uwarunkowania funkcjonowania własnych i partnerskich sieci sprzedaży znacząco się różnią - zarówno od strony formalno-prawnej jak i wynagrodzenia. Celem artykułu jest analiza wpływu wykorzystania partnerów sieci sprzedaży na efektywność logistyki sprzedaży.
Metody: Zastosowano metodą analizy porównawczej czterech podmiotów tworzących branżę telekomunikacyjną w Polsce z uwzględnieniem takich parametrów jak: liczba pracowników, średnia liczba aktywacji na pracownika, średni koszt na jednego pracownika, średni dochód na jednego pracownika, rentowność sprzedaży. Okres analiz obejmował lata, w którym badane podmioty stosowany równolegle sieci własne i partnerskie sprzedaży (1999-2016).
Wyniki: Porównując funkcjonowanie własnych i partnerskich sieci sprzedaży w oparciu o badane parametry, należy zaznaczyć, że te drugie cechują się znacznie wyższą liczbą zatrudnionych pracowników (o 73,19%). Ponadto rentowność sprzedaży w sieci partnerskiej jest o wiele wyższa niż w przypadku sieci własnej - o 141,69 punktów procentowych.
Wnioski: Partnerskie sieci sprzedaży charakteryzują się przeciętnie wyższą wartością sprzedaży i rentowności niż sieci własne. Jednocześnie zatrudniona w tej formie jest większa liczba pracowników. Należy wskazać, że pod względem penetracji rynku i uzyskiwania przychodów przez organizacje, to rozwiązanie jest korzystniejsze. Wartością dodaną badania jest określenie poziomu efektywności logistyki sprzedaży własnych i partnerskich sieci sprzedaży w branży telekomunikacyjnej.

Słowa kluczowe: logistyka sprzedaży, analiza porównawcza sieci sprzedaży, branża telekomunikacyjna, efektywność sprzedaży sieci własnych i partnerskich

Łukasz Brzeziński ORCID ID: https://orcid.org/0000-0002-4948-7118
Poznań School of Logistics
Faculty of Management and Logistics
Department of Management Sciences
ul. E. Estkowskego 6, 61-755 Poznań, **Poland**
e-mail: lukasz.brzezinski@wsl.com.pl

Piotr Cyplik ORCID ID: https://orcid.org/0000-0002-5775-6760
Poznan University of Technology
Strzelecka 11, 60-965 Poznań, **Poland**
e-mail: piotr.cyplik@put.poznan.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (1), 129-140

http://doi.org/10.17270/J.LOG.2020.380

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

USING ROBOTIC PROCESS AUTOMATION (RPA) TO ENHANCE ITEM MASTER DATA MAINTENANCE PROCESS

Andreas M. Radke, Minh Trang Dang, Albert Tan

1) mSE Solutions Pte. Ltd., **Singapore**, 2) Vinsmart, **Vietnam**, 3) Malaysia Institute for Supply Chain Innovation, **Malaysia**

ABSTRACT. **Background:** Manufacturing companies nowadays have to cope with ever-increasing speed and complexity to manage their global supply chain. Information flow manage the supply chain needs to be more accurate and real-time than ever before. Item master data management is no exception as well. This research demonstrates the potential benefits of applying robotic process automation (RPA) technology in master data management based on two companies in the manufacturing industry.

Methods: The method approached by the research was a qualitative method, utilizing interpretation of data extracted from literature and semi-constructed interviews.

Results: The article proposes a framework for RPA implementation in the master data managing process. Automation with software robots can greatly benefit the organization, namely: lower processing time, reduce human errors, lower operations cost, improved compliance level and higher data accuracy.

Conclusions: With the objective to examine the benefits of RPA in master data management, the researchers have investigated 2 companies in the manufacturing industry to understand how they have benefited from RPA for item master data management processes. The result showed that RPA is affirmed to bring about many benefits for the organizations through structured automation. The researchers have proposed a framework for implementing RPA to capture item master data based on the change management model and the framework is separated in 3 phases involving important tasks in each phase. Future researches might use this study as a stepping stone for further studies in cognitive RPA, utilizing cognitive technology in combination with RPA technology with the mean to achieve a higher level of automation.

Key words: Robotic process automation (RPA), master data management, manufacturing industry, business process improvement, productivity improvement.

INTRODUCTION

Manufacturing companies nowadays have to cope with ever-increasing speed and complexity to manage their global supply chain. Information flow manage the supply chain needs to be more accurate and real-time than ever before. Data, in particular master data, is the foundation of all digital initiatives, from key performance indicator (KPI) dashboards to optimization algorithms to prescriptive analytics – today categorized as descriptive, predictive and prescriptive analytics - and is ubiquitous [Vilminko-Heikkinen, Pekkola 2017, Silvola et al. 2010]. However, master data is often of poor quality due to the effect of poor data quality on artificial intelligence (AI) initiatives [Loten 2019]. Vas Narasimhan, chief executive officer of the leading pharma company Novartis AG, had to admit in an interview, that master data quality was insufficient to push artificial intelligence initiatives forward since it needs accurate data to learn [Shaywitz, 2019]. Data quality issues can be missing data, wrong data, typos, and much more. While automation operates very fast and reliable compared to human users, consider the versatility of human

Citation: Radke A.M., Dang M.T., Tan A., 2020. Using robotic process automation (RPA) to enhance Item master data maintenance process. LogForum 16 (1), 129-140, http://doi.org/10.17270/J.LOG.2020.380

Received: 05.08.2019, Accepted: 14.11.2019, on-line: 30.12.2019.

users who can compensate data quality errors ad-hoc.

To reduce the occurrence of issues with master data, in many companies the creation of master data is subject to stringent control processes: Four-eye principle, multiple gateways, preference of drop-down fields. However, the process of maintaining data quality suffers from multiple factors. The lack of direct interfaces between systems requires human users to transfer data manually between disconnected systems. Business processes to address data quality are designed in a green field mode and don't consider other business requirements and competing urgencies of daily operations. Business processes aren't intuitive and consistent onboarding, training and re-training efforts are missing, which result in quick deterioration of process adherence. The benefits of good data quality only become apparent at very different stages in the value creation process posing an incentive problem for the users responsible to enter the data and the ones using it.

Many organizations are looking at RPA as a generally cost-effective solution that helps to save time and lower compliance risk. The term RPA refers to programmed software robots that mimic repetitive manual tasks performed by human workers and replace these workers [Cewe, Koch, Mertens 2017, Tornbohm 2017]. From simple screen scraping RPA has now evolved to help organizations achieve greater efficiencies and support business growth in more complex and critical processes [Van der Aalst, Bichler, Heinzl 2018, Aguirre, Rodriguez 2017]. Instead of requiring time consuming process reengineering that leads to heavy investment on IT system transformations, RPA is able to perform such routine processes by running across systems. The main scope of RPA has been routine processes that don't change over time and are repeated thousands of times on a daily basis. Before RPA, organizations have applied many different special-purpose systems for planning and recording next to the enterprise resource planning (ERP) system yet indispensable processes still need to be carried out manually or under supervision of humans [Lowes, Lowes 2017]. Now, software robots relieve human users from low-value added back office work and make time for higher value-added tasks, thus increasing organizational efficiency and productivity.

However, in organizations there are many routine processes performed manually that are currently considered to lack the scale or value to apply automation, and master data creation is considered one of them. This research focuses on the perspective that master data is a core factor that directly affects the ability for digitalization to improve organizational performance. Erratic or incomplete master data can obstruct production which in turn impacts the return on investment of IT systems, because only manual case-specific intervention can resolve any issues. Maintaining master data is hence crucial to manufacturing industry especially in the era of industry 4.0 where internet of thing is promoted and business leaders all over the world have realized the importance of using high-quality data to drive business success.

To meet these expectations, this research suggests that businesses should use RPA to enhance item master management processes to capture the data. The authors investigate 2 companies where RPA was used to improve master data management process, to present the benefits and then propose a framework for managing master data management process using RPA. Evidences have shown that RPA could help to reduce transaction times, mitigate human errors and consequently reduce cost in manufacturing industry.

LITERATURE REVIEW

Master data contains all the cleansed and structured records stored in a business's system that characterize its entity. High quality master data hence is a prerequisite success factor for its performance [Hüner, Otto 2009]. Master data is also referred to as material master in the manufacturing industry as a major part of master data is constituted by bills of material (BOM), their detailed descriptions and inventory level, all of which are indispensable assets that provide useful insight into the manufacturing activities [Berson, Dubov 2007]. In a manufacturing company, it operating system can contains a large number of employees from many departments such as Purchasing, Logistics, Production, Production Planning, Finance, Accounting, Sales, etc. Thus, with the mean to provide a single point of reference, master data need to be stored in multiple sources so that it can be available to users from different departments and production plants [Haug et. al. 2013]. Though after the introduction of enterprise resource planning (ERP) systems, data discrepancy and redundancy issues has been reduced thanks to their single materials database concept [Haug, Arlbjørn, Pedersen 2009, Knolmayer, Röthlin 2006]. However, due to the large amount of data and management needs in the globalized context beyond the capabilities of traditional ERP technology, organizations are now facing difficulties in managing their database efficiently [Vilminko-Heikkinen, Pekkola 2017, Silvola et al. 2010].

Robotic process automation (RPA) is an emerging technology that base on the use of virtual robot to mimic human interactions across various systems [Zhang, Liu 2019, Lacity, Willcocks 2016]. RPA robots can be programed to carry out repetitive and rule-based tasks in replacement for human in a faster and more accurate manner [Willcocks, Lacity, Craig 2017]. It can operates over existing system without interfering on any of the systems as it only mimicking human activities like a digital version of human employees [Rajesh et al. 2018, Fersht, Slaby 2012]. One bot can be assigned multiple tasks or multiple bots can be assigned to do one task depends on the volume of the task [Madakam et al. 2019, Rajesh et al. 2018, Willcocks, Lacity, Craig 2017]. Hence Robotic Process Automation (RPA) has been proven as one of the reasonably priced and practical solutions to eliminate the need for human labours in repetitive structured task [Lacity, Willcocks 2016]. The advantages of RPA implementation has long been recognized by experts over the world. These advantages include and might not be limited to Table 1.

From Table 1, we can see that studies seem to be in agreement that RPA can bring about highly positive impacts: Processing time reduction; Productivity increase; Compliance levels improvement; Data accuracy improvement or human errors reduction; Costs minimization.

Table 1. Key benefits of RPA

No.	Studies	Processing times reduction	Productivity increase	Compliance levels improvement	Data accuracy improvement/ Human errors reduction	Cost reduction
1	Anagnoste 2018	✔	✔	✔	✔	
2	Bloem et al. 2014	✔	✔	✔		
3	Friedman 2006			✔		
4	Fung 2014	✔	✔	✔	✔	✔
5	Institute for Robotic Process Automation 2015	✔	✔	✔	✔	✔
6	Wald 2017	✔	✔		✔	✔
7	Kedziora & Kiviranta 2018	✔	✔		✔	✔
8	Lacity & Willcocks 2016	✔	✔	✔	✔	
9	Fersht & Slaby 2012	✔	✔	✔		✔
10	Fersht & Snowdon 2018	✔	✔	✔		✔
11	Rajesh, Ramesh & Rao 2018	✔	✔	✔	✔	
12	Sibalija, Jovanović & Đurić 2019	✔	✔	✔	✔	✔
13	Willcocks, Lacity & Craig 2015A	✔	✔	✔	✔	✔
14	Willcocks, Lacity & Craig 2015B	✔	✔	✔	✔	✔
15	Willcocks, Lacity & Craig 2017	✔	✔			
16	Zhang & Liu 2019	✔	✔			

Source: extracted from various literature

Table 2. RPA application by industry and function

Potential for RPA Low High

illustrative process with High-Potentail

Function	F & A	Procurment	Human Resource	Conatct Centre	Indusry Specific Purposes	
Industry	Accounts Payable, Acounts Receivables, General Leadger	Invoice processing, Requesting to Purchasing Orders	Payroll, Hiring, Candidate Managment	Customer Service		
Banking & Finanacial Services						✓ Cards activation ✓ Frauds Cliams Discovery
Insurance						✓ Claims Processing ✓ New Business Preparatiion
Healthcare						✓ Reports Automation ✓ System Reconciliation
Manufacturing						✓ Bills of Materail (BoM) Generation
High Tech & Telecom						✓ Service order Management ✓ Quality Reporting
Energy Utilites						✓ Account setup ✓ Meter Reading Validation

Source: Madakam, Holmukhe, Jaiswal, 2019

Table 2 indicates that Robotic Process Automation has several applications in numerous industries. The most common applications of RPA would be seen in data entry task where RPA logins to systems, reads emails, generate needed data and keys data in a structured form. Upper level can be seen in enterprise level as RPA can also transfer data from different systems to enterprise management system such as ERP. Specifically, manufacturing firm's application in bills of material (BOM) generation is discussed to be a highly promising area for RPA integration. We all know that material master management is one of the most important yet repetitive tasks. With above mentioned benefits, RPA is expected to become increasingly essential in master data management [Madakam, Holmukhe, Jaiswal 2019].

In all, master data management is important to the growth and desirable performance of businesses including manufacturing ones. Existing literature suggests that master data management is increasingly become harder of a challenge in nowadays marketplace, and a sufficient management tool is not yet found in the many organizations [Vilminko-Heikkinen, Pekkola 2017, Silvola et al. 2011]. Advances in technologies like that of RPA can help in enhancing this process in the near future. Literature review also pointed out that despite of the compelling possibility for growth of RPA in master data management field, not much RPA providers has been seen to circulate their business in this area [Kappagantula 2019].

RESEARCH METHOD

The aim of this research is to develop a framework to use RPA for capturing item master data for manufacturing companies. To develop the framework, pros and cons for RPA are evaluated while considering various business objectives. Two companies are selected for this research, one from the pharmaceutical company and another from the electronic company. These 2 companies have implemented RPA to capture item master data and thus fall within the scope of our research.

Company 1 – Electronic Company in Vietnam

The first case study was conducted on ABC Electronics Company in Vietnam. The process involved was for phone repairing where requests are sent to the factory in order to replace broken parts. Due to the nature of repair service, generation of BOM for production of a repaired phone cannot be automated via ERP system like normal production. The exception requests are collected and combined into the global supply chain management system – a legacy system shared between different departments within the company. Production planners then have to download these requests and generate excel data sheets base on the data on GSCM. Purchasing department then have to download BOM list from SAP and use excel tools to match and sort out the shortage materials using production planners' sheets from GSCM and downloaded BOM from SAP. The processed data is then sent back to the planners via emails to upload on SAP and generate exception production orders. The whole process needs to be done at least three times prior to weekly production at the end of the week in order to ensure availability and accuracy. However, repair production plan still suffers from countless plan postponement due to shortages of material that result partially from an inaccurate database. The problems are consistent with literature on challenges associate with master data management with three major issues being addressed: disconnected systems that require manual transfer of data, inconsistent material master in multiple systems; manual matching and sorting process depends purely on personal skill.

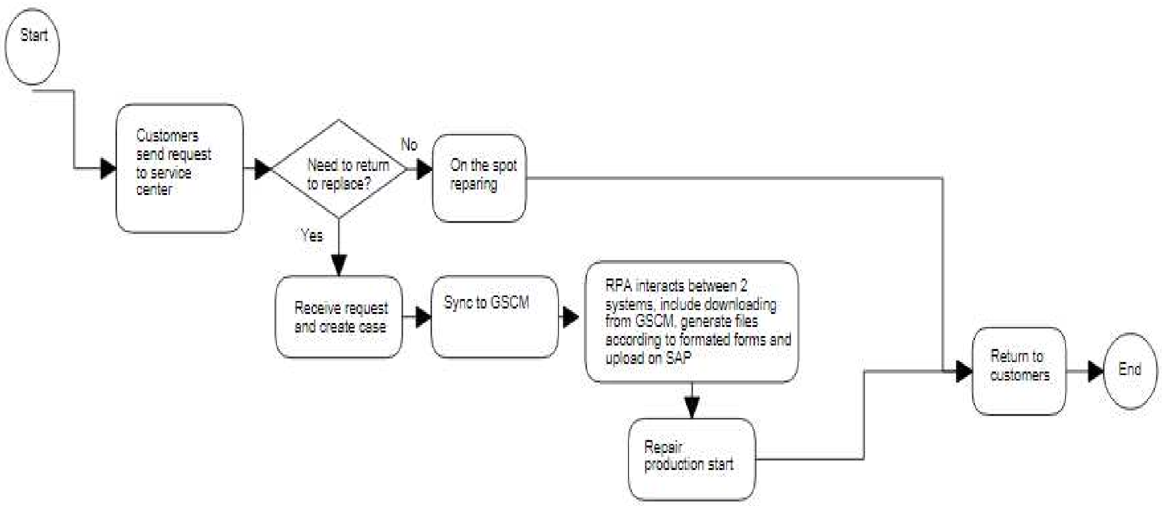


Fig. 1. Repair process flow after RPA implementation

Figure 1 shows the automated process after RPA implementation. The repetitive task such as logging in to GSCM and SAP, downloading BOM to spread sheet according to formulated layout, matching of BOM between two systems and upload on SAP to generate exceptional production order were taken over by a software robot (RPA). Firstly RPA open GSCM under assigned ID, and then download material master from the system. It then login to SAP and download the second material list via a BOM list download t-code. Next the robot matches material data between two downloaded sheets and generates final version of shortage components to upload on SAP. Any not-found issue will be recorded and reported for easier tracking and solving actions. Though issues like mismatching of material master still occur due to disconnections between systems, but in such cases, RPA will send an alert for mismatch errors to system users. The human employees then can focus on dealing with only these errors and carry out corrective actions to maintain material master in order to ensure better data synchronization the following time.

To evaluate the outcome, RPA was implemented partially in separated departments, one group containing departments applying RPA integration and another group containing departments without RPA support. Over the evaluation period significant differences was found separating the two groups. The group using RPA robot realized improvements that are similar to those discussed in the literature reviews:

- Reduce transaction times: Time taken to complete a request reduced by approximately 80%
- Increase productivity: Level of job satisfaction also raised as low-skilled tasks are eliminated; Human labour are reported to have more time to do other important tasks; Less production halts due to emergency material shortage
- Improve levels of compliance, reduce the human errors: RPA software robot provides traceable records that can support further improvement in aligning the two systems; Robots are programmed act in accordance with one set of structured if-then rules so human errors depending on excel skill and method of sorting is eliminated; Out of standard working process is eliminated
- Data accuracy: Increased due to standardization however due to misalignment between the legacy system and the ERP system, data accuracy did not reach 100%
- Minimize costs in term of poor production adherence, loss of customer satisfaction, extra working hour's salary, etc.

Company 2 – Pharmaceutical company in Singapore

For this company, the material master data quality was suffering from multiple issues similar to those introduced in previous part. The material master maintenance process requires repetitive interactions with multiple systems and user interfaces. There are two repetitive processes in this managing SKU on SAP, which are: Go to material master of predecessor SKU and retrieve parameters and Setup successor SKU with predecessor SKU. While doing these repetitive activities, the apparent issues were missing product dimensions and weights. Recently, the problem went beyond just missing data. When making the fields mandatory entries, users provided fake data or mock up data, hence master data recorded a significant number of pharmaceutical products has the size of a pack of cigarettes. In addition, the meaning of different material status wasn't widely understood, which lead to either friction or emergency fixes. For example, materials could be set up without dimensions and weights and then used for forecasting and production planning. This resulted in claims and escalations to provide data that simply was neither available nor required yet. Missing data was then usually obtained outside the standard processes based on personal relationships and manual transfers. On the other hand, users who were aware of the required data sometimes forgot to return to the material master setup to update missing data which was only noticed when subsequent process steps couldn't proceed. Follow-up users frequently have to create support tickets to the key users to ask for clarification of master data. The general process steps were well understood, but when rare use cases required exceptional process steps, the majority of users didn't recall them. This issue is rampant in complex processes. When confronted with a choice to fulfil an order of life-saving products or to ensure 100% master data quality, users opted in favour of the patient. Then, over time, the process short cuts became the standard process. This led to missing data which will have to be resolved during later data correction efforts in order to ensure accurate master data for the production of life-saving products. In addition, due to the nature of a multi-national corporation the IT system landscape is made up of multiple systems and multiple releases which increase the demand of interfaces beyond the available resources of the IT Department.

The RPA solution started with the coding of the standard operating procedure into the RPA software robot. In practice, the affinity for innovation among a small team was sufficient to acquire the robot coding skills with online available training materials. This allowed a regional prioritization of robot needs. It also allowed for fast iterations in an agile development approach with the users as product owners to ensure any activities which aren't part of the standard operating procedure were considered (e.g. a local log book of material creations). Major effort was required to ensure the IT Department support over the acquisition of the RPA software, and to ensure the Accounting department control over compliance of the agreements between legal entities. The new process is showed in Figure 2 where RPA is used to automate some of the steps.

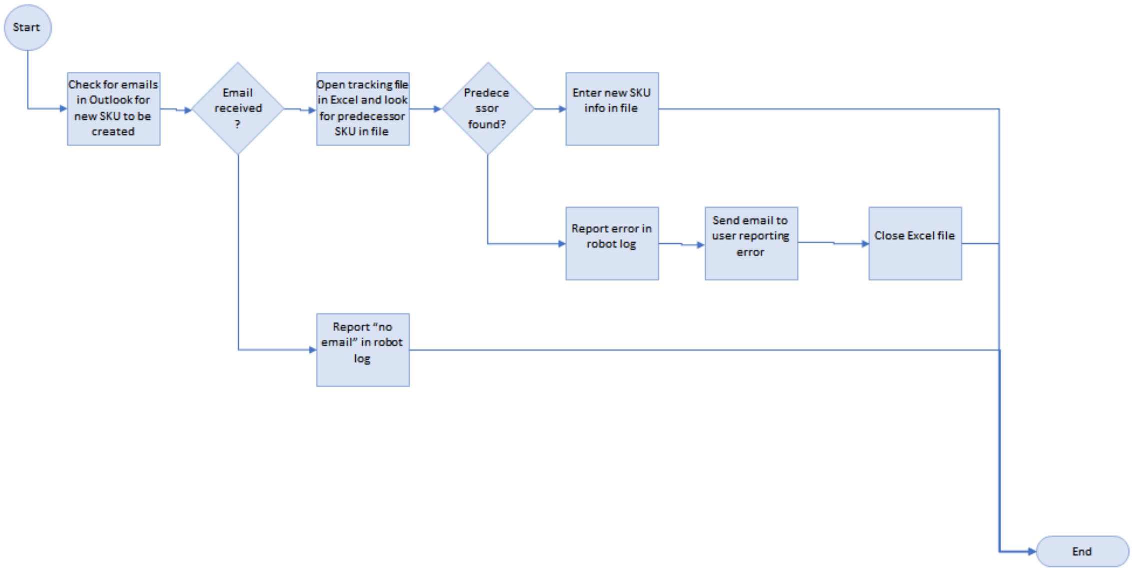


Fig. 2. Material master maintenance process after RPA implementation

As it turns out, system owners of legacy systems are generally favourable of RPA initiatives because they do not generate effort for the system owners but promise substantial benefits for the users. Process owners were found to be in favour due to the awareness of process adherence issues, the avoidance of process change and the avoidance of changes to user rights. Process adherence is guaranteed because the process steps are hardwired into the software robot. In addition, the standard process was not changed – it is well-defined however, the execution in real-life operations suffers due to lack of resources. Users rights of the robot are limited by the user credentials, so in case of any unforeseen errors, the user will be able resolve these with his/her authorizations. Data owners were supportive once the real-live environment of business processes is understood. In addition, they were a great source of parameter derivation rules. Data is often dependent on each other hence the robot was able to also check whether the combination of parameters were valid entries. In all, significant improvements were found in:

- Improved master data quality: SKU master data quality improves because the software robot is has highest process adherence (100%), and provides logs to trace back any issues; Master data becomes more consistent across multiple markets and systems because the standard operation procedure is the basis for coding
- Organizational efficiency: Productivity increased in each country supply chain due to reduced processing time and reduced peak workloads as the robot is able to work 24/7 and can reduce 80% of process duration; Single development can be transferred easily and modified to multiple systems within the same company
- Costs saving: Reduce peak workloads results in less work outside business hours; Costs of poor data quality are eliminated.

FINDINGS FROM THE TWO COMPANIES

In the first case, ABC Electronics Vietnam has applied RPA into their bill of material generation process and in the second case XYZ a pharmaceutical company based in Singapore has applied RPA into their material master maintenance process. As discussed by Rezazadeh and Carvalho [2017] prior to the implement of any innovation, it is crucial to conduct a value-base analysis in order to introduce the new technology in appropriate way. With the mean to assess the significance of RPA implementation in master data management related processes, the authors proposes a value positioning analysis. In the case of ABC Electronics, the volume of repetitive task is enormous because it deals with master data generation which contains hundreds of thousands of SKUs from out-of-warranty models to normal production models. Additionally, the task of updating material shortage for the repair production line is not only a time consuming repetitive task but it also occurs almost on a daily basis at the purchasing department given a fast moving nature associates with a mobile producer. Moreover, the repair service should not be delayed as it directly affects customer satisfaction. In other words, the outcome of the process has a significant value concerning customer satisfaction. Combining these characteristics, we can categorize the ABC case in the high volume, high value sector.

XYZ case however deals with the issue of implementing RPA in master data amendment process. This process is only triggered when there is a new set of data need to be updated on the ERP system. As literature review already addressed, HüNer, Otto and ÖSterle [2011] fundamental entities of master data tend to stay constant over the materials life-cycle, thus master data amendment process should be low in volume with regard to number of occurrences. The impact of ensuring this piece of master data however should be categorized significantly high. If master data is expose to human errors as mentioned in the case study discussion, it master data would gradually decreased in quality over time. As the master data's accuracy directly affects the quality, production and deliverable of many life-saving products, the act of ensuring 100% data entry adherence with additional logs to trace back using RPA is relatively of high value.

The results from both cases showed that the integration of RPA into the master data management process can bring about significant benefits as listed in Table 3.

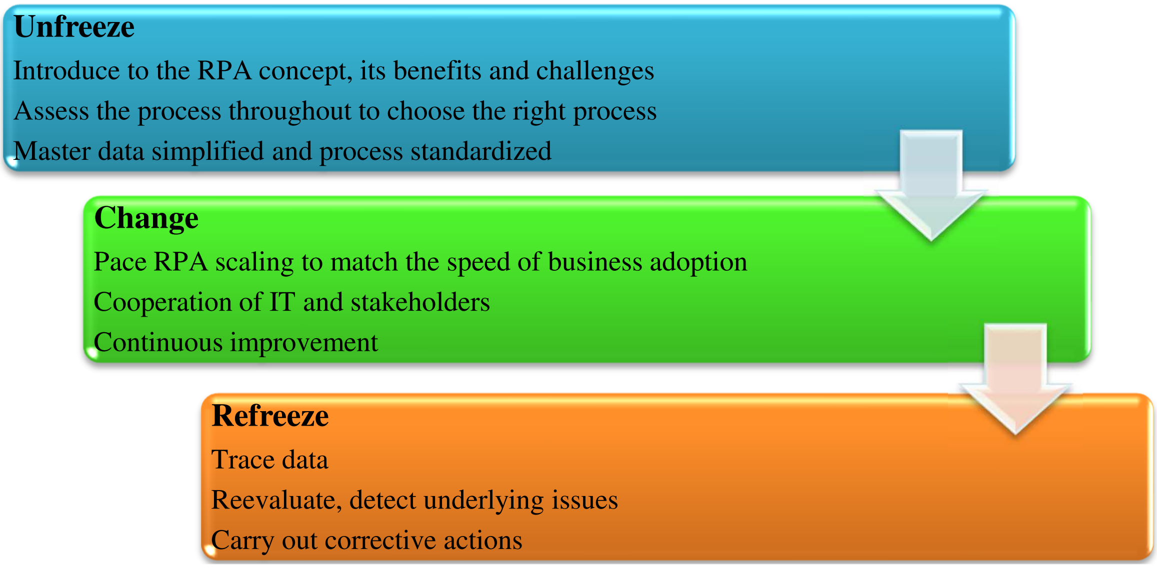
Table 3. Benefits of applying RPA in master data management in manufacturing industry

Benefits	ABC case	XYZ case
Improve master data quality	✔	✔
Reduce human errors	✔	✔
Reduce transactional time	✔	✔
Increase productivity	✔	✔
Free employees from repetitive tasks to focus on analysis tasks	✔	✔
Monetary benefit	✔	✔

In fact, this research has confirmed that integration of RPA software into master data management can create significant benefit to any size of master data as long as it is valuable to the performance of the organization. However each type of organization should have different problems arise when trying to introduce RPA into implementation. The XYZ company suggests that the master data process needs to be break into a really detailed level in order to construct a set of structured data to be automated at a suitable scale that fits the need of the organization. The ABC company, however, suggests that synchronization between separate systems and simplification of data prior to the implementation phase is crucial if the organization aims to achieve 100% adherence and data accuracy after using RPA. Besides, a clear introduction to the RPA concept, benefits and challenges would create better buy-in to the transition of the technology.

RECOMMENDATIONS

Based on the study from the 2 companies, the researchers have proposed the following framework in Figure 3 as the road map to RPA implementation taking into consideration the output of analyzed case studies.



Source: Lewin 1947

Fig. 3. RPA implementation roadmap

Figure 3 introduces a roadmap for RPA implementation with regard to master data process. The roadmap is elaborated from the Change management model developed by Lewin [1947]. At the initial stage, the organization should be in good preparation for the integration of the new technology. In this phase, it is most important to get buy-in to the adoption of RPA from stakeholders as it will be able to mitigate the challenge relates to lack of understanding discussed in the literature review section. Awareness and knowledge should be made available to stakeholders so that they will be able to fully understand the RPA concept and how it would empower the master data management process. Managers should involve in helping individuals see how RPA can profit their daily task, eliminate unnecessary manual effort and make their job simpler without limiting their career development. In addition to the fact that this builds certainty around the execution of RPA, it also mitigates the resistance within the organization. As literature pointed out, there are plenty of master data related transactions that can be automated. As the area of automation is defined, it is crucial to do master data normalization and process standardization. Because RPA is a program that can only work with structured data, this phase would help in reducing the potential noises and unstructured factors in the master data, which would then make the implementation smoother. Data simplify and process standardizes are also discussed to be vital in the successful outcome of RPA integration [Lacity, Willcocks 2016].

Next phase is when RPA is programmed and integrated into managing the designated master data process. Cooperation of IT and stakeholders are essential for better performance of automation. Following the advice given by IT and stakeholders after the implementation, the business should adjust the pace of RPA scaling to match the speed of business adoption.

Lastly, the refreeze phase will focus on ensuring the implementation is there to stay. Making use of the traceability characteristic of RPA, monitoring actions should be made to ensure continuous improvement. For instants, when operating, unstructured data should be identified, recorded, and reported to the system user. Further corrective actions should be carried out for better operational performance the following time.

CONCLUSION

Robotic process automation is an automation tool that organizations ought to have when trying to tackle repetitive, redundant and manual processes. With the aim to examine the benefits of RPA in master data management, the researchers have investigated 2 companies in the manufacturing industry to understand how they have benefited from RPA for item master data management processes. The method approached by the research was a qualitative method, utilizing interpretation of data attracted from literature and semi-constructed interviews. The result showed that RPA is affirmed to bring about many benefits for the organizations through structured automation. Applying RPA would lower processing time, human errors, and cost; increase productivity, compliance level, and data accuracy. The researchers have proposed a framework for implementing RPA to capture item master data based on the change management model [Lewin 1947], the framework is separated in 3 phase including important tasks in each phase. Overall, it stressed the importance of early preparation within the organization together with prior data simplification and process standardization in the success of implementing RPA in managing master data.

Due to the limited time frame, the researchers are not able to analyze the subjects in the study in a quantitative manner which might provide more accurate findings. As the study could only study two companies of the high-value proposition with regards to master data impact, future studies might consider testing the viability of the proposed framework in remaining sectors. Lastly, with the evolving of AI & machine learning technology, future researches might use this study as a stepping stone for further studies in cognitive RPA, utilizing cognitive technology in combination with RPA technology with the mean to achieve a higher level of automation.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This is part of a student master degree research project with minimum funding from the university.

REFERENCES

Aguirre, Santiago & Rodriguez, Alejandro. 2017. Automation of a Business Process Using Robotic Process Automation (RPA): A Case Study. 65-71. http://doi.org/10.1007/978-3-319-66963-2_7.

Anagnoste, Sorin. 2018. Setting Up a Robotic Process Automation Center of Excellence. Management Dynamics in the Knowledge Economy 6 (2): 307-322. http://doi.org/10.25019/MDKE/6.2.07.

Berson A., Dubov L., 2007. Master Data Management and Customer Data Integration for a Global Enterprise. McGraw Hill Professional. USA: NY.

Bloem J., van Doron M., Divesting S., Escoffier D., René M., van Ommeren E., 2014. The Fourth Industrial Revolution - Things to Tighten the Link Between IT and OT. https://www.fr.sogeti.com/globalassets/global/downloads/reports/vint-research-3-the-fourth-industrial-revolution

Cewe C., Koch D., Mertens R., 2018. Minimal Effort Requirements Engineering for Robotic Process Automation with Test Driven Development and Screen Recording. In: Teniente E.,

Friedman T., 2006. Gartner Study on Data Quality Shows That IT Still Bears the Burden,Gartner Research. Stamford, CT

Fung H.P., 2014. Criteria, use cases and effects of information technology process automation (ITPA). Advances in Robotics and Automation 3, (124). http://doi.org/10.4172/2168-9695.1000124

Anders H., Arlbjørn J.S., Pedersen A., 2009. A Classification Model of ERP System Data Quality. Industrial Management & Data

Systems109 (8): 1053-1068. http://doi.org/10.1108/02635570910991292

Anders H., Arlbjørn J.S., Zachariassen F., Schlichter J. 2013. Master Data Quality Barriers: An Empirical Investigation. Industrial Management & Data Systems 113 (2): 234-249. http://doi.org/10.1108/02635571311303550

Kedziora D., Kiviranta H-M., 2018. Digital business Value Creation with Robotic Process Automation (RPA) in Northern and Central Europe. Management 13 (2):161-174.

Knolmayer G.F., Röthlin M., 2006. Quality of Material Master Data and Its Effect on the Usefulness of Distributed ERP Systems. In: Roddick J.F. et al. (eds) Advances in Conceptual Modeling - Theory and Practice. Lecture Notes in Computer Science 4231. Springer:Berlin. http://doi.org/10.1007/11908883_43

Lacity M.C., Willcocks L.P., 2016. A new approach to automating services. MIT Sloan Management Review, Fall. ISSN 1532-9194.

Lewin K., 1947. "Frontiers in Group Dynamics: Concept, Method and Reality in Social Science; Social Equilibria and Social Change". Human Relations. 1: 5–41.

Loten A., 2019. AI Efforts at Large Companies May Be Hindered by Poor Quality Data, Retrieved from https://www.wsj.com/articles/ai-efforts-at-large-companies-may-be-hindered-by-poor-quality-data-11551741634

Madakam S., Rajesh M.H., Kumar J.D., 2019. The Future Digital Work Force: Robotic Process Automation (RPA). JISTEM - Journal of Information Systems and Technology Management, 16, e201916001. Epub January 10, 2019. http://doi.org/10.4301/s1807-1775201916001

Rajesh K.V.N., Ramesh K.V.N. Rao H.N., 2018. Robotic Process Automation: A Death knell to dead-end jobs? CSI Communications 42 (3):10-14

Shaywitz D., 2019, Novartis CEO Who Wanted to Bring Tech Into Pharma Now Explains Why It's So Hard, Retrieved from https://www.forbes.com/sites/davidshaywitz/2019/01/16/novartis-ceo-who-wanted-to-bring-tech-into-pharma-now-explains-why-its-so-hard/#54b1f46d7fc4 (last accessed, 24 Feb 2019) Robotic Process Automation;

Sibalija T., Jovanović St. Đurić S.J., 2019. Robotic process automation: overview and opportunities. International Journal – Advance Quality 46 (3)-(4).

Silvola R., Jaaskelainen O., Kropsu-Vehkapera H., Haapasalo H., 2011. Managing One Master Data - Challenges and Preconditions. Industrial Management & Data Systems 111 (1): 146-162. http://doi.org/10.1108/02635571111099776

van der Aalst, Wil M.P., Bichler M., Heinzl A., 2018. Robotic Process Automation, Business & Information Systems Engineering, 60, 4, 269-272.

Vilminko-Heikkinen R., Pekkola S., 2017. Master data management and its organizational implementation: An ethnographical study within the public sector. Journal of Enterprise Information Management 30 (3): 54-475.

Willcocks L., Lacity M., Craig A., 2015A. The IT function and Robotic Process Automation. The Outsourcing Unit Working Research Paper Series 15 (5): 1-39.

Willcocks L., Lacity M., Craig A., 2015B. Robotic Process Automation at Xchanging. The Outsourcing Unit Working Research Paper Series 15 (3):1-26.

Willcocks L., Lacity M., Craig A. 2017. Robotic Process Automation: Strategic Transformation Lever for Global Business Services? Journal of Information Technology Teaching Cases 7 (1) (05): 17-28. http://doi.org/10.1057/s41266-016-0016-9.

Zhang N., Liu B., 2019. Alignment of business in robotic process automation. International Journal of Crowd Science. http://doi.org/10.1108/IJCS-09-2018-001.

ZASTOSOWANIE AUTOMATYZACJI PROCESÓW (RPA) W UDOSKONALANIU PROCESÓW UTRZYMANIA DANYCH PODSTAWOWYCH

STRESZCZENIE. **Wstęp:** Firmy produkcyjne działają obecnie w warunkach coraz większej kompleksowości zarządzania swoim łańcuchem dostaw. Przepływ informacji wspomagający zarządzanie łańcuchem dostaw musi być coraz precyzyjniejszy oraz odbywać się w czasie rzeczywistym. Zarządzanie danymi podstawowymi nie jest tu żadnym wyjątkiem. Praca przedstawia potencjalne zalety zastosowania technologii automatyzacji procesów RPA w zarządzaniu danymi podstawowymi na podstawie dwóch firm produkcyjnych.

Metody: W pracy została zastosowana metoda jakościowa polegająca na interpretacji danych pochodzących z literatury fachowej oraz przeprowadzonych wywiadów.

Wyniki: Wysunięto propozycję zastosowania zasad RPA w procesie zarządzania danymi podstawowymi. Automatyzacja w połączeniu z oprogramowaniem robotów wpływa pozytywnie na pracę przedsiębiorstwa poprzez skrócenia czasu obróbki, redukcję błędów ludzkich, obniżenie kosztów operacyjnych, podniesienie wzajemnej zgodności danych oraz większej ich dokładności.

Wnioski: W celu określenia zalet zastosowania metody RPA w zarządzaniu danymi podstawowymi, zostały poddane analizie dwie firmy produkcyjne, które wdrożyły RPA w procesach zarządzania danymi podstawowymi. Otrzymane wyniki potwierdziły pozytywny wpływ wdrożenia automatyzacji. Zaproponowano model wdrożenia RPA oparty na modelu zarządzania zmianą i podzielony na trzy oddzielne etapy, z wyszczególnieniem zadań specyficznych dla każdego z tych etapów. Uzyskane wyniki mogą być zastosowane w dalszych pracach nad RPA.

Słowa kluczowe: automatyzacja procesów (RPA), zarządzanie danymi podstawowymi, produkcja, udoskonalanie procesów biznesowych, wzrost produktywności

Andreas M. Radke,
mSE Solutions Pte. Ltd., **Singapore**
e-mail: amradke.bvl@gmail.com

Minh Trang Dang,
Vinsmart.net, **Vietnam**
e-mail: v.trangdm5@vinsmart.net.vn

Albert Tan W. K.
Malaysia Institute for Supply Chain Innovation
No. 2A, Persiaran Tebar Layar, Seksyen U8
Bukit Jelutong, Shah Alam,
40150 Selangor, **Malaysia**
e-mail: albtan@mit.edu

LogForum
> Scientific Journal of Logistics <
2020, 16 (1), 141-159
http://doi.org/10.17270/J.LOG.2020.394
http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X
ORIGINAL PAPER

GREEN SUPPLY CHAIN PERFORMANCE AND ENVIRONMENTAL SUSTAINABILITY: A PANEL STUDY

Syed Abdul Rehman Khan[1], Yu Zhang[2], Solomon Nathaniel[3]
1) Singhua University, Beijing, **China**, 2) Chang'an University, Xi'an, **China**, 3) University of Lagos, Akoka, **Nigeria**

ABSTRACT. **Background:** The objective of this research is to identify the relationship between green logistics operations, national economic and environmental indicators in a panel of 42 selected global ranked logistics countries over the period from 2007 to 2018. The study aims to expand the domain of green logistics from the micro/firm level to the macro level.
Methods: This research paper has used a summary OLS (Ordinary Least Squares) method to test hypotheses. From 2007 to 2018, data panels for 42 countries were downloaded from the World Bank website.
Results: The findings of this study indicate that in selected panel countries, the green logistics business has a positive and statistically significant relationship with foreign direct investment inflows, renewable energy consumption, and energy demand. On the other hand, there is a significant negative correlation between CO_2 emissions and green logistics. In addition, foreign direct investment and renewable energy are the driving factors of the green logistics business and also promote environmental sustainability.
Conclusions: This research paper provides insights into the relationship between green logistics operations and economic and environmental sustainability. In addition, the scope of this research paper is much broader than previously published research papers, in which researchers discovered the relationship between green logistics and corporate performance. However, this research paper focuses on the macro level to understand the link between green logistics and national size indicators.

Key words: Green Supply chain management; Environmental sustainability; CO_2 emissions; Green logistics operations; Renewable energy sources

INTRODUCTION

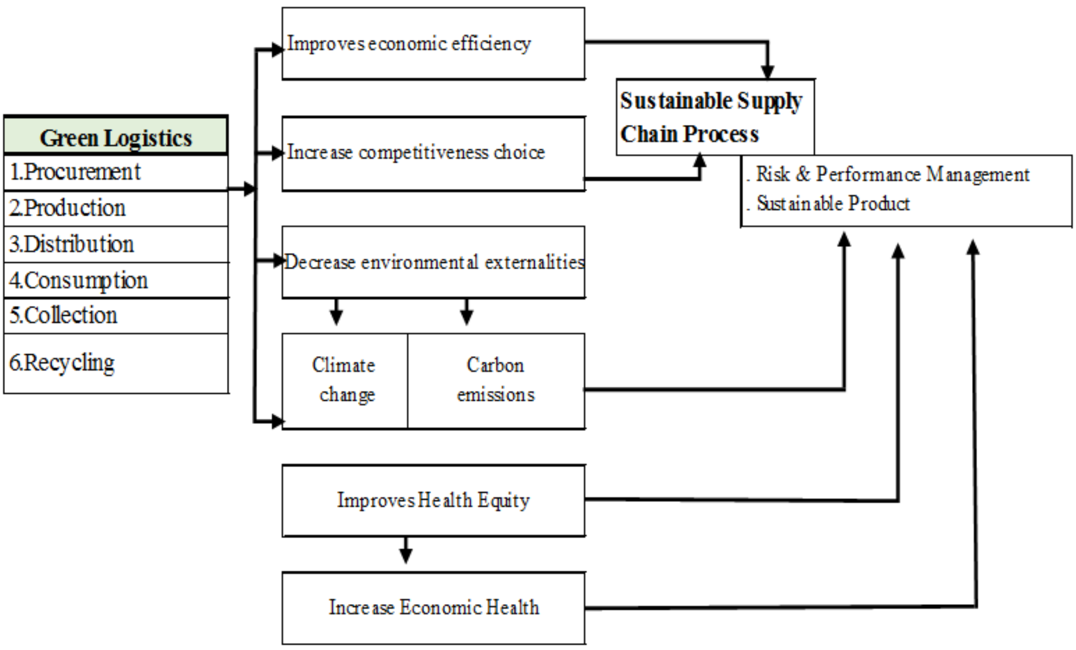
Logistics management is an integrated part of supply chain management. Global logistics activities can pose a significant threat to the environment in terms of GHG (greenhouse gases), CO_2 emissions, hazardous and toxic chemicals [Ai et al. 2015, Gruner, Power 2017]. The concept of green logistics management (GLM) is considered as an environmental innovation [Qureshi et al. 2016]. The primary objective of green logistics is to minimize the harmful effect of logistics and supply chain activities on the environment, mainly related to CO_2 emissions and greenhouse gas emissions and therefore build a sustainable balance between environmental, social and economic objectives [Dekker et al. 2012, Ceranic et al. 2017]. In the mid-1990s, the concept of green logistics management broadly realized by practitioners and industry experts. Undeniably, logistics activities are a significant contributor to environmental pollution, including greenhouse gas emissions, global warming, climate change, and CO_2 emissions. Khan et al. [2017] Conducted empirical work to analyze the relationship between green logistics and national economic indicators. The results revealed that manufacturing value-added and per capita income are affected by GHG and CO_2

Citation: Khan S.A.R., Zhang Y., Nathaniel S., 2020. Green Supply Chain Performance and Environmental Sustainability: A Panel Study. LogForum 16 (1), 141-159, http://doi.org/10.17270/J.LOG.2020.394
Received: 30.09.2019, Accepted: 08.11.2019, on-line: 30.12.2019.

emissions. Today's customers are more aware as compared to before regarding green products, and governmental authorities are more aggressive to implement green policies.

The European Commission EUROPA [2011 and 2017] report confirms that transport is the main cause of air pollution in terms of burning fossil fuels and energy. It is undeniable that nearly 10 million people are related to transportation-related industries, accounting for about 5% of total employment and contributing 4.6% of GDP. The main goal of the transport master plan adopted in 2016 and the subsequent railway reform is to provide a sustainable and stable roadmap for future investments. In European countries, the energy consumption of the transportation industry is decreasing, and the transportation energy intensity in 2014 and 2015 was 0.94 and 0.83, respectively. In the European country's 2020 strategy, Romania has performed well in renewable energy, national greenhouse gas emissions, and energy efficiency, while the renewable energy share was 24.7% in 2015. Romania has achieved the 2020 renewable energy target. On the other hand, Europe is firmly committed to economic decarbonization and the reduction of harmful emissions. European companies hold about 40% of global renewable energy technology patents [EUROPA 2017].

The concept of green logistics and transportation offers European countries the potential to gain a competitive advantage from competitors. Simão et al. [2016] confirmed that green logistics strategies can improve logistics performance while playing an important role in reducing carbon dioxide emissions from transportation activities. Vachon and Mao [2008] studied the green supply chain, and the results showed that the practice of green supply chain can not only improve the environmental performance but also improve the economic performance of enterprises. Zaman and Shamsuddin [2017] conducted a study on green logistics, and the results showed that logistics indicators are closely related to industry added value, energy prices and trade openness, which has inspired green supply chain management in the region.



Source: Zaman and Shamsuddin, 2017

Fig. 1. Relationship between green logistics, environmental and economic factors

Green logistics is an environmentally responsible concept that involves not only freight logistics [Abrams et al. In 2017, Chunguang et al. [2008], but also covers reverse logistics, including waste recycling, energy recycling, remanufacturing and landfills. Maritime [2016] investigated the impact of green management activities on customer satisfaction and long-term positioning. Researchers collected data from 214 companies and used structural equation modeling techniques to test the hypothesis. The results show that effective green practices can significantly increase customer satisfaction and promote repeat purchases. Zhu et al. [2008] The relationship between the adoption of GSCM (Green Supply Chain Management) practice and management support by Chinese enterprises was studied. They found that there was a significant positive correlation between management support and the approval of green practices after controlling for the effects of marketing, cost pressures, supplier and business size. The importance of green logistics across European countries is desirable for competing their goods in international markets and provides opportunities for green strategies that encourage improved economic and environmental performance in the region [Colicchia et al. 2017]. The relationship between green logistics and environmental, economic, and social factors can be explained using Figure 1.

In previous research, green logistics practices have been widely discussed at the company level. However, this research will provide a clear picture of green logistics at a macro level. In addition, this study will help discover the relationship between national economic indicators, including foreign direct investment (FDI), energy consumption, CO_2 emissions, greenhouse gas and renewable energy consumption, and green logistics performance. The rest of the research paper is structured as follows. Section 2 provides a literature review and assumptions. The third part discusses research methods. The fourth part discusses the analysis and results. The study concludes with a discussion of the results, policy analysis and conclusions.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

It is undeniable that green logistics is one of the key sub-components of green supply chain management because green supply chain management is the result of adopting different green practices, including green logistics, green manufacturing and green procurement [Zailani et al. 2012]. In the past few decades, green logistics has been affected by market competition, globalization and meeting customer needs [Isaksson et al. 2011]. The following sections provide detailed literature reviews.

The relationship between energy demand and green logistics

The relationship between energy demand and green logistics has been widely discussed in the supply chain and logistics management processes [Zhu et al .. 2008, Zaman et al. In 2017, Khan, Dong 2017, Zaman et al. 2016], and green practices in logistics activities require renewable energy to reduce carbon emissions, the negative impact of greenhouse gases and climate change on the environment, and promote the development of green products [Zaman et al. In 2016, Khan et al. 2018]. Anable et al [2012] argued that transport activities include longer Congestion during delivery consumes more energy for logistics activities. Iakovou et al. [2010] concluded that waste biomass is an appropriate solution to minimize dependence on fossil fuel energy. However, the cost of waste biomass utilization is a major burden on the company's financial statements for logistics activities. Mraihi and Abid [2013] believe that the relationship between economic activities and the energy used in transportation is one of the important relationships, and the energy use in the transportation sector should be fully studied.

The close connection between the logistics business and economic growth shows that the logistics and transportation sectors play a vital role in economic growth and transportation activities that are heavily dependent on fossil fuels and energy consumption [Khan et al. 2019]. In many European countries, including Germany, France, and the Netherlands, regulators have adopted strict environmental policies to stop pollution activities and encourage renewable energy and green logistics practices. Bhattacharya and others. [2016] The study found the impact of renewable energy consumption on economic growth. The results show that renewable energy consumption has a positive impact on economic and environmental performance. In addition, Bhattacharya et al. [2016] suggest that governments and international cooperation agencies must work together to promote the use of renewable energy and green logistics investment to achieve better environmental sustainability.

Limanond et al. [2011] studied the situation in Thailand. The research results show that the higher demand for energy in the transportation industry has a positive correlation with economic growth. Khan et al. [2016] emphasized that renewable energy and green practices can improve the financial performance of businesses. In addition, the use of renewable energy has not only improved the company's performance but also established a good market image and reputation. Li and Zhang [2016] believe that energy demand is an important contributor to the logistics industry, helping to save energy and ease energy pressure. Khan et al. [2017] conducted an empirical study, and the results confirmed that the logistics business consumes more electricity and more energy demand has led to increased value-added activities in the industry and increased economic performance of the country. Based on the above research, we propose the following hypotheses:

H1: The energy demand is positively associated with logistics performance

H2: Renewable energy consumption is positively correlated with green logistics performance

The relationship between economic growth and green logistics

Green logistics is closely related to economic growth because green logistics improve financial performance and eliminates waste by reducing costs. In addition, green processes, green product design, and green procurement management under supply chain and logistics management processes help companies adjust their economic performance [Min, Galle 1997, Zhang, Zhao 2012]. Zaman and Shamsuddin, [2017] conducted a study of 15 selected panel countries, and the results showed that green supply chain management can improve FDI inflows and reduce harmful effects on environmental sustainability. Hansen and Rand [2006] Foreign direct investment plays a vital role in healthier economic performance. The results confirm that foreign direct investment inflows have a positive and significant relationship with the country's economic growth. Bengoa and Sanchez-Robles [2003] studied 18 Latin American countries. They used panel data from 1970 to 1999, and the results showed that green supply chain operations have established a positive image for the country and attracted foreign investors. Khan et al. [2017] argued that the industry's manufacturing share of GDP was affected by CO_2 emissions and greenhouse gas emissions. Logistics performance encourages sector value-added and national economic growth.

On the other hand, the green logistics business has increased the inflow of foreign direct investment and the consumption of renewable energy [Khan et al. 2019]. Shahbaz et al. [2014] discovered a long-term relationship between air pollution, energy intensity and national economic growth in African countries. The research results show that energy has a positive correlation with carbon dioxide emissions, and the use of biofuels and renewable energy can improve environmental sustainability. In addition, biofuels and renewable energy are cheap compared to fossil fuels.

The increase in foreign direct investment has contributed significantly to China's economic growth [Wei et al., 2015]. The country is the world's second-largest recipient of foreign direct investment, which brings knowledge, capital and new management skills. Lu et al. [2010] conducted an empirical study to discover the relationship between green logistics performance and foreign direct investment (FDI) inflows. The results confirm that there is a positive correlation between sustainable logistics operations and increased foreign direct investment (FDI) inflows.

In addition, green logistics not only enhances and encourages renewable energy but also improves the economic performance of countries by increasing foreign direct investment and GDP per capita. Wanzala and

Zhihong [2016] inefficient and polluted logistics systems discourage investment and generate significant costs in end-to-end supply chain systems, such as higher import duties, expensive storage, and delays in customs clearance due to contaminated materials, Reduce exports and foreign direct investment inflows.

On the other hand, green logistics not only attracted foreign investors and more foreign direct investment inflows but also increased export opportunities and occupied new markets on the international stage. The literature cited above highlights the need for countries to establish sustainable green logistics systems to encourage green economies and transport policies to promote healthier foreign direct investment inflows. The study assumes:

H3: The green logistics performance is positively correlated with foreign direct investment

The relationship between environment and green logistics performance

Without proper policies for logistics operations, logistics and transportation activities will primarily impair environmental sustainability [Zaman, Shamsuddin 2017]. The flow of reverse logistics to environmentally friendly logistics will be minimized by reducing carbon emissions by implementing green supply chain processes and proposing measures, and by taking environmentally friendly steps in business and transportation activities to achieve "environmental sustainability". Implementation [Van-Hoek 1999]. Several studies were conducted to discover the correlation between environmental performance and logistics performance. Hayami and so on. [2015] believes that due to the dramatic increase in carbon dioxide emissions due to logistics and production activities, the government has failed to implement environmental protection policies to limit or reduce carbon emissions. Similarly, Boin, Kelle, and Whybark [2010] warn that we need to be prepared for ecological disasters due to the ever-increasing emissions of carbon dioxide and greenhouse gases. Wiebe, J. [2014] highlighted sustainability issues and explained that the main issue is not what people are doing. However, how they work, for example, if companies use renewable energy to produce products, they can not only save the environment but also reduce costs and improve logistics performance.

Nakamichi et al. [2016] estimate the total carbon emissions of each shipment, including transportation and production processes in Thailand. The findings show that placing manufacturing plants close to consumers can significantly reduce carbon dioxide emissions. The company uses global procurement as a competitive advantage, and because of the long delivery time and the long distance between customers/importers and suppliers, vehicles emit more carbon dioxide, which not only increases the considerable cost of the logistics system but also adversely affects. the effect on the environment. In short, carbon emissions are negatively related to logistics performance. Dangelico and Pontrandolfo [2013] confirmed that the company's financial performance is positively related to green practices and that CO2 emissions are not only negatively related to environmental performance but also negatively related to the company's financial performance. In addition, researchers believe that the use of renewable energy and better utilization of by-products may be the most appropriate options for reducing the cost of logistics systems and improving financial performance. Fang Yang [2016] emphasized that green practices in logistics and supply chain operations are positively related to business performance.

The main goal of adopting green practices in logistics operations is to reduce "footprint and CO2 emissions", but due to the implementation of environmental practices, companies may achieve higher financial performance [Esenduran et al. 2019, Aldakhil and others. 2018, Khan, Dong 2017, Khan et al. 2016]. Colicchia et al. [2016], the two companies have a better reputation, have established a good image with green practices, and have established environmental cooperation relationships with their supply chain partners. [Simão et al. [2016] Delay strategies can improve logistics performance and minimize carbon emissions from transportation activities by reducing total order delivery time. The findings of Hahn et al. [2010] show that many times, companies are under pressure from regulators and customers to adopt green practices or implement reverse logistics in their logistics systems, even if such green practices may have an impact on their financial goals It has a negative impact and is huge. Investment in green logistics systems and the cost of staff training may shrink the company's financial performance [Walley, Whitehead 1994]. However, in the long run, green investment is positively related to the environmental and financial performance of companies [Zhu et al. In 2008, Kenneth and others. 2012]. Zailani et al. [2012] claim that adopting environmentally friendly practices in logistics systems can improve company performance, while eco-designed products and practices can significantly reduce carbon dioxide and greenhouse gas emissions through the use of renewable energy.

The above-cited studies show that the need for green and environmentally friendly practices in logistics activities; therefore, it is desirable to reduce environmental concerns in logistics operations for healthier green logistics performance. The study hypothesizes that

H4: The environmental concerns in logistics operations are positively correlated with green logistics performance.

METHODOLOGY

The study found the relationship between green logistics operations, energy demand, environmental and economic factors in a group of 42 globally ranked logistics countries. There is no doubt that energy is a key factor for supporters of logistics operations and economic activities. On the other hand, in the absence of environmentally friendly practices, environmental and economic factors are negatively related to global logistics operations. The main purpose of this research is to link logistics operations with energy needs, environmental and economic factors. Table 1 shows the definition of the structure.

Table 1. Definition of Constructs

Constructs	Definitions
GLP (green logistics performance)	The logistics green practices have been adopted by the regulatory authority to reduce emissions, while GLP has been calculated by efficiency of customs clearance process to reduce carbon emissions, Quality of trade and transport-related infrastructure, and competence and quality of logistics services with minimum possible emissions.
FDI (foreign direct investment)	Foreign direct investment inflows is a leading indicator of handsome economic activities.
REC	REC is the renewable energy (% of total final energy consumptions) used and prompted by the government for protecting environment.
Energy	Energy is the energy consumption (Kg of oil equivalent per capita) in logistics operations.
CO2	CO2 is the carbon emissions (metric tons per capita) emits through logistics systems, which does harm to environmental sustainability.

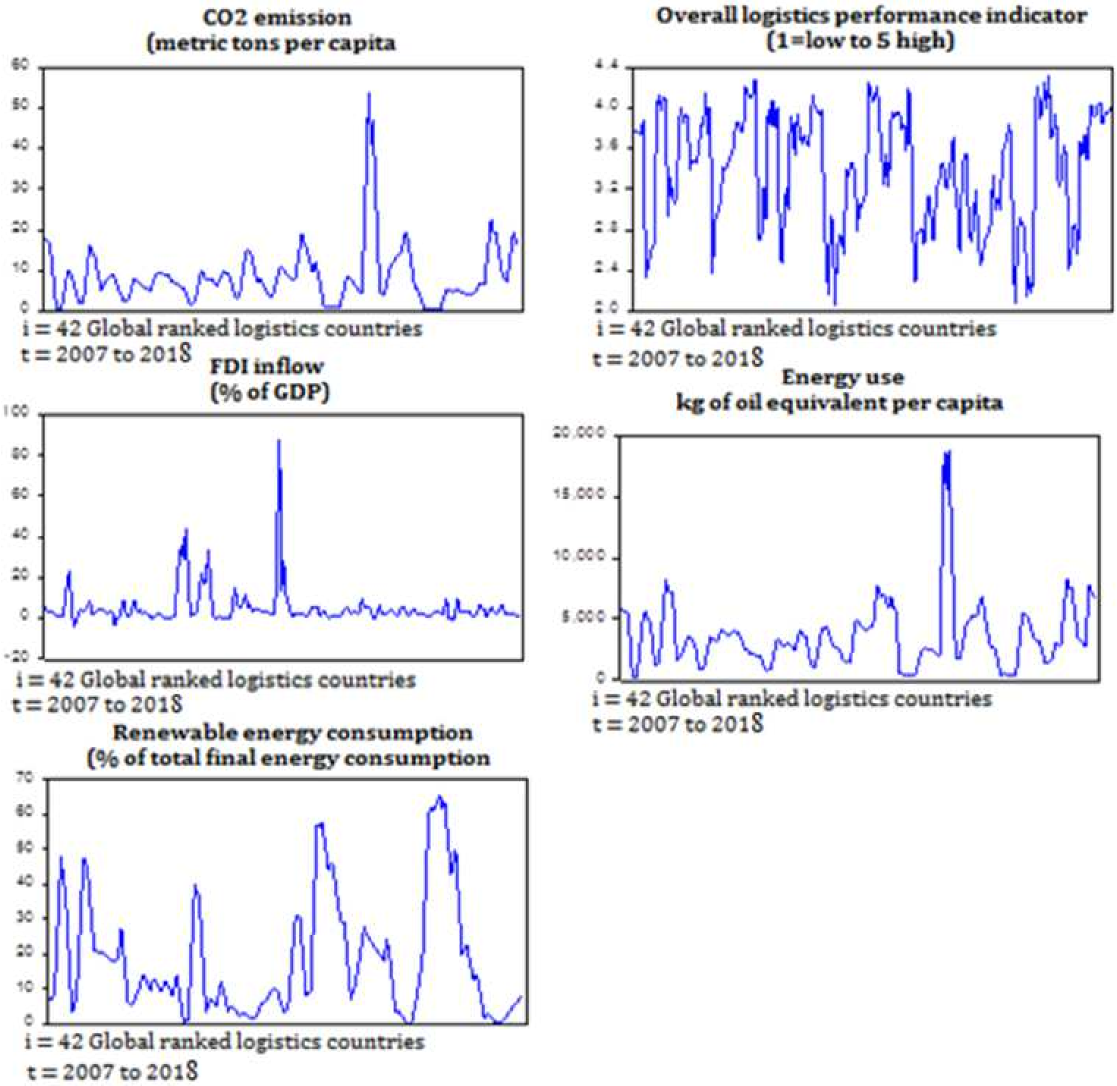
The equation given below will be used to estimate the factors green logistics under a panel of 42 selected global ranked logistics countries, i.e.,

$$GLP_{it} = \beta_0 + FDI_{it}\beta_F + CO2_{it}\beta_C + Energy_{it}\beta_E + REC_{it}\beta_R + \varepsilon_{it} \qquad (1)$$

where, GLP indicates overall green logistics performance; FDI indicates foreign direct investment net inflow; CO_2 shows the CO_2 carbon emissions metric tons per capita; Energy indicates GDP per unit of energy use; REC indicates the renewable energy consumption (% of total final energy consumption).

The primary objective of this research is to find the effect of explanatory variables (energy demand, foreign direct investment, renewable energy consumption, and CO_2 emissions) on logistics performance, so Pooled OLS (ordinary least square) estimator is used to test the research hypothesis. Pooled OLS is the most effective and suitable statistical method when data is stationary on level [Vachon, Mao 2008]. The research selected a panel of 42 countries namely, Australia (AUS), Belgium (BEL), Bangladesh (BGD), Brazil (BRA), China (CHN), Canada (CAN), Denmark (DNK), European Union (EUU), Egypt Arab Republic (EGY), France (FRA), Germany (DEU), Greece (GRC), Hong Kong (HKG), Ireland (IRL), Indonesia (IDN), Italy (ITA), Jordan (JOR), Japan (JPN), Kazakhstan (KAZ), Malaysia (MYS), Mexico (MEX), New Zealand (NZL), Netherlands (NLD), Norway (NOR), North America (NAC), Philippines (PHL), Portugal (PRT), Poland (POL), Pakistan (PAK), Qatar (QAT), Russian Federation (RUS), Sri Lanka (LKA), Saudi Arabia (SAU), Spain (ESP), Switzerland (CHE), Sweden (SWE), Sudan (SDN), Turkey (TUR), United Arab Emirates (ARE), Ukraine (UKR), United Kingdom (GBR), United States (USA) for the period of 2007 to 2016 for robust inferences. Figure 2 shows the plots of level data for ready reference.

The study used CO_2 emissions in metric tons per capita as an environmental factor; Energy demand variables include renewable energy use (REC) in the percentage of total energy consumption and GDP per unit of energy use (Energy), while foreign direct investment net inflow % of GDP use as an economic health indicator. The data has been downloaded directly from World Development Indicators, which is officially published by World Bank [2016].



Source: World Bank, 2016

Fig. 2. Graph of level data

ANALYSIS AND RESULTS

Table 2 lists descriptive statistics for endogenous and exogenous variables. The table shows that all selected variables have positive averages and have significant distribution peaks, indicating strong logistical support for 42 selected globally ranked logistics countries with healthier economic policies.

It is undeniable that higher positive averages of energy demand and CO_2 will harm environmental sustainability, and REC (Renewable Energy Consumption) can reduce the harmful effects of logistics operations. In addition, foreign direct investment inflows are attracted by green logistics operations and environmental protection policies implemented by regulators in various countries.

Table 2. Descriptive Statistics

	GLP	FDI inflow	Energy	CO2	REC
Mean	3.363691	5.562496	3330.214	7.753668	17.89986
Median	3.470000	3.040327	3062.361	7.240367	10.09366
Maximum	4.320000	87.44259	8343.109	22.56662	65.72482
Minimum	2.050000	-3.679174	173.5810	0.301083	0.008264
Std. Dev.	0.590638	9.789309	2121.857	5.202639	17.76116
Skewness	-0.418048	5.432041	0.509697	0.742526	1.196345
Kurtosis	2.028300	41.63141	2.422557	2.952168	3.325628

Table 3. Correlation Matrix

	GLP	FDI inflow	Energy	CO2	REC
GLP	1.000000				
FDI inflow	0.239731	1.000000			
Energy	0.571393	0.077207	1.000000		
CO2	0.420421	0.078731	0.811122	1.000000	
REC	0.276257	0.236142	-0.349946	-0.536392	1.000000

Table 3 gives the correlation matrix. It is found that environmental factors such as CO_2 emissions, energy demand, and renewable energy consumption are positively correlated with logistics performance indicators. The logistics business is an important factor in emissions and energy consumption, but the consumption of renewable energy is on the rise, and many developed and developing countries are transitioning to renewable energy.

Foreign direct investment (FDI) inflows are positively correlated with the logistics performance index. This means that inflows of foreign direct investment are attracted by environmental protection policies in business and logistics activities. Energy efficiency is positively related to FDI inflows and logistics performance. With the increase of renewable energy consumption and the reduction of carbon dioxide emissions, CO_2 emissions are negatively related to renewable energy consumption, which is a positive signal for a healthy and environmentally friendly logistics operation. Finally, foreign direct investment inflows are directly proportional to renewable energy, as REC (Renewable Energy Consumption) is the first step towards green production and logistics operations, and REC attracts foreign investors. It provides the opportunity to invest in a country, which is a positive signal for green logistics performance and economic health.

Before applying the combined OLS statistical method, we need to confirm that all endogenous and exogenous variables are stable at a level that meets the prerequisites of the combined OLS method. Table 4 shows the unit root test by considering three different standards, including the Levin, Lin & Chu test, ADF-Fisher test, and PP-Fisher test. The results of the unit root test confirm that all variables are stable at the level.

After fulfilling the essential parametric assumptions, OLS statistical method was used to determine: what is the magnitude of the relationship between endogenous (green logistics performance) and exogenous variables (FDI inflow, Energy, CO_2 emissions, and REC); and how much exogenous variables individually contribute to estimating green logistics performance. Table 5 shows hypothesis testing through the pooled OLS method.

Table 4. Unit root tests

Variables	Levin, Lin & Chu Test At level		ADF- Fisher Test At level		PP- Fisher Test At level	
	T-statistics	Prob.	T-statistics	Prob.	T-statistics	Prob.
GLP	-19.4131	0.0000	137.015	0.0001	215.51	0.0000
FDI inflow	-4.18247	0.0000	246.761	0.0000	285.08	0.0000
Energy	-6.09683	0.0000	181.213	0.0000	214.176	0.0000
CO2	-7.8911	0.0000	185.775	0.0000	216.141	0.0000
REC	3.45838	0.0315	71.7959	0.0431	84.0082	0.0324

Table 5. Hypotheses Testing for Green Logistics Performance

Hypothesis	Variable	Coefficient	Std. Error	t-Statistic	Prob.	Remarks
	(Constant)	3.101546	0.117147	26.47564	0.000	
H1	Energy	0.000374	0.000491	7.625093	0.000	Supported
H2	REC	0.009785	0.002943	3.325409	0.001	Supported
H3	FDI inflow	0.008634	0.004145	2.083032	0.039	Supported
H4	C02 emissions	-0.110549	0.022258	-4.966705	0.000	Supported

a. Dependent variable: Green logistics performance (F = 44.087, <0.001; Adjusted R = 59.6%)

The co-efficient of parameter estimates suggest the ‘Energy' (.00037, $p<0.01$), ‘REC' (.00975, $p<0.01$), ‘FDI inflow' (.0086, $p<0.05$) reflect a statistically significant and positive impact on green logistics performance. On the other hand, ‘CO_2 emissions' (-0.1105, $p < 0.01$) has indicated a significantly negative impact on green logistics performance. Therefore, our hypothesis (H1, H2, and H3) was accepted at the 0.01 confidence level, while hypothesis (H4) was accepted at the 0.05 confidence level, respectively. The results of pooled OLS analysis show that exogenous variables, including Energy, REC, and FDI inflow, have a statistically significant and positive relationship with green logistics performance, while CO_2 is negatively correlated with green logistics performance.

DISCUSSION

The research results show that energy is the most important and important factor. At a confidence level of 0.01, the driving force of logistics operation and energy is positively and significantly related to logistics performance. Similarly, Anable et al. [2012] and Shahbaz et al. [2014] also show that energy is the foundation of economic growth, economic activities are heavily dependent on logistics and supply chain operations, and energy has a significant negative impact on environmental sustainability It can be minimized by using renewable and green energy. Qureshi et al. [2016] conducted an empirical study, and the results showed that economic growth and energy demand have a strong relationship in developed countries in the world. On the other hand, which countries are suffering from energy shortages, their economic growth has been extended, and because of energy shortages, logistics and manufacturing cannot make a significant contribution to economic growth.

Energy demand shows positive signs of economic growth in developed countries, and reducing the impact of energy on sustainability, renewable energy, and clean energy is an appropriate choice to continue economic growth through logistics and supply chain operations. Bhattacharya and others. [2016] The results show that green energy is the best solution for green development. Without government support to promote clean technologies in logistics operations, green energy cannot be implemented. Zaman et al. [2016] A study of BRICS countries has shown that energy demand in developed countries is increasing. In the Chinese context, governments and regulators are working to improve their sustainable development image through the use of cleaner technologies, green and renewable energy [Zhu et al., 2008; Abdul et al., 2017]. In developed countries, renewable and green energy consumption is more flammable than in less developed countries, and one reason is that the government encourages governments and regulators in terms of tax exemptions and subsidies [Vance et al., 2015, Khan et al. 2019, Bhattacharya et al. , 2016, Bai, 2019, Abdul, Khan 2017]. Logistics operations and production activities are key factors for economic growth in any country, and countries using green logistics and sustainable logistics operations can reduce general energy consumption and increase operational efficiency by using green practices [Grekova et al. , 2014]. Research by Vance et al. [2015] confirms that the use of natural gas, renewable energy and green energy to generate electricity can significantly reduce costs by about 17%, and also plays an important decisive role in improving environmental sustainability and logistics operations effect.

Renewable energy plays an important role in implementing green practices, and REC (Renewable Energy) is the first step to achieving sustainable or green logistics business in the country. The results show that with a confidence level of 0.01, the performance of renewable energy and green logistics activities is positively correlated and significantly correlated. Parajuli et al. [2015] emphasized that biofuels can be part of green and clean energy, while countries engaged in biofuels and / or renewable green energy have healthier economic growth and improved sustainable logistics performance. Lee et al. [2015] conducted research and confirmed that the Chinese government and enterprises are working to adopt renewable energy to achieve a sustainable environment and healthier economic growth. On a similar track, Bhattacharya et al. [2016] A group study of 38 selected countries has shown that energy planners, governments and regulators should work together to encourage the use of renewable energy in production and logistics operations to achieve sustainable environmental growth.

Some developed countries are using 100% of clean energy procurement, including Denmark and Ireland, and their economic growth is more sustainable due to the higher performance of green logistics operations. In the energy sector and in the fight against climate change, the use of biofuels and jatropha oil is encouraging a viable alternative to fossil fuels [Jingura 2011]. The key advantage of biofuels is the reduction of greenhouse gas and carbon dioxide emissions. Compared to renewable energy systems, fossil fuels are expensive. Renewable energy provides locally available energy and also reduces the cost of buying fossil fuels. Renewable energy can not only deal with climate change but also improve the performance of green logistics [Zawaydeh 2017]. Abbasi and Nilsson [2016] explained that logistics activities have many negative effects on environmental sustainability. Because many countries still rely on non-renewable energy sources; severe adverse effects on climate change, air pollution, and people's health.

On the other hand, Abbasi and Nilsson [2016] insist that the use of green practices in logistics operations is inconclusive and that renewable energy is not used in production and logistics activities. The green development of logistics requires action to bring the greatest social and economic benefits without neglecting environmental issues. Egilmez and Park [2014] concluded that manufacturing and logistics are the main causes of air pollution, CO_2 emissions, greenhouse gases, and climate change, and these environmental issues can be addressed through green practices, such as the use of renewable energy. Zaman and Shamsuddin, [2017] The sustainable development of logistics business require renewable energy to reduce carbon dioxide emissions and improve PM 2.5 (fine particulate matter) air quality, and the green logistics business has also made a significant positive contribution to the country's economic development. increase.

Foreign direct investment inflows are a measure of healthier economic growth and business-friendly policies, while green practices in logistics and business activities have attracted foreign investors. In developed countries, FDI inflows are high due to environmentally friendly practices and strategies adopted by regulators. Our research shows that the inflow of foreign direct investment has a statistically positive correlation and significance with green logistics countries (confidence of 0.05). It is undeniable that carbon dioxide emissions, greenhouse gas emissions, and climate change have become global issues, and governments and business sectors are facing pressure from the international community, customers, and the United Nations (United Nations) to adopt green practices to reduce the harmful effects on the environment. Impact in manufacturing and logistics operations. Zaman and Shamsuddin, [2017] studied the performance of green logistics in European countries, and the results confirmed that foreign direct investment (FDI), industrial added value and energy have a positive and strong relationship with the generation of green logistics business. Wanzala and Zhihong [2016], non-green logistics systems have a negative correlation with national economic growth and are not conducive to foreign direct investment. In addition, unsustainable logistics will also incur heavy costs in the end-to-end supply chain, including heavy import duties and delays in customs clearance due to contaminated materials. On the other hand, the contaminated logistics system is also facing huge pressure from the government and customers, including severe punishment, bad reputation, and resistance to products from polluted enterprises [Khan, Qianli 2017].

Governments and regulators have implemented environmentally friendly policies to improve the country's image on the international stage, and in addition to pressure from local communities, they have also become incentives to adopt green practices in logistics systems [Taylor et al. 2014]. Zhao et al. [2008] conducted a study on the relationship between policy and green growth and found that environmental enforcement can be improved through vigorous enforcement by regulators. The main reasons for companies to participate in environmentally friendly policies include government policies, the degradation of the life-threatening global ecosystem, and pressure from customers [Li et al. 2016]. In addition, some monetary benefits also encourage companies to participate in green logistics operations, including improving their image and reputation in the international market, and reducing the cost of recycling, remanufacturing, and reusing technologies [Nurjanni et al., 2016]. HC's Chandan [2015] discusses how to build a company to focus its CS (Corporate Sustainability) work on environmental, social and financial aspects in line with the ten principles of the United Nations Global Compact in four key areas: the environment, Labor standards, anti-corruption, and human rights. The results confirm that green logistics business can reduce costs, increase pricing opportunities, and improve corporate image on the international stage. In addition, the government plays an important role in implementing environmental policies in promoting green practices in logistics and supply chain operations, and the adoption of higher green practices in logistics activities has not only attracted inflows of foreign direct investment [Pearson 2013, Forte Wait. 2017, Schaltegger, Synnestvedt 2002], but also provide more export opportunities for international markets [Abdul, Khan, 2017]. The company's sustainability provides a net present value benefit, but its marginal utility continues to decline until it reaches the optimal level of economic performance [Schaltegger, Wagner 2006, Park et al. 2016].

Higher CO_2 emissions and GHG (greenhouse gas) emissions are factors that represent poor environmental performance. The results show that in selected logistics countries with global confidence of 0.01, CO_2 emissions are significantly negatively correlated with green logistics performance. This result is also supported by other studies, including Dangelico and Pontrandolfo, [2013] confirming that the financial performance of enterprises is negatively correlated with higher CO_2 emissions and that larger amounts of CO_2 emissions not only impede the implementation of green logistics operations but Negative impact on the environment. The impact on the company's image and the considerable cost to the logistics system in terms of large consumption of fossil fuels, delays in customs clearance and heavy import duties due to contaminated materials. K. H. Lee and Wu [2014] Logistics activities are important factors that cause CO_2 emissions and greenhouse gases. In order to reduce the negative impact of logistics activities, companies need to use renewable energy in logistics activities to keep the environment clean and green. The Intergovernmental Panel on Climate Change (IPCC) confirmed that greenhouse gas emissions from industrial and logistics operations accounted for 21% and 14%, respectively [Wang et al. 2015]. Higher emissions are due to global logistics activities and longer lead times, and the harmful effects of carbon dioxide and greenhouse gases can be reduced by adopting green practices in logistics operations.

Similarly, Nakamichi et al. [2016] Long lead times between shippers and consignees result in higher CO_2 emissions. Further researchers suggest that placing manufacturing plants close to customers can reduce emissions while reducing the overall cost of the system and have a positive impact on environmental sustainability. CO_2 emissions and greenhouse gases are negatively related to ecological sustainability.

It is undeniable that many countries have failed to control pollution problems, undermining the country's environmental sustainability and economic growth [Nakamichi et al. 2016]. On the other hand, commercial activities and logistics activities have a strong positive relationship. If regulators fail to implement green practices in logistics operations, in other words, they will not be able to bring inflows of FDI and economic growth [Hayami et al. 2015]. Manufacturing and logistics activities are burning fossil fuels in large quantities and producing pollution, including nitrogen oxides, sulfur dioxide, volatile organic compounds and particulate matter [Silva, Zhu 2009, 2011]. The pollution spread to residential areas with storms and watercourses. It can cause serious health problems, including asthma attacks, weakened lung function, pneumonia, bronchitis, and various types of cancer. [Kawamoto 2008, Memon 2010]. Climate change is severely affected by global logistics activities and freight, as an increase in the number of vehicles means an increase in global greenhouse gas and carbon dioxide emissions, while the links between foreign direct investment, trade, and sustainable logistics activities have made economic profits and greatly increased Reduced carbon dioxide and greenhouse gas emissions. Adverse effects on the environment [Brooks 2008, Meyer et al. 2007]. Khan et al. [2017] A study of 15 globally ranked logistics countries shows that per capita income, manufacturing, and green logistics activities are severely affected by higher CO_2 and greenhouse gas emissions, while foreign direct investment (FDI) Inflows for regional sustainability [Zaman, Shamsuddin 2017, Khan et al. 2017]. In addition, the Causality Association has confirmed that more renewable energy demand will lead to higher performance of green logistics activities and positive economic growth in various countries. In addition, green logistics and supply chain operations have significantly improved energy efficiency, FDI inflows, sector and economic growth in selected countries [Khan et al. 2017].

CONCLUSIVE REMARKS

Long-term and sustainable logistics policies are needed to encourage green products to reduce the harmful effects of carbon dioxide and greenhouse gas emissions through environmentally friendly logistics practices. The key contribution of this research is to establish an environmentally friendly model that is highly consistent with the logistics operations and performance of 42 globally ranked logistics countries. The study used carbon dioxide emissions, FDI (foreign direct investment) inflows, energy demand, and renewable energy, all of which have logistics operations performance worldwide. In addition, the study found that inflows of foreign direct investment, renewable energy, and lower carbon dioxide emissions have had a positive impact on the green logistics operations of selected country groups. The study uses the collective least squares (OLS) (ordinary least squares) method to discover the impact of economic indicators on green logistics performance, and carbon dioxide emissions are negatively related to sustainable logistics performance. This problem can be solved by using renewable energy. To reduce the negative impact on environmental sustainability, FDI is also encouraged to flow into the country. These findings will help shape long-term green logistics policies to help conserve natural resources and address environmental issues, including higher carbon dioxide, greenhouse gas emissions, climate change, and global warming for a clean and green environment.

Green logistics operations performance measures the efficiency and commitment of countries to sustainable environmental and healthier economic development policies. In addition, the green logistics business also represents a healthy global financial competition for ecologically sustainable development. Government agencies can protect natural resources, reduce carbon emissions and control global warming and climate change. By adopting green initiatives in logistics and freight, this could severely disrupt natural flora and fauna around the world. A sound sustainable policy is a prerequisite for encouraging development. Green practices in global logistics operations and freight transportation will help achieve each country's sustainable growth agenda.

The study also has some limitations. For example, we only covered 42 globally ranked logistics countries from 2007 to 2016. However, future researchers may also conduct research in the EU, BRICS and SAARC countries to check whether this model has negative or positive effects. In this study, we only include exogenous variables (renewable energy, CO_2 emissions, foreign direct investment inflows, and energy demand) in the four countries' economies and the environment. However, future researchers may include more exogenous variables in the model, including industry value-added, manufacturing value-added, political stability, and research and development expenditure to study the relationship with green logistics performance.

POLICY ANALYSIS

The study confirms that energy demand, economic health, and environmental sustainability are closely related to environmentally friendly logistics operations in selected country groups. Studies show that green logistics performance improves energy efficiency, renewable energy consumption, economic growth, and foreign direct investment inflows while reducing carbon dioxide emissions, greenhouse gas emissions, and mitigating issues related to climate change. On the same track, renewable energy has an important and positive relationship with the green logistics business, attracting foreign investors and promoting economic growth. In short, the government needs to promote renewable energy in a country to promote environmentally friendly practices in logistics and manufacturing operations to increase economic growth and inflows of foreign direct investment.

Global logistics business consumes a lot of electricity, which is also an important factor causing CO_2 emissions, and a country's polluted environment will discourage foreign investors and create non-tariff barriers for local companies to export to the international market. On the other hand, the polluted logistics system still faces several problems, and it must bear heavy taxes in the entire logistics system. The government has imposed fines on domestic and foreign ports due to polluted logistics operations, a negative image of the company, and the country 's Negative Effects. The international community. The relationship between logistics indicators and economic and environmental sustainability clearly demonstrates that eco-friendly logistics operations will greatly improve renewable energy utilization and healthier economic activities, including improving foreign direct investment inflows into the region. Promote environmental sustainability.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research is supported by the fund of the Beijing Key Laboratory of Megaregions Sustainable Development Modelling, Capital University of Economics and Business (No. MCR2019QN09).

REFERENCES

Abbasi M., Nilsson F., 2016. Developing environmentally sustainable logistics. Exploring themes and challenges from a logistics service providers' perspective, Transportation Research Part D: Transport and Environment, 46(2), 273–283. http://doi.org/10.1016/j.trd.2016.04.004.

Abdul S., Khan R., 2017. Does national scale economic and environmental indicators spur logistics performance ? Evidence from the UK, Environmental Science and Pollution Research, 24(34), 26692-26705. http://doi.org/10.1007/s11356-017-0222-9.

Abdul S., Khan R., Qianli D., Zhang, Y., 2017. The Impact of Sustainable Supply Chain on Enterprise Performance : In the Perspective of China, Journal of Advanced Manufacturing Systems, 4(13), 134-175.

Abrams J., Becker D., Kudrna J., Moseley C., 2017. Does policy matter? The role of policy systems in forest bioenergy development in the United States, Forest Policy and Economics, 75, 41–48. http://doi.org/10.1016/j.forpol.2016.12.007

Ai T., Hon H., Sulaiman Z., 2015. Green Supply Chain Management, Environmental Collaboration, and Sustainability Performance, Procedia CIRP, 26, 695–699. http://doi.org/10.1016/j.procir.2014.07.035

Aldakhil A.M., Nassani A. A., Awan U., Abro M. M. Q., Zaman K., 2018. Determinants of green logistics in BRICS countries: An integrated supply chain model for green business. Journal of Cleaner Production, 195, 861-686. http://doi.org/10.1016/j.jclepro.2018.05.248

Anable J., Brand C., Tran M. Eyre N., 2012. Modelling transport energy demand: A socio-technical approach, Energy Policy, 41, 125-138.

Bai C., Kusi-Sarpong S., Ahmadi H.B., Sarkis J., 2019. Social sustainable supplier evaluation and selection: a group decision-support approach, International Journal of Production Research, http://doi.org/10.1080/00207543.2019.1574042

Bechtsis D., Tsolakis N., Vlachos D., Iakovou E., 2017. Sustainable supply chain management in the digitalization era: The impact of Automated Guided Vehicles, Journal of Cleaner Production, 142(35), 3970–3984. http://doi.org/10.1016/j.jclepro.2016.10.057

Bengoa M., Sanchez-Robles B., 2003. Foreign direct investment, economic freedom, and growth: new evidence from Latin America, European Journal of Political Economy, 19(3), 529-545.

Bhattacharya M., Paramati S. R., Ozturk I., Bhattacharya S., 2016. The effect of renewable energy consumption on economic growth: Evidence from top 38 countries, Applied Energy, 162(3), 733–741. http://doi.org/10.1016/j.apenergy.2015.10.104

Brooks C., 2008. Introductory Econometrics for Finance, 2nd ed., Cambridge University Press, New York.

Ceranic B., Markwell G., Dean A., 2017. Too Many Empty Homes, Too Many Homeless -A Novel Design and Procurement Framework for Transforming Empty Homes through Sustainable Solutions, Energy Procedia, 111(12), 558–567. http://doi.org/10.1016/j.egypro.2017.03.218

Chunguang Q., Xiaojuan C., Kexi W., Pan P., 2008. Research on green logistics and sustainable development. Proceedings of the International Conference on Information Management Proceedings of the International Conference on Information Management, Innovation Management and Industrial Engineering, ICIII 2008(3), 162–165. http://doi.org/10.1109/ICIII.2008.114

Colicchia C., Creazza A., Dallari F., 2017. Lean and green supply chain management through intermodal transport: insights from the fast moving consumer goods industry, Production Planning and Control, 28(4), 1–14. http://doi.org/10.1080/09537287.2017.1282642

Colicchia C., Creazza A., Dallari F., Melacini M., 2016. Eco-efficient supply chain networks: development of a design framework and application to a real case study, Production Planning and Control, 7287(11), 1–12. http://doi.org/10.1080/09537287.2015.1090030

Dangelico R. M., Pontrandolfo P., 2013. Being Green and Competitive: The Impact of Environmental Actions and Collaborations on Firm Performance, Business Strategy and the Environment, 24(13), 142-185, http://doi.org/10.1002/bse.1828

Dekker R., Bloemhof J., Mallidis I., 2012. Operations Research for green logistics – An overview of aspects, issues, contributions and challenges, European Journal of Operational Research, 219(3), 671–679. http://doi.org/10.1016/j.ejor.2011.11.010

Ding Z., Wang Y., Zou P. X. W., 2016, An agent based environmental impact assessment of building demolition waste management: Conventional versus green management, Journal of Cleaner Production, 133, 1136–1153. http://doi.org/10.1016/j.jclepro.2016.06.054

Egilmez G., Park Y.S., 2014. Transportation related carbon, energy and water footprint analysis of U.S. manufacturing: An eco-efficiency assessment, Transportation Research Part D: Transport and Environment, 32, 143–159. http://doi.org/10.1016/j.trd.2014.07.001.

Esenduran G., Atasu A., Luk N. Van W., 2019. Valuable e-waste: Implications for extended producer responsibility, IISE Transactions, http://doi.org/10.1080/24725854.2018.1515515.

Forte A., Zucaro A., Fagnano M., Fierro A., 2017. Potential environmental impact of bioethanol production chain from fiber sorghum to be used in passenger cars, Science of The Total Environment, 598, 365–376. http://doi.org/10.1016/j.scitotenv.2017.03.244

Golini R., Moretto A., Caniato F., Caridi M., Kalchschmidt M., 2017. Developing sustainability in the Italian meat supply chain: an empirical investigation, International Journal of Production Research, 55(4), 1183–1209. http://doi.org/10.1080/00207543.2016.1234724

Grekova K., Bremmers H. J., Trienekens J.H., Kemp R.G.M., Omta S.W.F., 2014. Extending environmental management beyond the firm boundaries: An empirical study of Dutch food and beverage firms, International Journal of Production Economics, 152, 174–187. http://doi.org/10.1016/j.ijpe.2013.12.019

Gruner R.L., Power D., 2017. Mimicking natural ecosystems to develop sustainable supply chains: A theory of socio-ecological intergradation, Journal of Cleaner Production, 149, 251–264. http://doi.org/10.1016/j.jclepro.2017.02.109

Hansen H., Rand J., 2006. On the causal links between FDI and growth in developing countries, World Economy, 29(1), 21–41. http://doi.org/10.1111/j.1467-9701.2006.00756.x

Hayami H., Nakamura M., Nakamura A.O., 2015. Economic performance and supply chains: The impact of upstream firms' waste output on downstream firms' performance in Japan, International Journal of Production Economics, 160, 47–65. http://doi.org/10.1016/j.ijpe.2014.09.012

Herold D.M., Lee K.-H., 2017. Carbon management in the logistics and transportation sector: an overview and new research directions, Carbon Management, 11(8), 1–19. http://doi.org/10.1080/17583004.2017.1283923

Isaksson O., Kossmann M., Bertoni M., Eres H., Monceaux A., Bertoni A., Wiseall S. Zhang X., 2013. Value-driven design - a methodology to link expectations to technical requirements in the extended enterprise, Proceedings of the 23rd Annual INCOSE International Symposium, Philadelphia, June 24 to 27 USA.

Jingura R.M., 2011. Technical options for optimization of production of Jatropha as a biofuel feedstock in arid and semi-arid areas of Zimbabwe, Biomass and Bioenergy, 35(5), 2127–2132. http://doi.org/10.1016/j.biombioe.2011.02.015

Kenneth W.G. Jr., Pamela J., Meacham J., Bhadauria V.S., 2012, Green supply chain management practices: impact on performance, Supply Chain Management: An International Journal, 17(3), 290-305.

Khademian A., Bagherpour R., 2017, Environmentally sustainable mining through proper selection of explosives in blasting operation, Environmental Earth Sciences, 76(4), 128-147. http://doi.org/10.1007/s12665-017-6483-2

Khan S.A.R., Qianli D., 2017. Impact of green supply chain management practices on firms' performance: an empirical study from the perspective of Pakistan, Environmental Science and Pollution Research, 13(2), 173-201. http://doi.org/10.1007/s11356017-9172-5

Khan S.A.R., Qianli D., SongBo W., Zaman K., Zhang Y., 2017. Environmental logistics performance indicators affecting per capita income and sectoral growth: evidence from a panel of selected global ranked logistics countries, Environmental Science and Pollution Research, 24(2), 1518–1531. http://doi.org/10.1007/s11356016-7916-2

Khan S.A.R., Dong Q., 2017a. Impact of green supply chain management practices on firms' performance: an empirical study from the perspective of Pakistan, Environmental Science and Pollution Research, 24(20), 16829-16844.

Khan S.A.R., Zhang Y., 2019a. Strategic Supply Chain Management, Springer International Publishing, Switzerland AG, ISBN 978-3-030-15058-7, http://doi.org/10.1007/978-3-030-15058-7.

Khan S.A.R., Dong Q. Yu Z., 2016. Research on the measuring performance of green supply chain management: in the perspective of China, Journal of Engineering Research in Africa, 27, 167-178.

Khan S.A.R., Dong Q., Zhang Y., 2016. Research on the measuring performance of green supply chain management: In the perspective of China, International Journal of Engineering Research in Africa, 27(12), 167-178.

Lanouar C., 2017. The impact of energy consumption and economic development on Ecological Footprint and CO_2 emissions: Evidence from a Markov Switching Equilibrium Correction Model, Energy Economics, 5, 134-150. http://doi.org/10.1016/j.eneco.2017.05.009

Lee A.H.I., Chen H.H., Chen S., 2015. Suitable organization forms for knowledge management to attain sustainable competitive advantage in the renewable energy industry, Energy, 89(21), 1057–1064. http://doi.org/10.1016/j.energy.2015.06.047

Lee K.H., Wu Y., 2014. Integrating sustainability performance measurement into logistics and supply networks: A multi-methodological approach, British Accounting Review, 46(4), 361–378. http://doi.org/10.1016/j.bar.2014.10.005

Li W.Y., Chow P.S., Choi T.M., Chan H.L., 2016. Supplier integration, green sustainability programs, and financial performance of fashion enterprises under global financial crisis, Journal of Cleaner Production, 135(15), 57–70. http://doi.org/10.1016/j.jclepro.2016.06.048

Lu Q., Cai S., Goh M., Souza R.De., 2010. Logistics Capability as a Factor in Foreign Direct Investment Location Choice, Proceedings of 2010 IEEE ICMIT, 163–168.

Mäkelä M., 2017. Forest Policy and Economics Environmental impacts and aspects in the forest industry : What kind of picture do corporate environmental reports provide ?, Forest Policy and Economics, 80, 178–191. http://doi.org/10.1016/j.forpol.2017.03.018

Maritime K., 2016. A study of the influence of sustainable management activities on customer satisfaction and long-term orientation in the shipping industry : evidence from users of Korean flagged shipping service, International Journal of Shipping and Transport Logistics, 8(1), 1–20.

Masoudipour E., Amirian H., Sahraeian R., 2017. A novel closed-loop supply chain based on the quality of returned products, Journal of Cleaner Production, 25, 138-159. http://doi.org/10.1016/j.jclepro.2017.03.067

Mohan N., Panda S., Sankar S., Basu M., 2017. ScienceDirect Corporate social responsibility , coordination and profit distribution in a dual-channel supply chain, Pacific Science Review, 16(14), 235–237.

Mraihi R., Abid M., 2013. Road transport-related energy consumption : Analysis of driving factors in Tunisia, Energy Policy, 62(13), 247–253. http://doi.org/10.1016/j.enpol.2013.07.007

Nakajima K., Nansai K., Matsubae K., Tomita M., Takayanagi W., Nagasaka T., 2017. Global land-use change hidden behind nickel consumption, Science of the Total Environment, 586, 730–737. http://doi.org/10.1016/j.scitotenv.2017.02.049

Nakamichi K., Hanaoka S., Kawahara Y., 2016. Estimation of cost and CO_2 emissions with a sustainable cross-border supply chain in the automobile industry: A case study of Thailand and neighboring countries, Transportation Research Part D: Transport and Environment 43, 158–168. http://doi.org/10.1016/j.trd.2015.12.018

Nurjanni K. P., Carvalho M. S., Costa L., 2016. Green supply chain design: a mathematical modelling approach based on a multi-objective optimization model, International Journal of Production Economics, 183, 421-432. http://doi.org/10.1016/j.ijpe.2016.08.028

Parajuli R., Dalgaard T., Jørgensen U., Adamsen A.P.S., Knudsen M.T., Birkved M., Gylling M., Schjørring J.K., 2015. Biorefining in the prevailing energy and materials crisis: A review of sustainable pathways for biorefinery value chains and sustainability assessment methodologies, Renewable and Sustainable Energy Reviews, 43, 244–263. http://doi.org/10.1016/j.rser.2014.11.041

Park D.H., Kashyap P., Visvanathan C., 2016. Comparative assessment of green supply chain management (GSCM) in drinking water service industry in Lao PDR, Thailand, and South Korea, Desalination and Water Treatment, 57(59), 28684–28697. http://doi.org/10.1080/19443994.2016.1194232

Qureshi R.N., Sheikh S., Khowaja A.R., Hoodbhoy Z., Zaidi S., Sawchuck D., Vidler M., Bhutta Z.A. Dadeslzen P.V., 2016. Health care-seeking behaviours in pregnancy in rural Sindh, Pakistan: a qualitative study, Reproductive Health, 13(34), 32-34, available at http://doi.org/10.1186/s12978-016-0140-1

Raza S.A., Shah N., Sharif A., 2019. Time-frequency relationship between energy consumption, economic growth, and environmental degradation in the United States: Evidence from transportation sector, Energy, http://doi.org/10.1016/j.energy.2019.01.077

Scur G., Barbosa M.E., 2017. Green supply chain management practices: Multiple case studies in the Brazilian home appliance industry, Journal of Cleaner Production, 141, 1293–1302. http://doi.org/10.1016/j.jclepro.2016.09.158

Shahbaz M., Salah Uddin G., Ur Rehman I., Imran K., 2014. Industrialization, electricity consumption and CO_2 emissions in Bangladesh, Renewable and Sustainable Energy Reviews, 31, 575-586.

Simão L.E., Gonçalves M.B., Taboada Rodriguez C.M., 2016. An approach to assess logistics and ecological supply chain performance using postponement strategies, Ecological Indicators, 63, 398–408. http://doi.org/10.1016/j.ecolind.2015.10.048

Taylor P., Ganapathy S.P., Natarajan J., Gunasekaran A., 2014. Influence of eco-innovation on Indian manufacturing sector sustainable performance, International Journal of Sustainable Development & World Ecology, 6, 37–41. http://doi.org/10.1080/13504509.2014.907832

Vance L., Heckl I., Bertok B., Cabezas H., Friedler F., 2015. Designing sustainable energy supply chains by the P-graph method for minimal cost, environmental burden, energy resources input, Journal of Cleaner Production, 94(3), 144–154. http://doi.org/10.1016/j.jclepro.2015.02.011

Walley N., Whitehead B.,1994. It's not easy being green, Harvardbusiness review, 72, 46-52.

Wang S., Song M., 2017. Influences of reverse outsourcing on green technological progress from the perspective of a global supply chain, Science of The Total Environment, 595, 201–208. http://doi.org/10.1016/j.scitotenv.2017.03.243

Wanzala W.G., Zhihong J. 2016. Integration of the extended gateway concept in Supply Chain disruptions Management in East Africa-Conceptual paper, International Journal of Engineering Research in Africa, 20, 235–247. http://doi.org/10.4028/www.scientific.net/JERA.20.235

Wei J., Lowry P. B., Seedorf S., 2015. The assimilation of RFID technology by Chinese companies: A technology diffusion perspective, Information and Management, 52(6), 628–642. http://doi.org/10.1016/j.im.2015.05.001.

World Bank. 2016. World bank indicators, available at https://data.worldbank.org/indicator (Accessed on June 2017).

Zailani S., Jeyaraman K., Vengadasan G., Premkumar R., 2012. Sustainable supply chain mangaement (SSCM) in Malaysisa: A survey, International Journal of Production Economics, 140(1), 330-340. http://doi.org/10.1016/j.ijpe.2012.02.008

Zaman K., Shamsuddin S. 2017. Green logistics and national scale economic indicators: Evidence from a panel of selected European countries, Journal of Cleaner Production. 143, 51–63. http://doi.org/10.1016/j.jclepro.2016.12.150

Zaman K., Khan A., Rusdi M., Adeline T., Tengku A., Hussain S., 2016. Dynamic linkages among energy consumption, environment , health and wealth in BRICS countries: Green growth key to sustainable development, Renewable and Sustainable Energy Reviews, 56, 1263–1271. http://doi.org/10.1016/j.rser.2015.12.010

Zawaydeh S., 2017. Economic, Environmental and Social Impacts of Developing Energy from Sustainable Resources in Jordan, Strategic Planning for Energy and the Environment, 36(3), 24–52. http://doi.org/10.1080/10485236.2017.11810169

Zhu Q., Sarkis J., Cordeiro J.J., Lai K.-H., 2008. Firm-level correlates of emergent green supply chain management practices in the Chinese context, Omega, 36(4), 577–591. http://doi.org/10.1016/j.omega.2006.11.009

ROZWÓJ ZRÓWNOWAŻONY W ZIELONYM ŁAŃCUCHU DOSTAW: STUDIUM PANELOWE

STRESZCZENIE. Wstęp: Celem pracy jest zidentyfikowanie zależności pomiędzy operacjami zielonej logistyki wskaźnikami ekonomicznymi i ekologicznymi w oparciu o panel 42 wybranych krajów z globalnego rankingu logistycznej w okresie od 2007 do 2018. Badanie to w szczególności rozszerza domenę zielonej logistyki z poziomu mikro czy poszczególnych przedsiębiorstw do skali makro.
Metody: W celu testowania hipotez zastosowano metodę OLS (najmniejszych kwadratów). Dane dotyczące wybranych 42 krajów zostały pobrane ze strony internetowej Banku Światowego dla okresu od 2007 do 2018.
Wyniki: Uzyskane wyniki pokazują statystycznie istotną i pozytywną współzależność z bezpośrednimi zagranicznymi inwestycjami, konsumpcją energii odnawialnej oraz popytem na energię w analizowanych krajach. Z drugiej strony emisja CO_2 oraz zielona logistyką są istotnie negatywne ze sobą skorelowane. Dodatkowo, FDI oraz źródła energii odnawialnej są kluczowymi czynnikami wspomagającymi operacje zielonej logistyki, która prowadzi do zrównoważonego rozwoju pod względem ekologicznym.

Wnioski: Prezentowana praca daje wgląd w zależności pomiędzy operacjami zielonej logistyki a ekonomicznym i ekologicznym rozwojem zrównoważonym. Dodatkowo, praca ta ma znacznie szerszy zakres niż wcześniejsze prace dotyczące tej tematyki, w których to zostały przedstawione zależności pomiędzy zieloną logistyką a działalnością firmy. Prezentowana praca skupia się ma poziomie makro w celu uchwycenia zależności pomiędzy zieloną logistyką a wskaźnikami na poziomie krajowym.

Słowa kluczowe: zarządzanie zielonym łańcuchem dostaw, rozwój zrównoważony, emisja CO_2, operacje zielonej logistyki, źródła energii odnawialnej

Syed Abdul Rehman Khan
School of Economics and Management
Singhua University, Beijing, **China**
e-mail: Khan_syed@sem.tsinghua.edu.cn

Yu Zhang
School of Economics and Management
Chang'an University, Xi'an, **China**
e-mail: Zhangyu19@foxmail.com

Solomon Nathaniel
University of Lagos, Akoka, **Nigeria**
e-mail: nathaniel_solomon21@yahoo.com

LogForum

> Scientific Journal of Logistics <

2020, 16 (1), 161-170

http://doi.org/10.17270/J.LOG.2020.389

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

THE NEXUS BETWEEN SUPPLIER QUALITY MANAGEMENT AND ORGANIZATION'S COMPETITIVE ADVANTAGE: AN EMPIRICAL EVIDENCE

Khairul Anuar Mohd. Ali

Universiti Kebangsaan Malaysia, Selangor, **Malaysia**

ABSTRACT. **Background:** Due to the increasing demand on product quality and operation efficiency, supplier quality management has become increasingly important in supporting organizations to achieve the desired excellence. With the rapid globalization happening in these few decades, the business world is experiencing a higher complexity phase. However, there are only a limited number of studies that has been conducted on supplier quality management (SQM) and organization's competitive advantage (OCA) in the context of multinational corporations (MNC). The purpose of this study is to identify critical elements in supplier quality management as well as testing the significance of supplier quality management in affecting organization's competitive advantage.

Methods: This study employed self-administered questionnaire that has been distributed to 355 respondents and the data is analyzed using Statistical Program for the Social Science (SPSS) software version 23. The population of study is concentrated on multinational corporations in Malaysia.

Results: The results revealed that 5 elements have been identified as critical elements for supplier quality management namely Tracking of Cost of Supplier Quality, Supplier Audit, Supplier Scorecard, Close Loop Corrective Action and Engagement of Suppliers in Quality System.

Conclusions: The findings of the study show that supplier quality management is found to be significantly affecting organization's competitive advantage in positive direction. The managerial implications of this study have been discussed as well.

Key words: Quality management, Supplier, Operation, Efficiency, Competitive advantage.

INTRODUCTION

Supplier quality management (SQM) is a set of activities initiated by the organization especially by the management in order to improve organizational performance. SQM normally involves activities such as measuring and tracking the cost of supplier quality, using performance based score cards to measure supplier performance, conducting supplier audits and establishing effective communication channels with suppliers among many more, with an aim of achieving customer satisfaction [Sharma, Modgil 2019, Carr, Pearson 1999]. Suppliers can be one of the sources of additional cost incurred if they are not performing well. Supplier's poor quality could possibly contribute to part of the production or service yield loss either directly or indirectly [Hong et al. 2019, Al-Shboul, Garza-Reyes, Kumar, 2018]. No doubt, organizations spend a substantial portion of their capital for the purchasing of raw materials, components, and services. In fact, 60% of cost goods sold is consisted of purchased goods [Dale 2002]. Thus, supplier quality is playing a vital role in controlling product or service cost as it can substantially give an impactful effect. Along with the increase of globalization in business world, supplier chain for organization is becoming

Citation: *Ali K.A.M., 2020. The nexus between supplier quality management and organization's competitive advantage: an empirical evidence. LogForum 16 (1), 161-170, http://doi.org/10.17270/J.LOG.2020.389*

Received: 25.09.2019, Accepted: 28.11.2019, on-line: 30.12.2019.

increasingly long and complicated, especially more and more organizations are outsourcing part of their production to strategic partners. In addition, many manufacturers are trying to streamline their production and practising lean inventory. Thus, they tend to face stock-out problem easily if suppliers are having quality trouble, which causing delay in delivery. Many scholars have stressed on the importance of supplier management. In fact, Supplier Chain Management (SCM) has come into the picture in early 1980s to suggest a series of activities to be coordinated by an organization as to procure and manage suppliers effectively [Oliver, Webber 1982]. In recent decades, competition in business world is becoming stronger and stronger with a big amount of suppliers competing with each other not only in term of cost, but also quality and delivery performance. Organizations understood a fact that the lowest acquisition cost does not necessarily result in the lowest product or service cost, as poor supplier quality may lead to higher product or service cost finally [Lo et al. 2018]. This is because poor supplier quality is potentially increases internal or external failure costs, which might provoke customer dissatisfaction as well as result an increment of customer complaint or warranty issue [Hong et al. 2019].

SCM is becoming an important element in determining sustainability of an organization. For a company to continue survive, it has to consider SCM that engage everyone within its organization as well as its supplier in sharing the same vision on the product, production and quality improvement. SCM is not only a sole procurement activity but it should rather be considered as a strategy with the purpose of achieving enduring beneficial buyer–supplier relationships [Carr, Pearson 1999]. Quality collaboration and reconciliation capacity is characterized as a company's coordination capacity to accomplish intuitive quality participation among its supply chain partners [Wu et al. 2006].

As part of SCM, SQM is considerably an important factor that an organization should be focusing to avoid potential damages that could bring down the organization's performance [Mandeep, Kanwarpreet, Doordarshi 2019]. Suppliers' non-conformance could invite serious fatal to an organization such as huge loss cost, product recall, tarnish of organization image or most serious loss of life. A good example that we can see, the massive recall involving 100 million vehicles worldwide by major car manufacturers such as Honda, Toyota, Ford, Mazda, BMW and so on due to the problematic airbags supplied by Takata, world largest airbag supplier [David 2016]. This failure has caused huge recall and replacement cost especially to Takata's major customer, Honda and most importantly, this problematic product has caused 11 death and 150 injuries, with some cases under review [David 2016]. Thus, this is why SQM is important for a reputable organization.

Similar to SCM, SQM is viewed as an integration of activities stretching across inter-organizational boundaries in order to achieve customer satisfaction [Yu, Huo 2018]. SQM is a managerial effort to create an operating environment in which organization is trying to integrate its suppliers' capability into its operational processes. The activities integrated are involving management responsibility, selection of supplier, supplier development, supplier quality measurement, supplier integration and supplier audits.

PROBLEM STATEMENTS

Although there are empirical studies discussed the impact of SQM to procurement performance [Famiyeh, Kwarteng 2018]. However, there are only a limited number of studies that has been conducted on supplier quality management and organization's competitive advantage in the context of multinational corporations in Malaysia [Ismail, Yunan 2016, Punnakitikashem et al. 2010]. To what extent SQM affects organization's competitive advantage; it is yet to be identified. Therefore, this study is to fill up the gap by identifying the effect of SQM on organization's competitive advantage especially in the context of multinational corporations (MNC) in Malaysia. Majority of the companies in Malaysia is concentrated in Klang Valley, thus the outcome of this research is expected to be able to be generalized as the current condition happening in the MNC in Malaysia.

Research Objectives

The objectives of this research are to identify the critical elements that result toward effective supplier quality management and to examine the impact of supplier quality management on organization's competitive advantage.

Research Questions

Based on objectives mentioned above, the research questions will be addressed on answering, what are the critical elements in Supplier Quality Management(SQM) for Multi National Cooperations (MNC) in Malaysia? Furthermore, does SQM give significant impact to organization's competitive advantage for MNC in Malaysia?

CONCEPTUAL FRAMEWORK

This research paper explores the relationships between supplier quality management and organization's competitive advantage in the context of multinational corporations in Malaysia. The modified model shown in Figure 1 below is established based on related factors and outcomes identified particularly related to supplier quality management aspect. In the proposed conceptual framework, "Supplier Quality Management" defined by 5 sub-dimensions is the independent variable identified, the dependent variable is Organization's Competitive Advantage.

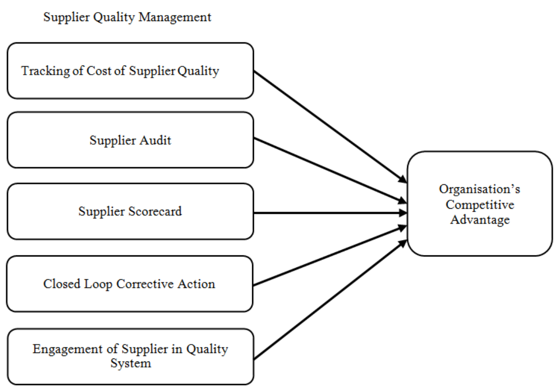


Fig. 1. Airports' strategic groups according to type and number of passengers

The sub-dimensions established for supplier quality management are actually based on the review of literature and theoretical background research done earlier [Projogo, McDermott, Goh, 2008, Rahman, 2006, Punnakitikashem et al. 2010, Dellana, Kros, 2014, Switala, Niestroj, Hanus, 2018, Ferdousi et al. 2018, Hong et al. 2019]. Those dimensions are identified to be related to practices that are applied for the purpose of supplier quality management. The five sub-dimensions have been established to define supplier quality management:

1. Tracking of Cost of Supplier Quality is about tracing and recording of loss or failure cost incurred due to problem originated by supplier.
2. Supplier Audit is a practice that is used to check and validate supplier's operation is in accordance to the requirements specified.
3. Supplier Scorecard is about measurement of supplier's performance based on key areas that define supplier's performance.
4. Close Loop Corrective Action is a PDCA (Plan-Do-Check-Action) based action used to manage supplier's counter measure against issues that arise.
5. Engagement of Supplier in Quality System is about involvement of supplier as part of the participant in the organization's quality management system so that organization's requirements and expectations can be communicated either directly or indirectly to supplier in a more effective way.

HYPOTHESIS

In order to obtain better understanding on the relationships between supplier quality management and organizational competitive advantage, these hypotheses are to be tested:

H1: Tracking of Cost of Supplier Quality is positively related to Organization's Competitive Advantage.

H2: Supplier Audit is positively related to Organization's Competitive Advantage.

H3: Supplier Scorecard is positively related to Organization's Competitive Advantage.

H4: Close Loop Corrective Action is positively related to Organization's Competitive Advantage.

H5: Engagement of Supplier in Quality System is positively related to Organization's Competitive Advantage.

METHODOLOGY

As the previous section has explained about the review of literature, related theoretical background and proposed conceptual framework with hypotheses intended to be tested. This part will explain the methodology used for this research including development of measurement for variables, sample and data collection as well as the data analysis method.

Development of Measurement For Variables

Definition of Variables - To achieve the objectives of this research, all the variables or dimensions proposed in conceptual framework need to be tested. A measurement scale would need to be developed to define the variables, so that the variables can be measured tangibly. From the review of relevant literatures and theories, the measurement items have been established to define each sub-dimension of independent variable (Supplier Quality Management) and dependent variable (Organization's Competitive Advantage).

Construction of Questionnaire and Pretesting - A structured questionnaire has been developed as an instrument for data collection. The self-administered questionnaire consists of 3 parts namely the organization's demographics, the general questions and research questions that developed from items defined in Table 1. Research questions are measured using seven-point Likert-type scale (ranging from 1= strongly disagree to 7= strongly agree).

Table 1. List of constructs and measurement items

Construct	Indicator	Details
Tracking of Cost of Supplier Quality	COQ1	Calculate and trace cost of poor quality
	COQ2	Monitor disruption caused by supplier quality problems
	COQ3	Additional freight cost for shipment expedition
	COQ4	Accountability of supplier for cost of poor quality
	COQ5	Cost of poor quality in supplier's assessment
Supplier Audit	SA1	Major suppliers are audited periodically
	SA2	Qualification audit is compulsory for new supplier
	SA3	Standard criteria for supplier audit
	SA4	Follow-up of suppliers in ranking
	SA5	Effectiveness of supplier audit
Supplier Scorecard	SSC1	Systemized scorecard procedure
	SSC2	Suppliers are ranked
	SSC3	Concern of suppliers in ranking
	SSC4	Supplier scorecard role for procurement negotiation
	SSC5	Supplier scorecard stimulates supplier's improvement
Closed Loop Corrective Action	CA1	Supplier's problem root cause investigation
	CA2	Reporting of corrective and preventive actions
	CA3	Review of supplier's report
	CA4	Tracing of actions implementations
	CA5	Effectiveness of close loop corrective action
Engagement of Supplier in Quality System	SE1	Supplier as part of quality system (QS)
	SE2	QS information is provided to supplier
	SE3	Suppliers are required to be accredited
	SE4	Develop supplier to comply with QS requirement
	SE5	Suppliers competency in fulfilling QS requirement
Organisation's Competitive Advantage	CADV1	Product cost
	CADV2	Competitive pricing
	CADV3	Competitive quality
	CADV4	Brand identity
	CADV5	Customer's perception

SAMPLE AND DATA COLLECTION

The Population and Sampling

The population of this research consists of multinational corporations in Malaysia. According to Suruhanjaya Syarikat Malaysia (2018)6, there are total 4,727 multinational corporations registered in Malaysia as of 31st December 2017. Majority of businesses in Malaysia are concentrated in Peninsular Malaysia, thus, estimated population size for this research would be approximately 4,700 companies. So based on Krejcie and Morgan (1970) table, the sample size should be n = 355.

Data Collection

Self-administered structured questionnaire is used for data collection. In total 362 responses received in return, 38 responded in printed copies (10.5% response rate), the rest are collected through electronic media (Google Form is used in this case). Overall response rate is unable to be calculated as the impact of social media spreading unable to be estimated. From all the 362 responses obtained, 7 were voided due to incompletion or inappropriateness in answering the questions. Finally, a total number of 355 responses were utilized for data analysis.

DATA ANALYSIS METHOD

After reviewed all data collected, the data from all the 355 valid responses were key-in into SPSS software for data analysis purpose. Meantime, the demographics and practices for quality management of respondents are being analyzed as well. All the statistical analysis was performed based on 95% confidence level. Two main analyses were employed in analyzing all data obtained: Descriptive Analysis for discrete measures by using one way ANOVA test and inferential analysis to examine the relationship suggested in proposed conceptual framework using regression.

RESULTS AND DISCUSSION

The significance of the relationship of supplier quality management (SQM) is tested using multiple regression (linear regression) ran on all the sub-dimensions defining SQM against organization's competitive advantage. Independent variables are Tracking of Cost of Supplier Quality (COQ), Supplier Audit (SA), Supplier Scorecard (SSC), Close Loop Corrective Action (CA) and Engagement of Supplier in Quality System (SE), while dependent variable is Organization's Competitive Advantage (CADV). Table 2 and Table 3 show the SPSS output of the mentioned regression.

Table 2. SPSS output on regression of SQM versus organization's competitive advantage, ANOVA

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	27.519	5	5.504	30.537	.000
	Residual	63.080	350	.180		
	Total	90.599	355			

a. Dependent Variable: MEAN_CADV
b. Predictors: (Constant), MEAN_SE, MEAN_SA, MEAN_COQ, MEAN_CA, MEAN_SSC

Table 3. SPSS output on regression of each sub-dimension versus organization's competitive advantage

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.363	.310		4.393	.000
	MEAN_COQ	.106	.049	.132	2.192	.029
	MEAN_SA	.116	.049	.125	2.357	.019
	MEAN_SSC	.202	.062	.198	3.267	.001
	MEAN_CA	.170	.065	.153	2.602	.010
	MEAN_SE	.112	.049	.117	2.311	.021

The relationship between variables is judged as significant if the significance value, $p < 0.05$. From Table 2, we may conclude from the regression result that SQM is having significant impact on organization's competitive advantage and the overall significance value, p is approximately 0 ($p < 0.05$). Further showed in Table 3, the significance value of each sub-dimension on organization's competitive advantage is showing value of $p < 0.05$ as well (ranging from 0.001 to 0.029). Thus, each sub-dimension defining SQM is having significant impact on organization's competitive advantage.

SUMMARY OF INFERENTIAL ANALYSIS

The purpose of the statistical analysis performed is to test the suggested hypotheses. The outcome of the analysis is summarized in Table 4.

Table 4. Summary of Inferential Analysis

Hypothesis	Correlation, R	Significant, p	Decision
H1: Tracking of Cost of Supplier Quality is positively related to Organization's Competitive Advantage.	+ 0.434	0.029	Accept
H2: Supplier Audit is positively related to Organization's Competitive Advantage.	+ 0.381	0.019	Accept
H3: Supplier Scorecard is positively related to Organization's Competitive Advantage.	+ 0.463	0.001	Accept
H4: Close Loop Corrective Action is positively related to Organization's Competitive Advantage.	+ 0.437	0.010	Accept
H5: Engagement of Supplier in Quality System is positively related to Organization's Competitive Advantage.	+ 0.345	0.021	Accept

Note: Relationship is significant $p < 0.05$

DISCUSSION

The objectives of this study were to answer two research questions stated earlier. Based on the data analysis, the outcomes would to be discussed to examine if the questions are able to be answered.

The first research question, what are the critical elements in supplier quality management (SQM) for MNC in Malaysia? SQM is actually a broad subject to be studied. There are many researches done by researchers intended to define the best practices for SQM [Al-Shboul, Garza-Reyes, Kumar, 2018] . As many organizations have realized the importance of supplier's quality in affecting the organizations' day to day operations, the necessity to manage supplier's quality is no longer an option but a must [Ferdousi et al. 2018] . SQM is about the act overseeing all suppliers' activities to ensure supplied parts achieve certain level of desired excellence. This would involve tracing and monitoring of suppliers' quality performance, checking and controlling their operations and finally developing them towards excellence. To define SQM practices, 5 sub-dimensions have been proposed to cater the three acts:

1. Tracking of Cost of Supplier Quality (COQ) – Tracing & monitoring

2. Supplier Audit (SA) – Checking & controlling

3. Supplier Scorecard (SSC) – Tracing and monitoring

4. Close Loop Corrective Action (CA) – Checking and controlling

5. Engagement of Suppliers in Quality System (SE) – Developing

From the result, it has proved that all the five sub-dimensions were significant, and they have positive relationship with organisational competitive advantage. As SQM is normally part of the requirement for quality standards, thus, the outcome is in line with the expectation. The result supported that the dimensions above are part of critical elements in SQM.

The second research question, does SQM give significant impact to organizational competitive advantage for MNC in Malaysia? Based from the result, it is observed that all the 5 dimensions (Tracking of Cost of Supplier Quality (COQ), Supplier Audit (SA), Supplier Scorecard (SSC), Close Loop Corrective Action (CA), and Engagement of Suppliers in Quality System) used to define SQM are significantly affecting organization's competitive advantage in positive direction. This indicates that the higher strength of SQM of an organization the more likely the organization to hold a higher competitive position and vice-versa. Consequently, the outcome of the data analysis proved to us that SQM gives significant impact on organization's competitive advantage with all the hypotheses tested are being supported. Thus, SQM does give a significant impact to organizational competitive advantage in the context of MNC in Malaysia.

CONCLUSION

Due to the increasing complexity in global business nowadays, SQM has become an important element that every organization should not neglect. The main elements that are identified as part of critical elements in SQM that will affect the strength of an organization's competitive advantage are: Tracking of Cost of Supplier Quality (COQ), Supplier Audit (SA), Supplier Scorecard (SSC), Close Loop Corrective Action (CA) and Engagement of Suppliers in Quality System (SE). The relationships between SQM with organization's competitive advantage are concluded to be significantly positive. All the hypotheses suggested are accepted through the statistical analysis conducted.

MANAGERIAL IMPLICATIONS

It is obvious that the findings of this study are important to help the managerial decision making processes. This study supports the importance of SQM practices to maintain a competitive position in the industry. Consequently it has a great impact on the organizational performance. The management of any organizations should be aware of this reality and emphasize on SQM as part of an important element of total quality management initiative in order to ensure the organizations' sustainability. The outcome of this study has provided a comprehensive model to the organization especially in the context of MNC in Malaysia on how to conduct SQM effectively by applying the correct practices. The model can be referred to as a constructive input for strategic planning towards achieving the targeted goals. Another implication is the benefit provided indirectly to all the organizations in any industry, whereby, the outcome of this study reveals the expectation of customers on SQM. It conveys a comprehensive input to organizations playing supplier's role on what are the intended practices by their customers and how they can perform better in meeting their customers' needs and requirements in order to attain higher customer satisfaction.

LIMITATIONS OF THE STUDY

There are several limitations identified for this study. Among those are, first, the outcome of the study can only be generalized in the context of MNC in Malaysia as the population of this study is concentrated on MNC in peninsular Malaysia. The outcome might be different with condition happening in all organizations across Malaysia as MNC and domestic organizations might have different concept and practices in SQM. Secondly, as SQM is a broad subject, the study is only conducted based on 5 sub dimensions in defining SQM. There could have more factors in SQM and probably more critical that the 5 factors identified. Thirdly, the samples selected for data collection consisted of MNC from all industries regardless their specialization. As the nature of industry may affect the SQM concepts and practices applied by an organization, which may result different outcome as compare to this study. However, this is unable to be identified in this study.

RECOMMENDATIONS FOR FUTURE RESEARCH

In view of the issues highlighted as limitations in this study, there are several recommendations to be taken as a measure of improvement in future research. First, the population of the study can be extended to a larger population, for example organizations in Malaysia, Southeast Asia or even Asia. So that it would provide more constructive and useful input for a broader scope of population. Second, more elements in SQM should be tested so that the beneficiaries may gain a better understanding on SQM. The more elements covered in SQM, the more effective SQM is likely to be for an organization. Lastly, studies specializing in particular industry can be conducted to provide a better insight on SQM particularly for specific industry. The outcome should be able to provide a more accurate, reliable and valid information to related industry.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

AL-Shboul M., Garza-Reyes J., Kumar V., 2018. Best supply chain management practices and high-performance firms. International Journal of Productivity and Performance Management, 67(9), 1482-1509. http://doi.org/10.1108/IJPPM-11-2016-0257

Carr S.A., Pearson J.N., 1999. Strategically managed buyer–seller relationships and performance outcomes. Journal of Operations Management, 17(5), 497–519. http://doi.org/10.1016/S0272-6963(99)00007-8

Dale H., Besterfield, 2002. Total Quality Management. Prentice Hall.

Dellana S.A., Kros J.F., 2014. An exploration of quality management practices, perceptions and program maturity in supply chain. International Journal of Operations & Production Management, 34 (6), 786-806. http://doi.org/10.1108/IJOPM-03-2013-0105

Ellram L.M., Murfield M.L.U., 2019. Supply chain management in industrial marketing–Relationships matter. Industrial Marketing Management, 79, 36-45. http://doi.org/10.1016/j.indmarman.2019.03.007

Famiyeh S., Kwarteng A., 2018. Supplier selestion and firm performance: Empirical evidence from a developing country's environment. International Journal of Quality & Reliability Management, 35 (3), 690-710. http://doi.org/10.1108/IJQRM-06-2016-0091

Ferdousi F., Baird K., Munir R., Su S., 2018. Associations between organisational factors, TQM and competitive advantage, Benchmarking: An International Journal, 25(3), 854-873. http://doi.org/10.1108/BIJ-05-2017-0110

Heizer J., Render B., 2017. Operations Management: Sustainability and Supply Chain Management, 12th edition. Pearson

Hong J., Liao Y., Zhang Y., Yu Z., 2019. The effect of supply chain quality management practices and capabilities on operational and innovation performance: Evidence from Chinese manufacturers. International Journal of Production Economics, 212, 227-235. http://doi.org/10.1016/j.ijpe.2019.01.036

Ismail A., Yunan Y..M., 2016. Service quality as a predictor of customer satisfaction and customer loyalty. LogForum 12 (4), 269-283. http://doi.org/10.17270/J.LOG.2016.4.7

Kiley D., 2016. Electronic sources: The Takata Airbag Recall Is Now a Full-Blown Crisis. http://fortune.com/2016/06/10/the-takata-airbag-recall-is-nowa-full-blown-crisis/ [10 June 2016]

Krejcie R.V., Morgan D.W., 1970. Determining Sample Size for Research Activities. Educational and Psychological Measurement, 30(3), 607-610. http://doi.org/10.1177/001316447003000308

Lo S.M., Zhang S., Wang Z., Zhao X., 2018. The impact of relationship quality and supplier development on green supply chain integration: A mediation and moderation analysis. Journal of cleaner production, 202, 524-535. http://doi.org/10.1016/j.jclepro.2018.08.175

Mandeep K., Kanwarpreet S., Doordarshi S., 2019. Synergetic success factors of total quality management(TQM) and supply chain management (SCM): A literature review. International Journal of Quality & Reliability Management, 36(6), 842-863. http://doi.org/10.1108/IJQRM-11-2017-0228

Oliver R.K., Webber M.D.. 1982. Supply-chain management: logistics catches up with strategy. In: M. Christopher, ed.1992. Logistics: The strategic issues. London: Chapman & Hall, 63-75.

Prajogo D.I., McDermott P., Goh M., 2018. Impact of value chain activities on quality and innovations, International Journal of Operations & Production Management, 28(7), 615-635. http://doi.org/10.1108/01443570810881785

Punnakitikashem P., Laosirihongthong T., Adebanjo D, McLean M.W., 2010. A study of quality management practices in TQM and non-TQM firms: International Journal of Quality & Reliability Management, 27 (9), 1021-1035. http://doi.org/10.1108/02656711011084819

Rahman S., 2006. Quality management in logistics: an examination of industry practices, Supply Chain Management: An International Journal, 11 (3), 233-240. http://doi.org/10.1108/13598540610662130

Sharma S., Modgil S., 2019. TQM. SCM and operational performance: an empirical study of Indian pharmaceutical industry. Business Process Management Journal. 1463-7154. http://doi.org/10.1108/BPMJ-01-2018-005

Suruhanjaya Syarikat Malaysia. 2018. Electronic sources: Company & Business Statistics for Year 2018. Suruhanjaya Syarikat Malaysia (SSM) https://www.ssm.com.my/en/statistic-totalbusinesscompanies?

Switala M., Niestroj K., Hanus P., 2018. Examining how logistic service providers' adaptability impacts logistics outsourcing performance, customers' satisfaction and loyalty, Logforum 14 (4), 449-465. http://doi.org/10.17270/J.LOG.2018.298

Wu F., Yeniyurt S., Kim D., Cavusgil S.T., 2006. The impact of information technology on supply chain capabilities and firm performance: A resource-based view, Industrial Marketing Management. 35 (4), 493-504. http://doi.org/10.1016/j.indmarman.2005.05.003

Yu Y., Huo B., 2018. Supply chain quality integration: relational antecedents and operational consequences. Supply Chain Management: An International Journal, 23 (3), 188-206. http://doi.org/10.1108/SCM-08-2017-0280

Yoo S.H., Cheong T., 2018. Quality improvement incentive strategies in a supply chain. Transportation Research Part E: Logistics and Transportation Review, 114, 331-342. http://doi.org/10.1016/j.tre.2018.01.005

Zhu Q., Lai K.H., 2019. Enhancing supply chain operations with extended corporate social responsibility practices by multinational enterprises: Social capital perspective from Chinese suppliers. International Journal of Production Economics, 213, 1-12. http://doi.org/10.1016/j.ijpe.2019.02.012

ZALEŻNOŚĆ POMIĘDZY ZARZĄDZANIEM JAKOŚCIĄ DOSTAWCY A PRZEWAGA KONKURENCYJNĄ ORGANIZACJI: PRZYKŁAD EMPIRYCZNY

STRESZCZENIE. **Wstęp:** Ze względu na wzrastające wymagania odnośnie jakości wyrobów oraz efektywności operacji, zarządzanie jakością dostawcy staje się coraz istotniejszym elementem wspomagającym uzyskanie przez organizację pożądanej skuteczności. Wraz z gwałtownym wzrostem globalizacji na przestrzeni ostatnich kilku dziesięcioleci, wzrasta również stopień kompleksowości operacji biznesowych. Mimo to istnienie niezbyt duża liczba badań poświęconych zarządzaniu jakością dostawcy (SQM) oraz przewagą konkurencyjną organizacji (OCA) w kontekście międzynarodowych korporacji (MNC). Celem tej pracy jest zidentyfikowanie elementów krytycznych w zarządzaniu jakością dostawcy jak również przetestowanie istotności wpływu zarządzania jakością dostawcy na przewagę konkurencyjną organizacji.

Metody: W pracy wykorzystano specjalnie do tego celu przygotowaną ankietę, na którą zebrane odpowiedzi od 355 ankietowanych. Uzyskane w ten sposób dane poddano analizie statycznej przy pomocy programu statystycznego Social Science (SPSS) wersja 23. Populacja poddana badaniom była skoncentrowana w międzynarodowych korporacjach w Malezji.

Wyniki: Na podstawie uzyskanych danych zidentyfikowano 5 elementów jako elementy krytyczne dla zarządzania jakości dostawcy: śledzenie kosztu jakości dostawcy, audyt dostawcy, ocena dostawcy, działania korygujące oraz zaangażowanie dostawców w system jakości.

Wnioski: Uzyskane w pracy wyniki wskazują, że zarządzanie jakości dostawcy istotnie wpływa w sposób pozytywny na uzyskanie przez organizację przewagi konkurencyjnej.

Słowa kluczowe: zarządzanie jakością, dostawca, operacje, efektywność, przewaga konkurencyjna

Khairul Anuar Mohd. Ali ORCID ID: https://orcid.org/0000-0001-6631-7463
Graduate School of Business (GSB-UKM)
Universiti Kebangsaan Malaysia
43400 UKM Bangi
Selangor, **Malaysia**
e-mail: kabma@ukm.edu.my

LogForum

> Scientific Journal of Logistics <

2020, 16 (1), 171-181

http://doi.org/10.17270/J.LOG.2020.386

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

RECOVERY ALTERNATIVES DECISION BY USING FUZZY BASED PREFERENCE SELECTION INDEX METHOD

Emre Bilgin Sari

Dokuz Eylul University, İzmir, **Turkey**

ABSTRACT. **Background:** The electrical and electronics sector has become one of the rapidly developing and growing sectors, as a result of technological and economic developments. Rapid changes in consumer demands and needs have increased the use of electrical and electronic equipment and shortened product life cycle, resulting in an increase in equipment waste. Therefore, recovery alternatives for electrical and electronic equipment waste should be considered subject. The aim of this study is to evaluate the recovery alternatives of electrical and electronic wastes and to determine the best.

Methods: Multi-criteria decision-making techniques used to select the best among multiple alternatives have many application areas. The selection of recovery alternatives based on criteria includes some fuzzy topics. For this reason, the fuzzy logic approach was used to evaluate the answers of the decision makers and the fuzzy numbers obtained were analyzed by PSI method and criterion weights were determined and alternatives were listed.

Results: According to results of analysis, social responsibility and environmental awareness criteria have the highest values for selecting recovery alternatives. In addition, remanufacturing, regeneration and recycling take the first place among the alternatives.

Conclusions: Recovery of electrical and electronics waste is an important subject in current conditions. Alternative methods vary from reuse to incineration, but correct choice of recovery techniques rely on multi criteria and decision should be made adhering to them.

Key words: recovery, multi-criteria decision-making, fuzzy, preference selection index.

INTRODUCTION

As a result of technological and economic developments in recent years, the electricity and electronics sector has become one of the rapidly developing and growing sectors. This growth in the sector significantly changes people's lifestyles and consumption habits. On the one hand, more innovative, well designed and multifunctional electronic products are offered to the market at attractive prices in order to make consumers' lives better and more comfortable. Moreover, consumers' search for a better lifestyle shortens the lifecycle of these products, which leads to an increasing interest in waste electrical and electronic equipment (WEEE) worldwide.

With the efficient management of WEEE, products and materials can be recovered efficiently without being sent to landfills. Thus, it is possible to protect living health, improve environmental conditions and improve financial performance [Flygansvaer et al. 2018]. The process of reassessing electrical and electronic products is complex and focuses not only on reuse or recycling within the scope of reverse logistics, but also on the proper treatment or disposal of hazardous substances such as lead and mercury to eliminate or minimize the risks to human health and environment. [Yu, Solvang 2016].

Citation: *Sari E.B., 2020. Recovery alternatives decision by using fuzzy based preference selection index method. LogForum 16 (1), 171-181,* http://doi.org/10.17270/J.LOG.2020.386

Received: 23.09.2019, Accepted: 02.12.2019, on-line: 30.12.2019.

Due to the rapid development of technology, the continuity of innovations and the rapidly changing demands, the life of electronic products is shortened. Therefore, deprecated electronic products are quickly discarded or disposed. This results in a large amount of electronic waste [Zhao et al., 2018, Flygansvaer et al., 2018]. It is very important that the electronic products that are no longer used can be recovered without harming human health and the environment. Many factors such as regulations, corporate awareness and the increase in the number of conscious consumers have led electronic manufacturers to reverse logistics activities. Therefore, the electronics sector fulfills its responsibility for the re-evaluation and proper recovery of end-of-life products with regulations such as WEEE, RoHS (Restriction on Hazardous Substances) [Ravi et al., 2008].

Today, not only forward logistics from the manufacturer to the consumer, the concept of reverse logistics which takes into consideration the issues such as product recovery and re-evaluation also comes to the fore. Although it is thought to be the opposite of forward logistics, reverse logistics differs from in many decision points [Bilgin 2012]. Reverse logistics is aiming to recover value from end-of-life or obsolete products, that cannot be used in a suitable way by planning, operating, managing effective material, information and money flows. Reverse logistics obtain value from end-of-life or no-use products which is a process from consumer to raw material supplier [Yu, Solvang 2016].

With the effect of the increasing importance of environmental and waste disposal issues, mandatory legislation and corporate social concerns, businesses are awareness to focus on reverse logistics activities under conditions of intense competition [Prakash, Barua 2016]. For this reason, in this study, it is aimed to determine the recovery alternatives of the companies operating in the electronics sector in the Aegean Region within the scope of reverse logistics and focusing on reverse logistics activities for the returning products for different reasons. To this end, a focus group consisting of academicians and experts who are knowledgeable about the subject of the study was formed. And Delphi method was applied to determine the dimensions and criteria of the subject. After determining the criteria, PSI (Preference Selection Index) method was used to select the most suitable alternative for remanufacturing, recycling, cannibalizing, repairing, direct reuse and incineration / burying alternatives for electronic products.

In the second part of this study, some studies from the academic literature on reverse logistics and recovery are examined. In the third chapter, the method used in the study is explained briefly and in the fourth chapter the application stages and findings are presented. In the last section, a general evaluation is made in which the results of the study are interpreted.

LITERATURE RESEARCH

Nowadays, technological developments are rapidly increasing and product life cycle is shortened, customers are constantly demanding new products, and all these products are turned into waste even before the end of their service life. These facts are forcing the companies to an effective reverse logistics management. Reverse logistics in a narrow sense refers to all activities related to the collection, recovery or disposal of used products; in broader manner, cooperation between the producer and the consumer in order to minimize the generation of waste by re-use, re-production, recycling or safe disposal of products that are no longer used in order to increase renewable energy sources [Bouzon et al., 2016].

The responsibilities imposed on the producers and the legislation on waste put pressure on the producers to take back the products that have reached the end of their life and dispose of these products in an appropriate way. Studies have shown that the rate of return is high especially for electronics, computers, cameras, mobile phones, automobiles, chemical and medical products [Prakash, Barua 2016]. For the recovery of the products returning to the enterprise, it is important to classify and evaluate the products and apply the most appropriate recovery alternative.

Recovery alternatives of products depending on the degree of remanufacturing; modernization, cannibalization, repair, direct reuse, recycling and incineration. Remanufacturing; the products are completely dismantled according to the component levels and brought to the quality standards applicable to new products, comprehensive inspection and replacement of broken / old parts [Bilgin, 2012]. Regeneration; the quality of used products is to raise to higher level by disassembly, to check and to replace the broken components. The upgrade can also be accomplished by replacing outdated modules or components with technologically superior ones. Cannibalization; recovering a small number of items returned for use in any of the aforementioned recovery alternatives for reuse. Repairing; returning products to work again. The quality of repaired products may be lower than that of new products. Recycle; It refers to the re-use of the material obtained by destroying the original features and functions of the products and parts as a result of subjecting them to various separation processes [Wadhwa et al., 2009]. Direct reuse; in the process of returning pallets, containers without any changes on materials such as cleaning or cleaning and so on. Small operations are directly involved in the process. The alternative to incineration / burying is the destruction of the product by the enterprises when they no longer have any other options. Instead of disposing of the returned products, the company determines the most suitable recovery alternative for the processes and reduces the consumption of new materials by using the materials evaluated from these products, thus producing many additional values, especially economic [Bilgin 2012].

In this study, selection of the most suitable recovery alternative for an enterprise producing electronic products is discussed by using multi - criteria decision making approach. Firstly, the criteria are determined by using Delphi method, and in the next stage, the most suitable recovery alternative was selected by using the PSI method. Since there are many criteria affecting the alternatives, multi-criteria decision-making methods can be used to selection of alternatives. The Preference Selection Index (PSI) is a multi-criteria decision-making method used by firstly Maniya and Bhatt [2010]. PSI provides systematic evaluation without the need for additional weighting of the criteria.

Some of the studies conducted in the literature to evaluate recovery alternatives are as follows: Wang et al. [2018] used interval-valued Fuzzy DEMATEL and interval-valued fuzzy Gray Relational Analysis methods in order to determine the best scenario among alternatives for the evaluation of urban solid wastes. Agrawal et al. [2016] preferred to use AHP and Fuzzy TOPSIS methods in order to determine the best alternative for disposing the product for an Indian electronics company producing mobile phones. Jindal and Sangwan [2016] used AHP and TOPSIS methods in a fuzzy environment to evaluate the product recovery processes. Samantra et al. [2013] used fuzzy cluster and VIKOR methods together to determine the optimum recovery alternative for the product. Mahapatara et al. [2013] made the selection of reverse production alternatives by TOPSIS method. Ravi and Shankar [2012] used the ANP method to evaluate recovery alternatives in the automobile industry. Wadhwa et al. [2009] evaluated the recovery alternatives of returned brown goods with fuzzy TOPSIS. Ravi et al. [2005] ANP and balanced scorecard methods using the combination of end-of-life computers to model the selection of the most appropriate among the recovery alternatives.

One of the most important issues to be considered in the recovery of electronic wastes is the efforts to recover the precious and scarce resources in the electrical and electronic products such as gold, silver, zirconium and palladium. In this respect, Sun et al. [2017], a mathematical formulation has been developed to determine how much of these metals in electronic waste will be recovered. In the same study, the scarcity of the precious metals in electronic products on the basis of resources was determined and it was clearly revealed which kind of metals should be evaluated with priority recovery alternatives.

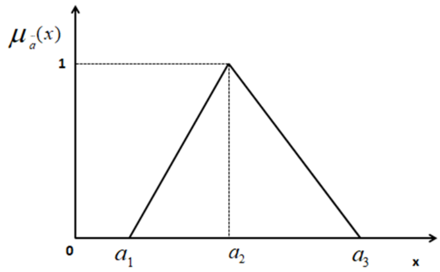
METHOD

In particular, the fact that the relative weight of the occurrence factors is not taken into account and that the uncertainty of information does not allow for the calculation of the exact values and computations is a common point of these criticisms. In order to overcome these deficiencies of the classical method, fuzzy logic approach and factor weighting methods are assumed to be more effective than the model proposed.

Fuzzy set theory is a tool that was developed by Zadeh [1965] and can be used to describe mathematically complex and ambiguous systems that have difficulty in expressing exact numbers [Yadav, et al., 2003]. The application of fuzzy set theory in risk assessment problems of FMEA has several advantages over deterministic models such as the use both quantitative and qualitative data together to obtain consistent results, the direct interpretation of failure modes using linguistic variables. In addition, fuzzy logic is considering the uncertainty of a system affected by many factors [Liu 2016].

The fuzzy set is a set of elements that do not have definite boundaries, have gradual transitions, and have certain membership degrees. This cluster describes a convex structure of fuzzy numbers, each with a membership degree between 0 and 1 [Hu, et al., 2009]. Certain membership degrees are determined using membership functions rather than definitive expressions, such as members or members in determining the membership of this cluster [Zadeh 1975]. In the definition of membership functions, the proximity of the numbers is used, and the membership functions are usually represented by triangular membership functions and trapezoidal membership functions according to the situation of this neighbourhood [Sanayei et al., 2010]. In applications, triangular membership functions are preferred mostly for ease of calculation. In this study, triangular membership function is used.

Triangle membership function is defined by three parameters a1, a2 and a3. Here, a1 and a3 respectively, the lower and upper limit values of the number of fuzzy a2 is the mean value of the middle [Salehi, Tavakkoli-Moghaddam 2008]. Triangle membership function is defined in equation 1 and the triangular form is shown in the Figure 1.



$$\mu_{\tilde{a}}(x)=\begin{cases}\dfrac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2\\ \dfrac{a_3-x}{a_3-a_2}, & a_2 \le x \le a_3\\ 0, & otherwise\end{cases} \qquad (1)$$

Source: Salehi, Tavakkoli-Moghaddam, 2008

Fig. 1. Triangle membership function

Another important feature of the fuzzy logic approach is that it allows to give meaning to difficult situations with quantitative values. The concept of linguistic variable is very practical in dealing with situations that are too complex to be reasonably defined by traditional quantitative expressions [Zadeh, 1975]. A linguistic variable is a factor whose values are words in language and fuzzy numbers are used for expressing these linguistic variable values. Linguistic variables and the conversion the fuzzy numbers are explained in Table 1.

Table 1. Linguistic variables and triangular fuzzy numbers

Linguistic Variables	Triangular Fuzzy Numbers
Very Low	(0,0,1)
Low	(0,1,3)
Medium Low	(1,3,5)
Medium	(3,5,7)
Medium High	(5,7,9)
High	(7,9,10)
Very High	(9,10,10)

Source: Zadeh, 1975, cited in: Liu, et al., 2015

One of the most important steps of fuzzy logic approach is the process of defuzzication. Defuzzification is performed to obtain a best non-fuzzy performance (BPN) value. Between the techniques like as center of area (COA), mean of maximal (MOM), and a-cut; the COA has practical process and is calculated with equation 2 [Alcan, et al., 2013].

$$x_o(a) = a_1 + [(a_3 - a_1) + (a_2 - a_1)]/3 \qquad (2)$$

Following the defuzzication process, The Preference Selection Index (PSI) is used for selection, PSI is developed by Maniya and Bhatt [2010] and is used for multi-criteria decision making (MCDM) problems. The PSI is explained as a method that stands out due to its feature that determines the weight of the criteria and which does not require relative weighting.

In the PSI method, the overall preference value calculated for each criteria and the preference index (I_j) are calculated for each alternative, and the height of the preference index value allows the alternative to be determined as the best alternative [Maniya, Bhatt 2010]. The use of the PSI method arises in situations where it is difficult to decide the criteria weight [Attri, Grover 2015].

In the literature, the PSI method is used for ranking or selection of alternatives, and the validity of the method is compared with the other commonly used methods. Firstly, Maniya and Bhatt [2010] applied the PSI for material selection problem and the results were compared with the outputs obtained by TOPSIS and GTMA methods. Sawant, et al., [2011] in their study used the PSI method for the problem of automatic-oriented vehicle selection, sixteen different models were ranked based on nine criteria. In the study, for used criteria were desired the maximum and minimum values and the results were compared with the TOPSIS method. Mufazzal and Muzakkir [2018] and Noryani et al., [2018], in their researches; PSI was discussed with AHP, ANP, DEA, ELECTRE, GRA, GTMA, MAUT, PROMETHEE, SAW, TOPSIS, VIKOR.

Advantage of the PSI method; it is the direct implementation of the alternative to assess the performance of the alternative and to calculate the rating score. On the other hand, the disadvantage is the method that does not allow the user to consider the qualitative factors [Noryani et al., 2018]. This is related to the method based on calculations that determine the weight of criteria within its own systematic.

The steps taken by the PSI method in Maniya and Bhatt [2010] are as follows:

Step - 1: Defining the problem and determining the criteria.

Step - 2: Rows are the alternatives A=[A_i, i=1, 2, … , n], columns are the set of criteria C=[Cj, j=1, 2, … ,m], and the value of cells X_{ij}, represent the decision matrix.

Step - 3: Normalization of the decision matrix is the standardization of the criteria measured by different units.

The normalization of the criteria in different units is 0 - 1, and the reinterpretation of the data to show if the maximum value of the criterion is better, 1 is the best, 0 is the worst, if the minimum value of the criterion is better, 0 is the best, 1 is the worst.

$N_{ij} = \frac{X_{ij}}{X_{ij\ \max}}$; $\forall$ i,j $\rightarrow$ if the great value represents better (3)

$N_{ij} = 1 - \frac{X_{ij}}{X_{ij\ \max}}$; $\forall$ i,j $\rightarrow$ If the small value represents better (4)

Step - 4: Calculating preference variation value (PV_j).

$$PV_j = \sum_{i=1}^{n} [N_{ij} - \overline{N_j}]^2 \quad (5)$$

$\overline{N_j}$: is the average of the normalized values of the alternative j

$$\overline{N_j} = \frac{1}{n}\sum_{i=1}^{n} N_{ij} \quad (6)$$

Step - 5: Determining the overall preference value ψ_j for each criteria. For each criteria, the overall preference value deviation θ_j is found. (Quantitative Weighting).

$$\theta_j = 1 - PV_j \quad (7)$$

$\psi_j = \frac{\theta_j}{\sum_{j=1}^{m}\theta_j}$ $\rightarrow$ Sum of the overall preference values of the criteria equals the one ($\sum \psi_j = 1$) (8)

Step-6: Calculating the index value.

$$I_i = \sum_{j=1}^{m} (N_{ij}\ x\ \psi_j) \quad (9)$$

The results are accepted as Preferred Selection Index (PSI) and are shown as I_i. PSI values are used for alternative selecting, sorting, and comparing, with the highest value showing better.

COMPUTATIONAL EXPERIMENTS

The recovery alternatives of the products are affected by many factors like environmental, social, technical, economic and so on. When determining these factors, the opinions and interests of the stakeholders must be taken into consideration. A crucial factor for one stakeholder may conflict with the interests of another stakeholder. Therefore, it is necessary to determine the product recovery option with a method that covers all stakeholders involved in the process.

This provides a method to guide the decision-making process on the recovery option of electronic products that have completed their working life.

Within the scope of reverse logistics, a project group consisting of academicians and experts working in the reverse logistics process has been formed in this study, in which the evaluation options of the electronic manufacturers operating in Aegean Region are evaluated. As a result of the interviews and literature review on the subject, Cost, Duration, Economic Gain, Product Quality, Environmental Awareness, Legal Regulations, Pollution and Social Responsibility was selected as the criteria of the study; Remanufacturing (A1), Regeneration (A2), Recycling (A3), Cannibalization (A4), Repair (A5), Direct Reuse (A6) and Incineration / Burying (A7) were identified as alternatives [Sharma et., al. 2016, Lou, Wang 2009].

Based on the project group consisting of 5 people and the information obtained from the literature, seven alternatives determined for the recovery of electronic wastes were evaluated by the expert group within the framework of eight criteria. Decision-makers evaluated the significance of the criteria and each alternative according to these criteria. The Fuzzy Decision Matrix obtained with the help of equations (1) and (2) is shown in Table 2.

Table 2. Fuzzy decision matrix

	Cost	Process Length	Economic Gain	Product Quality	Environmental Awareness	Legal Regulation	Pollution	Social Responsibility
Remanufacturing	(0,1.4,5)	(0,2.4,5)	(3,7.4,10)	(3,5.8,10)	(5,8.4,10)	(1,4.2,9)	(3,7.4,10)	(5,8.4,10)
Regeneration	(1,5,9)	(0,1.8,5)	(5,8.4,10)	(3,7,10)	(3,7,6,10)	(1,4.6,9)	(3,6.6,10)	(5,8.4,10)
Recycling	(0,2.4,5)	(1,5.4,9)	(5,7.8,10)	(3,7.4,10)	(3,7.4,10)	(3,7.4,10)	(5,7.4,10)	(3,7.4,10)
Cannibalization	(3,7.4,10)	(5,8.2,10)	(3,7.4,10)	(1,5,9)	(5,8.2,10)	(1,5,9)	(3,6.2,9)	(3,7.4,10)
Repairing	(1,4.6,9)	(1,5,9)	(5,8,10)	(3,7.4,10)	(3,8,10)	(0,2,5)	(3,7,10)	(5,8.2,10)
Direct Reuse	(3,7.4,10)	(5,8.2,10)	(5,7.8,10)	(3,7.4,10)	(5,8.4,10)	(1,5.4,9)	(3,6.2,9)	(3,7.4,10)
Incineration / Burying	(0,1.8,5)	(3,7.4,10)	(0,1.4,5)	(0,2,5)	(0,2.6,5)	(0,2.2,5)	(0,2.6,5)	(1,4.6,9)

Source: own work

Table 3. Decision matrix

	C1	C2	C3	C4	C5	C6	C7	C8
A1	2,13	2,47	6,80	6,27	7,80	4,73	6,80	7,80
A2	5,00	2,27	7,80	6,67	6,87	4,87	6,53	7,80
A3	2,47	5,13	7,60	6,80	6,80	6,80	7,47	6,80
A4	6,80	7,73	6,80	5,00	7,73	5,00	6,07	6,80
A5	4,87	5,00	7,67	6,80	7,00	2,33	6,67	7,73
A6	6,80	7,73	7,60	6,80	7,80	5,13	6,07	6,80
A7	2,27	6,80	2,13	2,33	2,53	2,40	2,53	4,87

Source: own work

In order to defuzzy the total fuzzy matrix, the Center of Area (COA) method was used as described in the methodology section, and the decision matrix was reached shown as Table 3.

PSI Calculations

After the decision matrix is formed in the PSI method, a normalized decision matrix is formed to standardize the values. Table 4 shows the normalized decision matrix and shows the $\overline{N_j}$ values.

Table 4. Normalized decision matrix

	C1	C2	C3	C4	C5	C6	C7	C8
A1	0,686	0,681	0,872	0,922	1,000	0,696	0,089	1,000
A2	0,265	0,707	1,000	0,980	0,880	0,716	0,125	1,000
A3	0,637	0,336	0,974	1,000	0,872	1,000	0,000	0,872
A4	0,000	0,000	0,872	0,735	0,991	0,735	0,188	0,872
A5	0,284	0,353	0,983	1,000	0,897	0,343	0,107	0,991
A6	0,000	0,000	0,974	1,000	1,000	0,755	0,188	0,872
A7	0,667	0,121	0,274	0,343	0,325	0,353	0,661	0,624
$\overline{N_j}$	**0,363**	**0,314**	**0,850**	**0,854**	**0,852**	**0,657**	**0,194**	**0,890**

Source: own work

Table 5. Overall preference value

	C1	C2	C3	C4	C5	C6	C7	C8
A1	0,105	0,135	0,000	0,005	0,022	0,002	0,011	0,012
A2	0,010	0,154	0,023	0,016	0,001	0,003	0,005	0,012
A3	0,075	0,000	0,016	0,021	0,000	0,118	0,038	0,000
A4	0,132	0,099	0,000	0,014	0,019	0,006	0,000	0,000
A5	0,006	0,002	0,018	0,021	0,002	0,098	0,008	0,010
A6	0,132	0,099	0,016	0,021	0,022	0,010	0,000	0,000
A7	0,092	0,037	0,332	0,261	0,278	0,092	0,218	0,071
PV_j	0,551	0,526	0,404	0,360	0,344	0,329	0,279	0,106
Q_j	0,449	0,474	0,596	0,640	0,656	0,671	0,721	0,894
W_j	**0,088**	**0,093**	**0,117**	**0,126**	**0,129**	**0,132**	**0,141**	**0,175**

Source: own work

Following the creation of a normalized decision matrix, it is necessary to find the preference variance and to determine the overall preference value. Overall preference value can be considered as benchmark weights. Table 5 shows the overall preference value calculation step.

When the overall preference values that determined for each criteria, were examined, the highest weight was given to the Quality indicator with a value of 0.222. The second most significant weight is given to the Performance indicator with a value of 0.207. These two criteria with the highest weight are the values used for the OEE calculation. As a result of the overall preference value for each criterion, the values accepted as the PSI for each alternative are calculated. Table 6 shows the calculation of PSI values.

Table 6. Calculation of PSI values

	C1	C2	C3	C4	C5	C6	C7	C8	**PSI**
A1	0,060	0,063	0,102	0,116	0,129	0,092	0,013	0,175	**0,749**
A2	0,023	0,066	0,117	0,123	0,113	0,094	0,018	0,175	**0,729**
A3	0,056	0,031	0,114	0,126	0,112	0,132	0,000	0,153	**0,723**
A4	0,000	0,000	0,102	0,092	0,127	0,097	0,027	0,153	**0,598**
A5	0,025	0,033	0,115	0,126	0,115	0,045	0,015	0,174	**0,648**
A6	0,000	0,000	0,114	0,126	0,129	0,099	0,027	0,153	**0,646**
A7	0,059	0,011	0,032	0,043	0,042	0,046	0,093	0,109	**0,436**

Source: own work

When the preference index values calculated by PSI method are examined, it is seen that A1 has the highest value and it is followed by M2 and M3 recovery alternatives. They are remanufacturing, regeneration and recycling which are the value adding activities are more than others. And the last chosen alternative is A7 and it is incineration / burying which is the destruction operation and there is no gain.

CONCLUSIVE REMARKS

The subject of recovery activities in order to create value and use effective resources is becoming increasingly important for products that have reached the end of their useful lives be. Recovery activities represent an important area within the development policy of many countries where projects are prepared. Recovery operations, micro-scale firm, macro-scale, as well as the economic contribution to the national economy; social responsibility awareness and production systems are becoming more environmentally friendly. Within the scope of the study, the recycling of electrical and electronic wastes has been covered in the scope of this important waste recovery. PSI method has been used within the framework of fuzzy approach, since it will be difficult to make certain decisions about the selection of recovery alternatives.

As a result of the interviews with the decision-making expert group, the most important criterion is social responsibility and environmental awareness criteria and the cost criterion takes the last place in determining the weights of the PSI method with the evaluations taken on the choice of recovery alternatives; it is a reflection of the consciousness that occurs on this subject. As a result of the analyzes, remanufacturing, regeneration and recycling take the first place among the alternatives, this is again an indication of the growing awareness in this regard.

In this study, conversely with other studies in the literature, fuzzy based PSI method was used. Although remanufacturing is seen as the best alternative in the literature, it is an innovative approach to support this result with the PSI method. In future studies, it may be suggested to create more specific research results on the basis of products by making evaluations for each product group by acting on electronic product groups. The study can also be expanded by comparing the results with other multi-criteria decision-making methods.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

Statutory fund of Dokuz Eylul University.

REFERENCES

Agrawal S., Singh R.K., Murtaza Q., 2016. Disposition decisions in reverse logistics by using AHP-fuzzy TOPSIS approach, Journal of Modelling in Management, 11(4), 932- 948. http://doi.org/10.1108/JM2-12-2014-0091.

Alcan P., Balin A., Başlıgil H., 2013. Fuzzy multicriteria selection among cogeneration systems: a real case application, Energy Build, 67, 624–634. http://doi.org/10.1016/j.enbuild.2013.08.048.

Attri R., Grover S., 2015. Application of preference selection index method for decision making over the design stage of production system life cycle, Journal of King Saud University-Engineering Sciences, 27(2), 207-216. http://doi.org/10.1016/j.jksues.2013.06.003.

Bilgin E., 2012. (original language) Tersine lojistik ağı tasarımı: Geri dönüşüm alanında bir uygulama. Yayınlanmamış Yüksek Lisans Tezi, Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü, İzmir. [translated in English] Reverse logistics network design: An application in the field of recycling. Unpublished Master's Thesis, Dokuz Eylül University Institute of Social Sciences, İzmir.

Bouzon M., Govindan K., Rodriguez C.M.T., Campos L.M.S., 2016. Identification and analysis of reverse logistics barriers using fuzzy delphi method and AHP, Resources, Conservation and Recyling, 108, 182-197. http://doi.org/10.1016/j.resconrec.2015.05.021.

Flylgansvaer B., Dahlstrom R., Nygaard A., 2018. Exploring the pursuit of sustainability in reverse supply chains for electronics, Journal of Cleaner Production, 189, 472-484. http://doi.org/10.1016/j.jclepro.2018.04.014

Hu Y., Wu S., Cai L., 2009/ Fuzzy multi-criteria decision making TOPSIS for distribution center location selection. 2009 International Conference on Networks Security, Wireless Communications and Trusted Computing, 2, 707-710, IEEE. http://doi.org/10.1109/NSWCTC.2009.102.

Jindal A., Sangwan K.S., 2016. A fuzzy based decision support framework for product recovery process selection in reverse logistics, International Journal of Services and Operations Management, 25(4), 413-439. http://doi.org/10.1504/IJSOM.2016.080274.

Liu H.C., 2016, FMEA using uncertainty theories and MCDM methods. In FMEA Using Uncertainty Theories and MCDM Methods, 13-27, Springer, Singapore. http://doi.org/10.1007/978-981-10-1466-6_2.

Liu H.C., Liu L., Liu N., Mao L.X., 2012. Risk evaluation in failure mode and effects analysis with extended Vikor method under fuzzy environment. Expert Systems with Applications, 39(17), 12926-12934. http://doi.org/10.1016/j.eswa.2012.05.031.

Mahapatara S.S., Sharma S.K., Parappagoudar M.B., 2013. A novel multi-criteria decision making appraoch for selection of reverse manufacturing alternatives, International Journal of Services and Operations Management, 15(2), 176-195. http://doi.org/10.1504/IJSOM.2013.053644.

Maniya K., Bhatt M.G., 2010. A selection of material using a novel type decision-making method: preference selection index method, Materials and Design, 31, 1785-1789. http://doi.org/10.1016/j.matdes.2009.11.020

Mufazzal S., Muzakkir S.M., 2018. A new multi-criterion decision making (MCDM) method based on proximity indexed value for minimizing rank reversals, Computers and Industrial Engineering, 119, 427-438. http://doi.org/10.1016/j.cie.2018.03.045.

Noryani M.I., Sapuan S.M., Mastura M.T., 2018. Multi-criteria decision-making tools for material selection of natural fibre composites: a review, Journal of Mechanical Engineering and Sciences Malaysia, 12(1), 3330-3353 http://doi.org/10.15282/jmes.12.1.2018.5.0299.

Prakash C., Barua M.K., 2016. An analysis of integrated robust hybrid model for third-party reverse logistics partner selection under fuzzy environment, Resources, Conservation and Recyling, 108, 63-81. http://doi.org/10.1016/j.resconrec.2015.12.011.

Ravi V., Shankar R., Tiwari M.K., 2005. Analyzing alternatives in reverse logistics for end-of-life computers: ANP and balanced scorecard approach, Computers and Industrial Engineering, 48, 327-356. http://doi.org/10.1016/j.cie.2005.01.017.

Ravi V., Shankar R., 2012. Evaluating alternatives in reverse logistics for automobile organisations, International Journal of Logistics Systems and Management, 12(1), 32-51. http://doi.org/10.1504/IJLSM.2012.047057.

Ravi V., Shankar R., Tiwari M.K., 2008. Selection of a reverse logistics project for end-of-life computers: ANP and goal programming, International Journal Of Production Research, 46(17), 4849-4870. http://doi.org/10.1080/00207540601115989

Salehi, M., Tavakkoli-Moghaddam, R., 2008, Project selection by using a fuzzy TOPSIS technique. World Academy of Science, Engineering and Technology, 40, 85-90. http://doi.org/10.5281/zenodo.1327468.

Samantra C., Sahu N.K., Datta S., Mahapatara S.S., 2013. Decision-making in selecting reverse logistics alternative using interval-valued fuzzy sets combined with VIKOR approach, International Journal of Services and Operations Management, 14(2), 175-196. http://doi.org/10.1504/IJSOM.2013.051828.

Sanayei A., Mousavi S.F., Yazdankhah A., 2010. Group decision making process for supplier selection with vikor under fuzzy environment. Expert Systems with Applications, 37(1), 24-30. http://doi.org/10.1016/j.eswa.2009.04.063.

Sawant V.B., Mohite S.S., Patil J., 2011. A decision-making framework using a preference selection index method for automated guided vehicle selection problem, International Conference on Technology Systems and Management (ICTSM), 12-16. http://doi.org/10.1007/978-3-642-20209-4_24.

Sharma S.K., Mahapatra S.S., Parappagoudar M.B., 2016. Benchmarking of product recovery alternatives in reverse logistics, Benchmarking: An International Journal, 23(2), 406-424. http://doi.org/10.1108/BIJ-01-2014-0002.

Sun Z., Cao H., Xiao Y., Sietsma J., Jin W., Agterhuis H., Yang Y., 2016. Toward sustainability for recovery of critical metals from electronic waste: the hydrochemistry processes. ACS Sustainable Chemistry and Engineering, 5(1), 21-40. http://doi.org/10.1021/acssuschemeng.6b00841.

Wadhwa S., Madaan J., Chan F.T.S., 2009. Flexible decision modeling of reverse logistics system: A value adding MCDM approach for alternative selection, Robotics and Computer-Integrated Manufacturing, 25(2), 460-469. http://doi.org/10.1016/j.rcim.2008.01.006.

Wang Z., Ren J., Goodsite M.E., Xu G., 2018. Waste-to-energy, municipal solid waste treatment, and best available technology: comprehensive evaluation by an interval-valued fuzzy multi-criteria decision making method, Journal of Cleaner Production, 172, 887-899. http://doi.org/10.1016/j.jclepro.2017.10.184

Yadav O.P., Singh N., Goel P.S., Itabashi-Campbell R., 2003. A framework for reliability prediction during product development process incorporating engineering judgements. Quality Engineering, 15(4), 649-662. http://doi.org/10.1081/QEN-120018396.

Yu H., Solvang W.D., 2016. A stochastic programming approach with improved multi-criteria scenario-based solution method for sustainable reverse logistics design of waste electrical and electronic equipment (WEEE), Sustainability, 8(12), 1-28. http://doi.org/10.3390/su8121331.

Zadeh L.A., 1975. The concept of linguistic variable and its application to approximate reasoning, Information Sciences, 8, 199-249. http://doi.org/10.1016/0020-0255(75)90036-5.

Zhao Y., Cao Y., Li H., Wang S., Liu Y., Li Y., Zhang Y., 2018. Bullwhip effect mitigation of green supply chain optimization in electronics industry, Journal of Cleaner Production, 180, 888-912. http://doi.org/10.1016/j.jclepro.2018.01.134

PODEJMOWANIE DECYZJI RECYCKLINGOWYCH PRZY ZASTOSOWANIU METODY WSKAŹNIKOWEJ WYBORU PREFERENCJI

STRESZCZENIE. Wstęp: Przemysł elektryczny i elektroniczny to gałęzie przemysłu o dużej dynamice wzrostu i rozwoju, będącej wynikiem rozwoju technologicznego i ekonomicznego. Gwałtowne zmiany popytu i potrzeb konsumentów wpłynęły na wzrost zapotrzebowania na sprzęt elektroniczny oraz skróciły cykl życia produktu, co w efekcie doprowadziło do zwiększenia ilości odpadów sprzętowych. Dlatego też istotnie jest zajęcia się tematyką odzyskiwania części ze zużytego sprzętu elektrycznego i elektronicznego. Celem pracy jest ocenienie metod odzyskiwania elementów ze zużytych sprzętów oraz wybór najlepszej z tych metod.

Metody: W wielu obszarach stosuje się techniki wielokryterialne podejmowania decyzji w celu dokonania wyborów pomiędzy różnymi alternatywami. Wybór metody odzyskiwania w oparciu o kryteria obejmuje zagadnienia modeli rozmytych. Z tego też powodu, zastosowano logikę rozmytą do oceny odpowiedzi osób decyzyjnych a uzyskanie liczby rozmyte zostały poddane metodzie PSI, w wyniku której uzyskano kryteria ważone jak i listę alternatyw.

Wyniki: Na podstawie uzyskanych wyników stwierdzono, że kryteria odpowiedzialności i świadomości ekologicznej mają najwyższą wartość przy selekcji metod odzyskiwania. Dodatkowo, najczęściej wybieranymi metodami były: przerób, regeneracja oraz recykling.
Wnioski: W istniejących obecnie uwarunkowaniach, odzyskiwanie elementów ze zużytego sprzętu elektrycznego i elektronicznego jest bardzo ważne. Metody alternatywne obejmują całą paletę od ponownego użycia do spalenia, jednakże prawidłowy wybór stosowanej techniki odzysku powinien opierać się na wielokryterialnym procesie decyzyjnym.

Słowa kluczowe: odzyskiwanie, wielokryterialne podejmowanie decyzji, wskaźnik preferencji wyboru

Emre Bilgin Sari ORCID ID: https://orcid.org/0000-0001-5110-1918
Faculty of Economics and Administrative Sciences
Department of Production Management
Dokuz Eylul University, Faculty of Economics and Administrative Sciences, İzmir, **Turkey**
e-mail: emre.bilgin@deu.edu.tr

LogForum

> Scientific Journal of Logistics <

2020, 16 (2), 193-207

http://doi.org/10.17270/J.LOG.2020.403

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

THE NEW SILK ROAD: OPPORTUNITIES FOR GLOBAL SUPPLY CHAINS AND CHALLENGES FOR FURTHER DEVELOPMENT

Norbert Wagener[1], Bernard Aritua[2], Tong Zhu[2]

1) Poznan School of Logistics, Poznań, **Poland,** 2) The World Bank Group, **China**

ABSTRACT. **Background:** Efforts to revive the New Silk Route from Europe to Asia have been on-going since the late 1970s. However, the launch of the Belt and Road Initiative (BRI) of the PR China in 2013 has given new impetus to Europe-Asia connectivity. Between 2014 and 2018 the number of block trains between China and Europe (including Russia) increased from 298 to 4,982 per year. Will this trend continue? Which bottlenecks and challenges appear? What are opportunities for respective countries, policy makers, shippers and logistics operators? The paper contributes to the scientific question of further and sustainable segmentation of intermodal transport markets in the context of global supply chains.

Methods: Based on a literature review and interviews with logistics operators and shippers the authors analyze the present design and operational parameters of the intermodal land bridge traffic system, major challenges and bottlenecks and propose measure how to enable further growth and to improve the sustainability of this traffic.

Results: Main issues of the further development of the New Silk Road Europe China are technological innovations, digitalization of supply chains, optimizing of intermodal transport and gateway concepts, corridor management and new trading patterns with e-commerce.

Conclusions: Although this intermodal land bridge connection will likely continue to be a niche market, it offers considerable transit time and cost savings for specific types of freight where air freight is too expensive and maritime logistics is too slow. At higher freight costs compared with the sea freight and lower fares than air cargo this is especially interesting for high value cargo and the Northern provinces of China; also for opportunities in Central Asia, and the Caucasus. The new transport route promotes not only investments into production sites for export at locations in the Northern provinces but also opens new opportunities for European exports of industrial goods and FMCG for the growing middle class in China. The total logistics costs from the viewpoint of a shipper can be more competitive via land bridge than via sea. Both production and distribution networks of large companies (e.g. BASF, HP, BMW) and small and medium sized companies (here especially through e-commerce) can benefit from a further integration of markets and globalization of supply chains.

Key words: New Silk Road, Belt and Road Initiative, Global Supply Chains, Intermodal Transport, Digitalization, Corridor Management.

A part of this study was presented as oral presentation at the „8th International Logistics Scientific Conference WSL FORUM 2019" in Poznan (Poland), 18th-19th of November 2019.

INTRODUCTION

"Silk Route" is a term describing a network of land based trade routes, formerly with caravans between China and Europe initiated during the Chinese Han Dynasty (207 BC to 220 AD). These trade routes cross China, Kazakhstan, Kyrgystan, Turkmenistan, Tajikistan, Uzbekistan, Iran, the Caucasus and Turkey. Over time the routes and names changed. Nowadays the "New Silk Route" (also "Iron Silk Route") covers this historical Southern route but also a Central route via Kazakhstan and Russia as well as Northern routes via Mongolia and Russia (Fig. 1).

Citation: *Wagener N., Aritua B., Zhu T., 2020. The New Silk Road: Opportunities for Global Supply Chains and Challenges for Further Development. LogForum 16 (2), 193-207, http://doi.org/10.17270/J.LOG.2020.403*

Received: 06.11.2019, Accepted: 13.01.2020, on-line: 30.03.2020.

A major backbone is the Trans-Siberian Railway whose construction started in 1891 under the Russian Tsar Nikolaus III and connects Moscow with Vladivostock at the Pacific. With 9,289 km it is the longest railway in the world. At the eve of containerization in the 1970s of the 20th century this route gained importance for rail container transport from Europe (mainly Germany, Switzerland and Finland) to Russia and China. Since the beginning one can recognize steady improvements of operation from inefficient waggon loads, on demand traffic and unpredictable transit times towards more efficient block trains, fixed schedules and very competitive transit times. The growing foreign trade between China and Europe, the industrialization of North China and the increased reliability of intermodal rail connections were the main drivers of this development.

Especially the introduction of time table related train schedules and reliability of service were the very preconditions to integrate this route into supply chains of intercontinental production and distribution networks.

Source: Beifert, et al., 2018

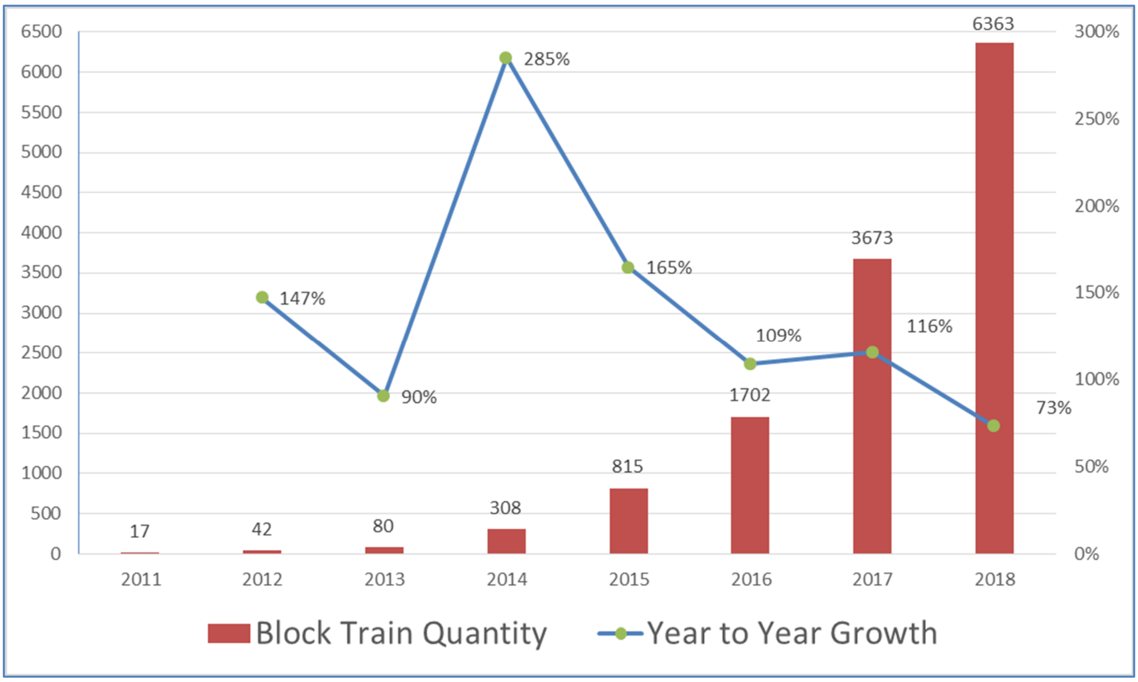
Fig. 1. Eurasian Corridors

DEVELOPMENT OF THE CHINA – EUROPE LANDBRIDGE TRAFFIC

The “New Silk Route” has experienced a dynamic rise since the start of the BRI of the PR China in 2013. Physical connectivity and trade are prioritized by BRI along with other aspects including policy, finance, and culture. From 2013 to 2018, the total value of goods trade between China and BRI countries exceeded US$6 trillion. As a consequence, logistics has been impelled. Especially, between 2013 and 2018 the number of block trains between China and Europe (including from / to Russia and Central Asia) increased from 80 to 6,363 per year. As of June 2019, a cumulative number of 17,000 China-Europe block train trips was completed reaching 53 cities in 16 countries via east, middle, and west gateways respectively Manzhouli, Erenhot, and Khorgos [Belt and Road Portal, 2019].

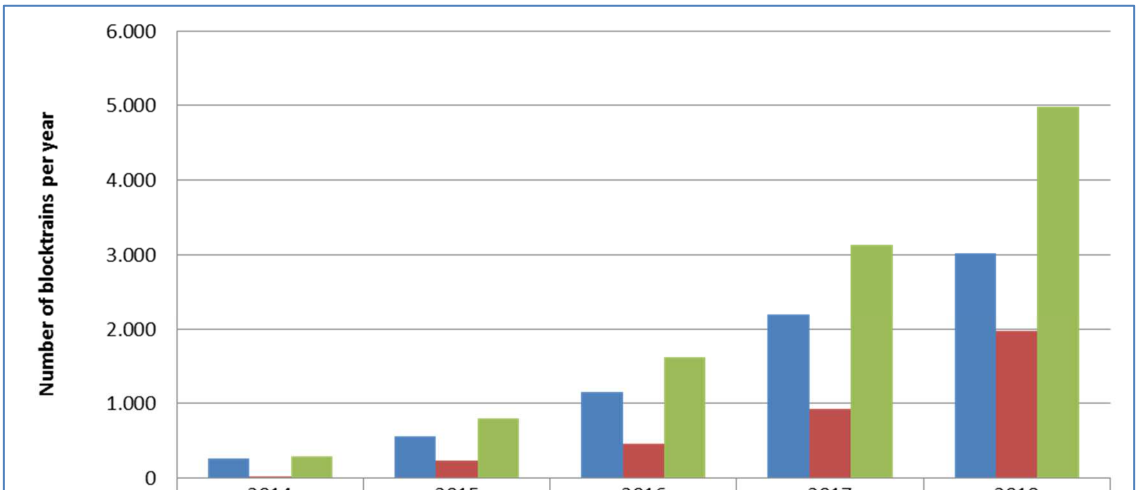
78% of all block trains from / to China relate to Europe. The Chinese government's forecast that around 5,000 block trains will travel to Europe in 2020 has already been reached in 2018. With an average capacity of 90 TEU / train, this equates to some 450,000

TEU in both directions. The unbalance of the traffic could be reduced continuously.



Source: Belt and Road Portal, see https://www.yidaiyilu.gov.cn/ydylcylznzd/cjc/102467.htm

Fig. 2. Number of block trains between China and Europe (including Russia)



	2014	2015	2016	2017	2018
Westbound	270	567	1.157	2.200	3.015
Eastbound	28	236	458	930	1.967
Total	298	803	1.615	3.130	4.982

Source: Chinese Railways, https://card.weibo.com/article/m/show/id/2309404326026917355445

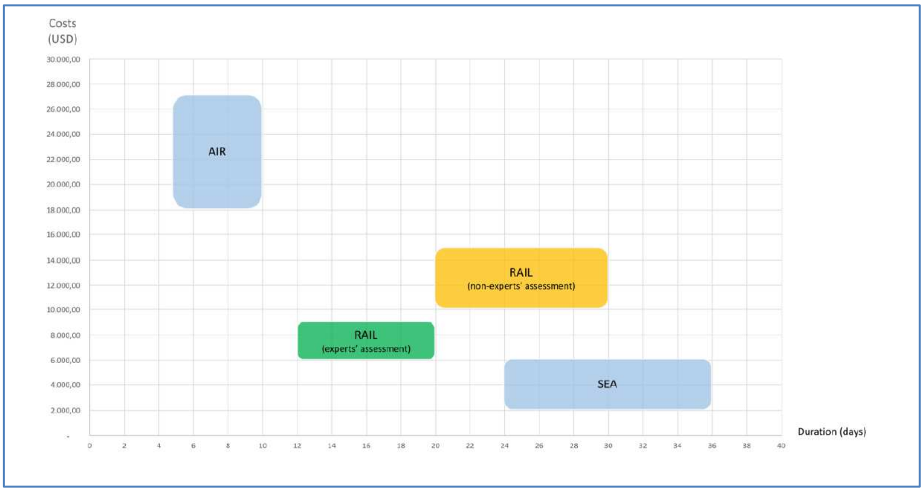
Fig. 3. Number of block trains (Eastbound / Westbound) between China and Europe (excluding Russia)

INTEGRATION OF THE NEW SILK ROUTE INTO GLOBAL SUPPLY CHAINS

The "New Silk Route" opens new opportunities for global supply chains as well as for the regional development in the northern provinces of China but also for developing regions in transit countries along the corridors. Multinational companies and exporters benefit from the new rail based corridors complementing the established sea and air services between China and Europe. Picture 4 shows that the time / costs – ratio of rail shipments lays between air and sea transport, i.e. half of the time of sea freight for one third of the costs of air freight.

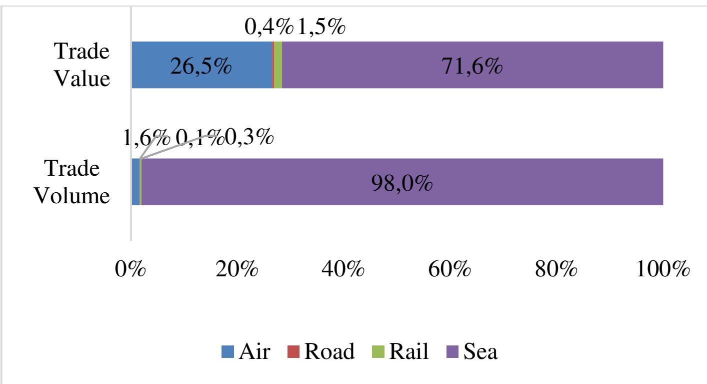
With this specific time / costs ratio the rail services between China and Western Europe serve a special market segment for more time but less costs sensitive commodities than in sea freight, especially to/from Northern China and inland destinations in Western Europe.

According to a recent study it is estimated, if cargo sent by ocean vessel had a value higher than € 85,000 per TEU, it would be more cost-effective to shippers to send it by rail. This study comes to the conclusion, that of the two-way sea freight of forecasted 40 million TEU (including empty containers) in 2040, around 2.5 million TEU could transfer to rail [Steer Davies Gleave, 2018].



Source: Beifert, et al., 2018

Fig. 4. Estimation of the standard TEU container shipment from China (e.g. Chongqing) to Western Europe (e.g. Duisburg, Germany)

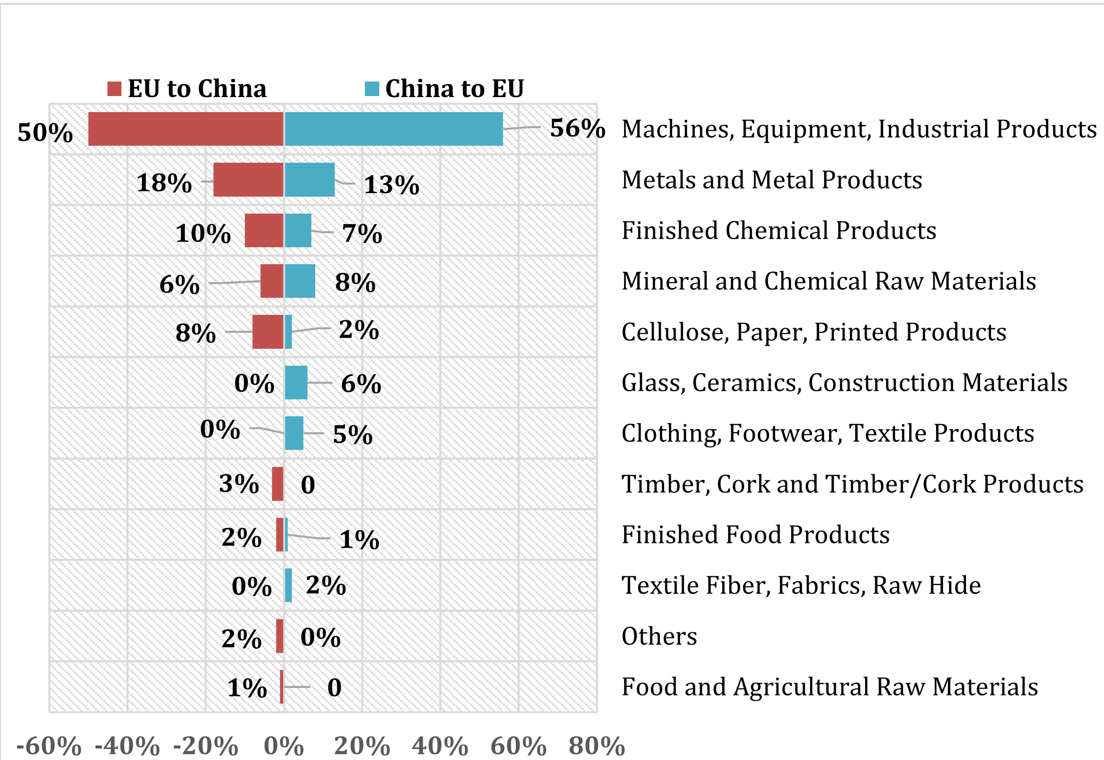


Source: World Bank Internal Analysis

Fig. 5. Composition of China-Europe Freight by Value and Volume by Transport Mode (2016)

For the foreseeable future, the majority of freight by volume will continue to use maritime routes. However, for the niche markets, the land bridge offers an interesting alternative. As of 2016, about 98% of Europe-China freight is moved by maritime transport with aviation and railways accounting for 1.6% and 0.3% respectively. Air freight dominates high value goods. Although constituting 1.6% of total freight volume, air cargo makes up some 27% of value of freight. The opportunity exists for freight between € 6,000 to € 15,000 per ton to use the rail-based land bridge. The challenge is making this alternative mainstream.

For transit rail freight between Europe and China, further analysis shows that most of freight coming from Europe to China consists of private cars and components as well as of engineering products (engine parts, pumps, electrical components etc.). These manufactured products constituted 50% of total freight by volume. Other notable products include chemical products and timber by products (paper and pulp). The reverse cargo from China to Europe is made up of machinery, equipment, and industrial products which make up about 55%. Others include raw minerals and chemical materials, construction materials, clothing, textiles, and footwear. All these major freight categories are niche freight types suitable for containerization that would normally not go by air freight due to the costs of transit but which moving by ship would take longer than most shippers would prefer.



Source: World Bank Internal Analysis

Fig. 6. Commodity Structure of EU Railway-Carried Exports to/Imports from China (2016)

In the current situation, containers remain the preferred method of delivery of freight between Europe and China. The use of containers guarantees preservation of cargo, standard dimensions, reduced packaging costs, accelerated cargo handling, and can facilitate unified shipping documents and forwarding. Therefore, any discussion of infrastructure and logistics needs for transit freight between Europe and China must take place, primarily, in the context of intermodal freight solutions.

In a globalized economy production sites of large multinational companies or collaboration networks move over time as a result of seeking optimum profitability. Also consumption behaviors change with increasing welfare. As a result, international trading patterns may change gradually or even totally in the future. Therefore, predicting future patterns in freight transport is very difficult . Logistics strategists in multinational companies seek to plan their supply chains as cost efficient and as flexible and agile as possible. International transport operators and logistics service providers are in need to offer alternatives and permanent adjustments of their services. In this respect the "New Silk Route" should not be seen as a point to point corridor between Europe and Asia only but as a comprehensive transport network connecting numerous locations in more than 40 countries in Asia and Europe which allows a high degree of flexibility in changing supply chains and distribution to markets.

Example: BMW supply chain Leipzig (Germany) - Shenyang (China)

An example for changing trade patterns and corresponding adjustments of supply chains is the development of BMW in China. The country is BMW's largest single sales market, with 560,000 vehicles sold there in 2017. BMW plans to invest 3.5 billion € in China, in particular in new and existing plant facilities in Shenyang, increasing production capacity to 650,000 vehicles a year from the early 2020s. The plants produced 400,000 vehicles in 2017. The new plant will produce fully electric, partly electric, and conventional vehicles on the same line [Industrial Equipment News, 2018].

The first BMW container train was launched in 2011 as a private company train. About 8,000 different car components are carried over the 11,000 km route from Leipzig and Regensburg to China, for assembling in the joint venture company BMW Brilliance in Shenyang. Now the train needs 17 days only (20 days door-to-door) and runs daily on the relation Leipzig – Shenyang. Compared with airfreight the rail transport saves 150,000 tons CO_2 per annum. The train is operated by DB Schenker and is open for third clients also. (Railways, 2016) German car manufacturers send about 63,000 cars CKD (completely knocked down) annually for further assembling in China in order to avoid high import duties. [Handelsblatt, 2019] With the new factory in Shenyang for electric cars the import of components may be expected to rise thus reducing the imbalance of the trade. These dedicated company trains between production sites serve as "warehouses on wheels" within Just-In Time international supply chains. 100% reliability is a very precondition for production planning systems and sales programs.

Source: Belorussian Railways, 2019

Fig. 7. Route of the BMW company train between Leipzig and Shenyang via Brest and Zabaikalsk

OBSTACLES AND CHALLENGES

The lack of interoperability of railways in terms of legal, operational and technical terms is a major historical obstacle for traffic along the routes. But there are also capacity, economic and financing constraints which need to be tackled.

Lack of systematic design and coordination

There are over 60 cities operating westbound block trains to Europe. All these routes are managed by local governments. The lack of systematic top-level design and regional coordination has led to inefficiency in terms of railway capacity utilization and resource allocation.

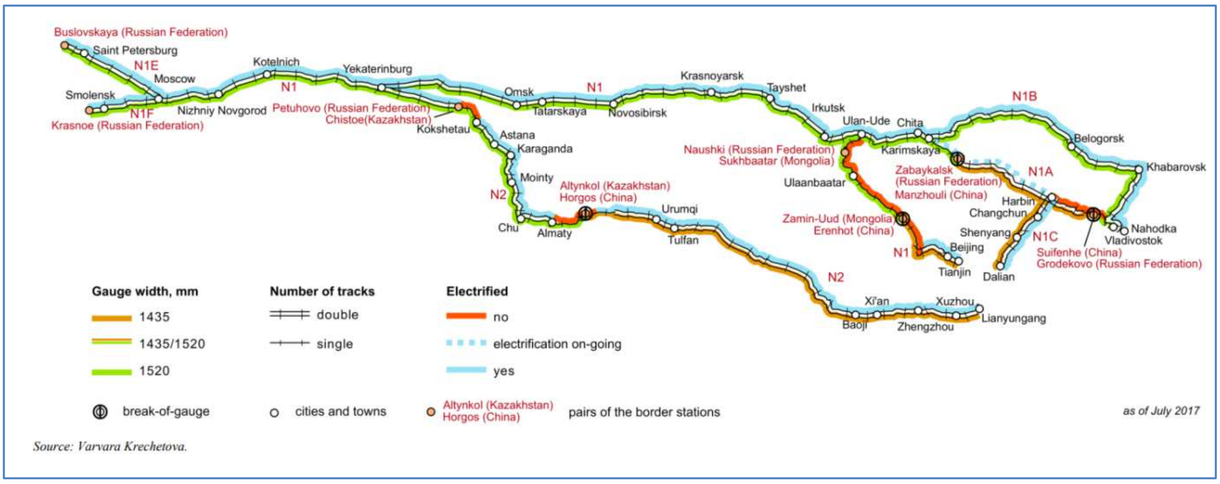
Different technical systems of railways

Different gauges, electricity systems, train lengths, signaling and rule books are the main technical obstacles. For example on the route from Duisburg (Germany) to Lanzhou (China) depending on the routing 77% to 95% is double track and 68% to 95% is electrified.

Table 1. Technical parameters of different routes between Duisburg and Lanzhou

Sections of the route	**Distance, km**	**Double track, km**	**Electrified, km***
TransSib – Kazakh route			
Duisburg – Moscow	2,363	2,363	2,363 with 3kV DC and 25kV AC 50Hz
Moscow – Dostyk	4,353	3,514	**3,514 with 3kV DC and 25kV AC 50Hz**
Dostyk – Lanzhou	2,402,3	1,676	295 with 25kV AC 50Hz
Total Duisburg Lanzhou	**9,118,3**	**7,553**	**6,172**
TransSib – Mongolian route			
Duisburg – Moscow	2,363	2,363	2,363 with 3kV DC and 25kV AC 50Hz
Moscow – Zamyn Uud	7,021	5,654	5,649 with 3kV DC and 25kV AC 50Hz
Zamyn Uud – Lanzhou	2,645	1,781	1,857 with 25kV AC 50Hz
Total Duisburg Lanzhou	**12,029**	**9,798**	**9,869**
TransSib – Manchurian route			
Duisburg – Moscow	2,363	2,363	2,363 with 3kV and 25kV50Hz
Moscow – Zabaykalsk	6,660	6,442,4	6,442,4 with 3kV and 25kV50Hz
Zabaykalsk – Lanzhou	4,033	3,579	3,042 electrified with 25kV50Hz
Total Duisburg – Lanzhou	**13,056**	**12,384,4**	**10,201,2**

Source: European Commission DG TREN, 2012



Source: UNESCAP

Fig. 8. Illustration of Existing Rail Routes Connecting Western China to Europe

For example, the Russian railway lines on the TSR are electrified and double tracked with several of the remaining sections in process of electrification. The main constraint is in Mongolia were the lines are single tracked and in poor condition.

In general, however, since transit trains travel on scheduled services, the railways in Russia and Kazakhstan are more than able to accommodate the containerized services at current volumes. Container transit through Belarus runs through an electrified double-track section. Moreover, some $2.5 billion were invested in 2011–2017 in projects designed to enhance the Belarusian Railways' capacity, including a $700 million investment in the development of Belt and Road routes. To deal with the congestion on the European railway network, some shippers have set up distribution centers to complete the final leg by truck. This is likely a short-term solution. In the long run, on-going investments in Polish railways and the rest of the EU rail network will alleviate the capacity constraints on the networks. However, it is likely that in the medium term this will affect the level of service and cap the potential growth in throughput [Bernard Aritua, 2019].

Quality and capacity of crossing point between Brest in Belarus and Małaszewicze in Poland

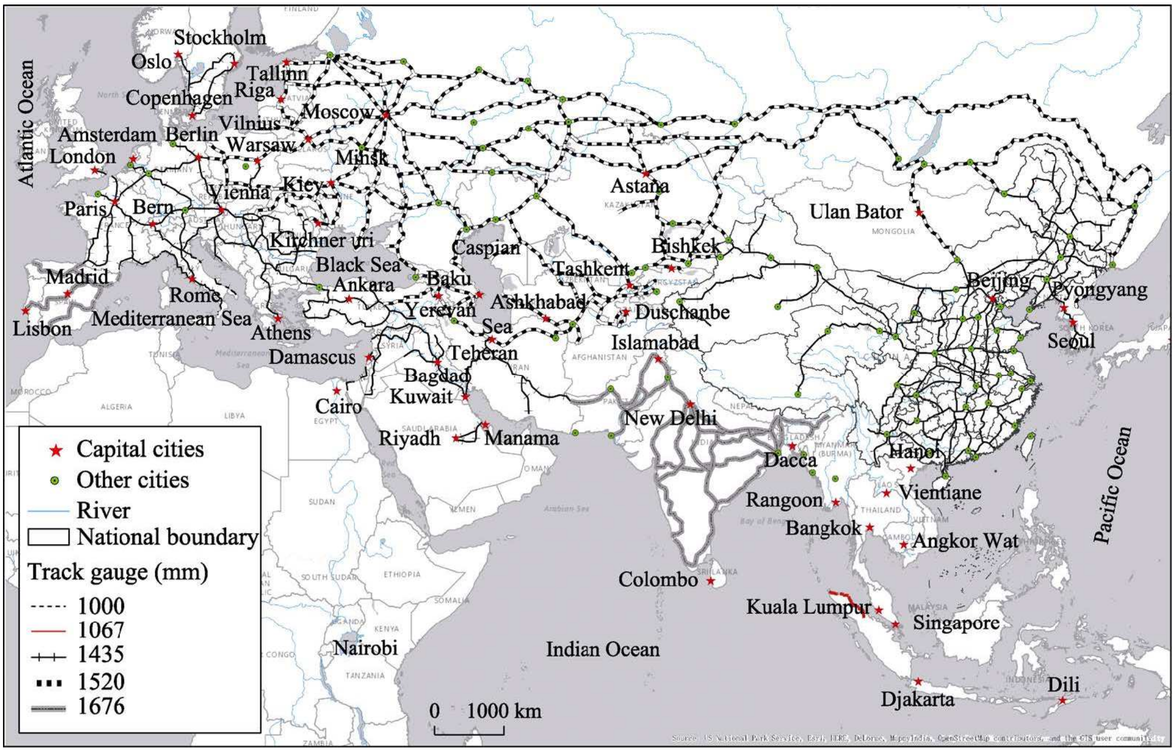
Most trains on the Northern routes access Europe through the Belarus-Poland link. The importance of Belarus has been magnified by the breakdown of political relations between Russia and Ukraine – which would otherwise serve as a secondary entry point to Europe. Before the transit freight between Europe and China increased dramatically in 2016 an average of 5 trains per day crossed the border from Belarus to Poland at the Belarus-Małaszewicze crossing. By the end of 2017 the number of trains exceeded 10 per day. This has proved to be more than the crossing can efficiently handle. Due to change in railway gauge, all freight needs to be transshipped and because the railway infrastructure, locomotive fleet, and rolling stock have not been upgraded for a long time, this crossing is an impediment to free flow traffic. As traffic has increased, this has placed considerable strain on the transshipment facilities. The response by operators has been to look for alternative end-points in Europe, such as Lithuania, Finland and Kaliningrad until capacity at the main crossings is increased.

Train length restrictions

The length of trains composed by various railway companies depends on a number of factors: length of station tracks, train weight, locomotive power, route profile, technical capabilities of route legs (crossing points/stations, side tracks, passing tracks and way stations, whether automatic block systems are employed, intermediate light signals), station track plans and profiles, shunting work conditions at individual stations, technical and technological capabilities of intermediate and line stations, marshalling yards, etc. The length of the train determines the load - in this case, the number of containers loaded onto container platforms. Typically, most trains from China bound for Europe are 801m long. This is not a problem until the trains get to Poland which according to applicable norms and regulations cannot accommodate trains exceeding 600 m. Therefore, as part of the transshipment the train-lengths must be reduced while the remaining containers wait at the marshalling yard for the next train [Aritua, 2019].

Railway Track Gauge changes

The difference in railway track gauges between former USSR countries (1,520 mm), the PRC (1,435 mm), and Western Europe (1,435 mm) requires the transshipment of cargoes or exchange of bogies at border crossing stations. Three main options exist to increase interoperability: (a) transshipment from rolling stock running on 1,435/1,520 mm gauge to rolling stock running on 1,520/1,435 mm gauge; (b) use of variable gauge rolling stock, enabling seamless transition from one gauge to another; (c) bogie exchange at an interchange station. At present, the least cost option is transshipment but this relies on the capacity of siding tracks and gantries [Aritua, 2019]. A China-Europe block train goes through two transshipments on average before reaching a final destination, adding 50% of operational cost [Jiaoe, 2018].



Source: Jiaoe, 2018

Fig. 9. Rail Track Gauges in BRI Countries

Administrative & legal obstacles

There are some challenges related to border and customs formalities, however, feedback from forwarders and logistics companies report that these do not currently represent a serious barrier for transit rail freight and trade. Most countries in the region have started pursuing a coherent policy designed to standardize rules and documents to minimize the time required to complete formalities. These efforts are codified in agreements within the Eurasian Economic Union and Trans-Asian railway agreements.

Insufficient standardization of shipping documents and technical regulations remains the main administrative and legal obstacle to the increase of freight along the whole route. Railway freight traffic is regulated in EU countries by the Convention concerning International Carriage by Rail (COTIF). CIS countries, the Baltic States, Albania, Iran, the PRC, the DPRK, Vietnam, Mongolia, Hungary, and Slovakia use the Agreement on International Goods Transport by Rail (SMGS). The use of the CIM/SMGS common consignment note gives a strong competitive edge to railway shipments through Eurasian space. However, more work needs to be done to standardize normative documents and technical regulations used in Eurasian countries (rules for shipping various types of cargoes, rolling stock operating parameters, environmental standards, etc.). For Eurasian railway services, implementation of the CIM/SMGS common consignment note in electronic form is assessed to be the biggest potential source of bottleneck alleviation that would reduce delays and economic losses. [UNESCAP, 2017] Legal and regulatory systems are being harmonized for the transit freight through the Eurasian Economic Union, yet additional coordination between the Eurasian Economic Union and China would be advantageous.

Economic & financing challenges

In order to promote regional development and to meet freight volume targets Chinese province governments subsidize block train costs. Subsidies range from under 50 % to about 75 % of the unsubsidized costs [World Bank Group, 2019]. The Chinese government is going to reduce these subsidies continuously which challenges transport operators and their customers to find new solutions to make block trains more economical. The growing traffic and the need for more efficient operation require big infrastructure investment and rail rehabilitation projects which go beyond the financial possibilities of investors or governments, especially of smaller countries. Also megaprojects bear high risks which need to be controlled.

Table 2. China-Europe Block Train Subsidy by province in China (2018)

City	Subsidy to China-Europe Block Train
Harbin, Xi'an, Hefei	US$3000 per Forty-foot Equivalent Unit (FEU)
Chengdu, Chongqing, Guangzhou	US$7,300-7,500 per FEU
Suzhou	Corporate income tax refund
Chongqing	Land resource and corporate income tax refund
Ministry of Finance of China set a subsidy of US$0.8 per FEU per km as the national guideline	

Source: China Ports and Harbours Association, 2019, China Business Journal, 2019

OPPORTUNITIES FOR THE FUTURE

How could the traffic become more efficient and profitable in order to compensate subsidies?

Gateway concepts and high performance terminals

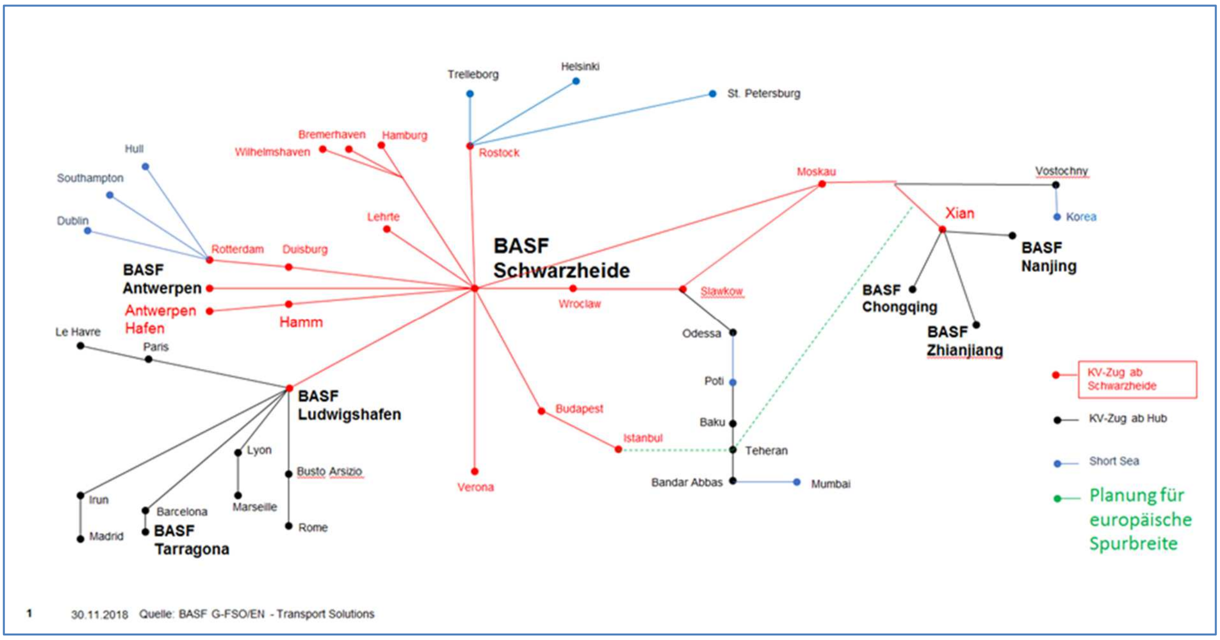
Gateway concepts for container trains would reduce costs further (like airline hubs) through bundling of cargo flows on the main route. Also the last mile transport per road could be reduced. Nowadays trains go to Hamburg and Duisburg and then the on-carriage into the opposite direction backwards to Berlin etc. is on road. More Eastern gateways (e.g. in Małaszewicze (PL) or in Schwarzheide (D) could serve as consolidation / bundling hubs connected by train connections further on. More cargo could be attracted, train frequency could be increased, more stations could be connected and finally costs could be reduced.

Małaszewicze (Poland) is a well- suited location for such a gateway function since there is a change of track width between 1,520 mm / 1,435 mm. Also the different maximum train lengths of up to 955 m in Belarus and of 600 m in Poland require the marshalling of waggons and consolidation of new segmented resp. consolidated trains to Europe resp. to Belarus. Under the provision of adequate infrastructure capacities a future gateway concept in Małaszewicze could serve as a high performance mega hub connecting high capacity and high frequency block trains from Asia with lower capacity and high frequency trains further on to several different locations in Europe and respectively vice versa. Such a mega hub could serve several incoming and outgoing trains by direct transshipment of containers between trains without marshalling of waggons.

Also industry related gateway concepts are feasible. BASF is planning such a gateway for Asian traffic in Schwarzheide in the Eastern part of Germany.

Trains from Western, Northern and Southern Europe will be directed to Schwarzheide where containers are transshipped to trains serving different locations in Eastern Europe and Asia. This enables a higher efficiency and frequency of services.

Significant impulses for Schwarzheide as a gateway are provided by developments in the Chinese market. At present, rail transport of dangerous goods on container trains in China is not yet possible, as regulations prevent this. According to industry insiders, the opening for the transport of dangerous goods is expected. In addition, BASF continues to invest in China and expand the network of production sites. In Guandong, the BASF Group is planning a production site with an estimated investment of approximately $ 10 billion. Completion is scheduled for 2030 [Hofmann, 2018].



Source: BASF, cited in Wagener, et al., 2019

Fig. 10. Intermodal terminal Schwarzheide (Germany) as a future gateway to Eastern Europe / Asia in the BASF production network

Corridor management

Especially on the Trans-Caspian route the service is too expensive and not reliable. A better co-operation of countries and railways and a corridor management would be of benefit. On the 1520 mm countries (Russia, Kazakhstan, White Russia) the company "The United Transport and Logistics Company – Eurasian Rail Alliance" (JSC UTLC ERA) as a joint venture of the Kazakh, the Russian and the White Russian railways operates as a joint operator of block trains running through their territories. Also in the European Union rail freight corridors are defined and managed jointly by the European rail infrastructure providers.

Reduction of empty returns from Europe through more balanced trade

In 2018 the Eastbound trade was 1/3 less than the Westbound trade, this results in higher rail freight per container and costs for returning empty containers. A solution is to attract more FMC (Fast Moving Consumer Goods) Eastbound through e-commerce platforms and consolidation / containerization of express cargo in Germany, also for SME export.

Increasing capacity of containers

Nowadays maritime ISO containers prevail, but in land transport the 45' pallet wide high cube container could offer a larger capacity. 40' standard container can carry 22 pallets (1 layer), 45' pallet wide can carry 26 Euro pallets (80 x 120 cm). This would increase the capacity by almost 20%.

Expanding the markets for landbridge container traffic

More volume on the landbridge routes could be generated through nodes on the routes connected by antenna routes which serve as feeder connections to middle size agglomerations, like a "fishbone". Also to open the rail market for dangerous goods on Chinese side would boost the demand considerably. This higher traffic volume would result in lower costs through economy of scale.

Digitalization and Blockchain

Information technology has already improved the operation on the landbridge routes considerably. Containers can be equipped with sensors and real time information via GIS can be provided to the shippers on the actual GPS position of the container, temperature, intrusion and shocks. Operators integrate information from railways on platforms for their clients. Beyond this blockchain technology is an opportunity for the near future to enable full data interoperability, i.e. full paperless information between all parties involved, instant financing and fully door-to-door-tracked container movement in a trusted and secure manner. New technologies such as blockchain have the potential to take over supply chain management and disrupt traditional ways of working. A Proof of Concept (PoC) for Samsung seafreight between Korea and Rotterdam demonstrated that a comprehensive supply chain management system with paperless integration of physical, administrative and financial flows is now feasible [TransFollow, 2019].

Global supply chain involves participants such as manufactures, forwarders, shippers, customs agents, and insurers. Blockchain technology has been proofed as a transparent and immutable shared record book to track containers. Each participant in a global supply chain is able to monitor the status of goods movement with corresponding permissions. Information is shared across the consensus network with high level of security and durability. No party can modify, delete or append any record unilaterally. Blockchain with its featured smart contract framework provides solutions to improve logistics efficiency through the following key features:

- Greater transparency of the logistics process.
- Less paper work and clear responsibility. A pre-defined smart insurance contract is stored on a blockchain and is executed automatically as part of a transaction.
- Trust and credibility grow as all transactions are immutably recorded.
- Costs are reduced by eliminating intermediators.
- Optimize business processes by analysing information chains recorded by blockchain.

POLICY AND FINANCIAL IMPLICATIONS AND RECOMMENDATIONS

1. It is important for countries along the new Silk Road to harmonize trade and investment policies which are often restrictive, and trade agreements between corridor economies tend to be shallow and fragmented. Gaps in infrastructure compound gaps in policy, and cross-regional integration is mostly missing. Border delays can be over 40 times higher in low-performing countries than in the best performing countries.
2. Integrated and synchronized development of infrastructure – particularly for countries in Central Asia will derive more benefit than if countries build railways or roads in isolation. Cross-border cooperation can further enhance the value of a country's investments - by adopting harmonized standards for infrastructure.
3. The value of individual railway projects depends on the realization of others. Project selection and appraisal and the inclusion of BRI projects in national development strategies are essential to avoid stranded infrastructure. Cooperation among participating countries can also ensure that projects are not redundant and that they maximize value from a regional perspective.
4. Some policy reforms to facilitate trade and improve corridor performance require country-specific actions and cooperation. Supply-chain bottlenecks in a single country could block the potential benefit of the entire corridor in unlocking new trade opportunities. Deepening trade agreements among corridor economies could reduce the current fragmentation and establish the rules and mechanisms for trade and other policy reforms.
5. Some Financing Issues– several risks and challenges have to be managed to ensure the benefits are also passed onto transit countries. This includes coordinating infrastructure investments on critical links that cross borders, managing social, environmental, and corruption related risks; and managing public debts. A range of policy and financing instruments will be needed to derisk and to deliver key

infrastructure while addressing soft issues related to non-tariff barriers (World Bank Group, 2019). International finance institutions can initiate and safeguard investments and institutional mechanisms to support cross-border programs (Beifert, et al., 2018).

CONCLUSIONS

The New Silk Route between Europe and Asia has proven its importance for an effective functioning of synchronized global supply chains. After a dynamic rise of the intermodal traffic on this New Silk Road since 2013 the route now reaches limits for further growth. Major challenges for further growth are limitations in capacities due to infrastructure bottlenecks, lack of interoperability of railways and of sustainable efficiency (subsidies). As major instruments for further improvements on the New Silk Road country specific actions into infrastructure and international co-operation for a joint corridor development and management could be identified. Also on the operating level co-operation is needed to develop joint train platforms on main routes which are connected via hubs with spoke connections into different regions on both ends of the route in Asia and Europe, complemented by real time information platforms and block chain solutions for trade and transport data.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

Statutory fund of Poznan School of Logistics.

REFERENCES

Aritua B.N.H., 2019. World Bank Policy Research Working Paper Series: The Belt and Road Initiative Connectivity and Infrastructure Gaps, Beijing: s.n.

Beifert A., Sherbanin Y., Vinokurov E., 2018. Challenges and Opportunities of Economic Integration within a Wider European and Eurasian Space - Trans-Eurasian Land Transport Corridors: Assessment of Prospects and Barriers, Laxenburg (Austria): IIASA International Institute for Applied Systems Analysis.

Belorussian Railways, 2019. Press Centre - BMW. [Online] Available at: https://www.rw.by/cargo_transportation/container_transportation/accelerated_trains/bmw/ [Accessed 25 08 2019].

Belt and Road Portal, 2019. Six Years' Review of Belt and Road Initiative. [Online] Available at: www.yidaiyilu.gov.cn/xwzx/gnxw/102792.htm

China Business Journal, 2019. [Online] Available at: http://www.wuliujia2018.com/html/37743.html [Accessed 27 09 2019].

China Ports and Harbours Association, 2019. [Online] Available at: http://www.port.org.cn/info/2019/203356.htm [Accessed 27 09 2019].

European Commission DG TREN, 2012. RETRACK WP 13: Potential for Eurasia land bridge corridors & logistics developments along the corridors, Brussels: European Commission.

Handelsblatt, 2019. Neue Seidenstraße - Wie Österreichs Bahn die europäische Konkurrenz im China-Geschäft abhängen will. [Online] Available at: https://www.handelsblatt.com/unternehmen/handel-konsumgueter/neue-seidenstrasse-wie-oesterreichs-bahn-die-europaeische-konkurrenz-im-china-geschaeft-abhaengen-will/21229642.html [Accessed 25 08 2019].

Hofmann S., 2018. BASF plant 10-Milliarden-Projekt in China. Handelsblatt, Issue 09.07.2018.

Industrial Equipment News, 2018. BMW Ramps Up Investment in China. [Online] Available at: https://www.ien.com/supply-chain/news/21026860/bmw-ramps-up-investment-in-china [Accessed 25 8 2019].

Jiaoe W., 2018. An organizational model and border port hinterlands for the China-Europe Railway Express. Journal of Geographical Sciences, 28(9), 1279.

Railways, 2016. Sibirische Zugroute wird zum Erfolgsmodell. [Online] Available at:

https://www.dbcargo.com/resource/blob/1796314/544f6a52a136911bc1a0b148b866c714/BMW-data.pdf [Accessed 30 08 2019].

Steer Davies Gleave, 2018. Research for TRAN Committee: The new Silk route - opportunities and challenges for EU transport, Brussels: European Parliament, Policy Department for Structural and Cohesian Policies.

TransFollow, 2019. First blockchain container shipped to Rotterdam. [Online] Available at: https://transfollow.org/news/blockchain-deliver/ [Accessed 30 08 2019].

UNESCAP, 2017. Comprehensive Planning of Eurasian Transport Corridors to Strenghen the Intra- and Inter-Regional Transport Connectivity, s.l.: UNESCAP.

Wagener N., Bamler N., Behrens R., 2019. Potenzialstudie für den intermodalen Güterverkehr in der Wirtschaftsregion Lausitz, Bad Muskau: ZukunftsWerkstatt Lausitz.

World Bank Group, 2019. Belt And Road Economics - Opportunities and risks of transport corridors, Washington: International Bank for Reconstruction and Development / The World Bank.

NOWY JEDWABNY SZLAK: MOŻLIWOŚCI GLOBALNEGO ŁAŃCUCHA DOSTAW I WYZWANIA DLA DALSZEGO ROZWOJU

STRESZCZENIE. Wstęp: Próby stworzenia Nowego Jedwabnego Szlaku z Europy do Azji są podejmowane praktycznie bez przerwy od lat 70-tych XX wieku. Jednak dopiero utworzenie inicjatywy Belt and Road Initiative (BRI) przez Chiny w 2013 zdynamizowały stworzenie połączenia między Europą a Azją. W okresie 2014 do 2018 ilość transportów szynowych pomiędzy Chinami a Europą (włączając Rosję) wzrosła z 298 do 4982 rocznie. Czy trend ten będzie utrzymany? Jakie są ograniczenia i wyzwania? Jakie są możliwości dla współudziałowców (krajów), twórców polityki, przewoźników i operatorów logistycznych? Praca ta jest naukowym pytaniem dotyczącym dalszej segmentacji transportu intermodalnego w kontekście globalnych łańcuchów dostaw.

Metody: W oparciu o przegląd literatury naukowej oraz wywiadów przeprowadzonych z operatorami logistycznymi i przewoźnikami, przeanalizowano projektowe i operacyjne parametry system intermodalnych transportów, główne wyzwania i ograniczenia oraz zaproponowano środki umożliwiające przyszłościowy wzrost i zrównoważony rozwój tego typu transportu.

Wyniki: Głównymi czynnikami umożliwiającymi dalszy rozwój Nowego Jedwabnego Szlaku Europa Chiny są nowacje technologicznego, cyfryzacja łańcuchów dostaw, optymalizacja transportu intermodalnego i koncepcji bram, zarządzanie korytarzami oraz nowe metody handlu oparte o e-handel.

Wnioski: Jakkolwiek intermodalne połączenia lądowe pozostaną na razie zapewne rynkiem niszowym, to oferują one istotną oszczędność czasu tranzytu oraz ponoszonych kosztów w przypadku specyficznych typów ładunków, dla których fracht lotniczy jest zbyt drogi a morski zbyt wolny. Szczególnie północne prowincje Chin są zainteresowane tym typem transportu o aczkolwiek wyższych kosztach w stosunku do transportu morskiego ale niższych niż w przypadku transportu lotniczego. Jest to również wielka możliwość dla Centralnej Azji i Kaukazu. Nowe szlaki transportowe promują inwestycje nie tylko w obszary produkcyjne eksportowe dla lokalizacji w północnych prowincjach ale także otwierają nowe możliwości dla eksporterów europejskich dóbr przemysłowych oraz FMCG skierowanych do konsumentów z rosnącej klasy średniej w Chinach. Całkowite koszty logistyczne z punktu widzenia wysyłającego mogą być bardziej konkurencyjne w przypadku trasy lądowej aniżeli trasy morskiej. Duże korporacje zarówno produkcyjne jak i dystrybucyjne (np. BASF, HP, BMW) jak również firmy małej i średniej wielkości (szczególnie korzystające z możliwości e-handlu) mogą wiele zyskać na dalszej integracji rynków oraz globalizacji łańcuchów dostaw.

Słowa kluczowe: Nowy Szlak Jedwabny, Belt and Road Initiative, globalne łańcuchy dostaw, transport intermodalny, cyfryzacja, zarządzanie korytarzem

Norbert Wagener
Poznan School of Logistics, Poznan, **Poland**
e-mail: norbert.wagener@wsl.com.pl

Bernard Aritua
Senior Infrastructure & Logistics Specialist – Central Asia, China and Mongolia
The World Bank Group, **China**
e-mail: baritua@worldbank.org

Tong Zhu
Transport Analyst
The World Bank Group, Bejing **China**
e-mail: tzhu1@worldbank.org

LogForum

> Scientific Journal of Logistics <

2020, 16 (2), 209-218

http://doi.org/10.17270/J.LOG.2020.395

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

RUSSIA'S NATIONAL LOGISTICS SYSTEM: MAIN DIRECTIONS OF DEVELOPMENT

Ruslan Beysenbaev, Yuri Dus

Dostoevsky Omsk State University, Omsk, **Russia**

ABSTRACT. **Background:** The subject of this research is the formulation of recommendations for the improvement of the national logistics system of the Russian Federation. The aim of the work is to analyze Russia through 6 dynamic indicators across 11 years. It should be understood that state policies and measures take time to be implemented and carry certain costs with them, which precludes momentary full-scale development. Triage is needed to understand the critical sectors of the national logistics system that are the most underdeveloped at the current moment, with future resources already aimed at small-scale development and/or helping newly developed logistics areas function at a satisfactory level. By itself, logistics development is very important for any country in the current international market, with Russia having the potential to be a crucial transport link between East-West/West-East product and container flows.

Methods: Russia's country-level logistics system is analyzed by us through the use of the World Bank's Logistics Performance Index and its 6 indicators. Detailed observation allows the pinpointing of problematic areas and further development of group solutions and recommendations at the state level.

Results: Recommendations for national logistics system development grouped in a prioritized list with 2 different resulting scenarios. Division of measures is needed since resource scarcity may not allow wide full-scale eradication of all identified logistical bottlenecks at once. Approximate results of scenario implementation given through comparable estimates made by governmental bodies.

Conclusions: The developed scenarios with appointed integration conditions are aimed at the development of Russia's national logistics system for a better competitive situation in the international market.

Key words: Logistics Performance Index (LPI), Russia, international transport corridors, international logistics, infrastructure, state transport policy.

INTRODUCTION

Transport and logistics services facilitate international trade and play an important role in the growth and development of any economy. The quality and efficiency of logistics services can be important for international trade, as a weak logistics infrastructure and insufficiently developed operational processes can be some of the main obstacles to integration into international trade.

Logistics services link several industries within local economies. They also link the domestic economy with the international one and provide links between various interdependent manufacturing sectors (agriculture, manufacturing, tourism, and so on). The economy is strengthened by efficient transportation and logistics systems since it is important for manufacturers to safely transport their goods in a cost-effective way with minimal time delays.

The continued growth of world trade and the desire of many countries to accelerate the pace of integration into the global trading system will depend not only on maintaining an open global economic system but also on increasing the number and effectiveness of supporting structures, such as country-level logistics systems.

Citation: *Beysenbaev R., Dus Y., 2020. Russia's national logistics system: main directions of development. LogForum 16 (2), 209-218, http://doi.org/10.17270/J.LOG.2020.395*

Received: 28.10.2019, Accepted: 09.01.2020, on-line: 30.03.2020.

Empirical studies suggest that transport infrastructure inefficiencies can have an adverse effect on trade. For example, in a study of air travel in South Africa [Dettmer et al. 2014], it was concluded that a more liberal market for air transportation services could reduce transport costs and facilitate further trade integration. A general view of logistics being a significant factor of international trade has been echoed in several studies, through export-import and logistics variables correlation analysis [Beysenbaev 2018], through international trade statistics and logistics variables panel data analysis [Luttermann et al. 2017] and through focused regional research [Edirisinghe 2013].

Thus, logistics efficiency plays an important role in economic growth and improving the country's competitiveness. Inefficient logistics increases overall costs and reduces the likelihood of global integration [Guner and Coskun 2012]. Evaluating the effectiveness of logistics requires the use of various indicators that characterize its efficiency and productivity. Macroeconomic criteria and indicators characterizing the efficiency of logistics or its individual components have different methodological approaches.

One of the most widespread among researchers is the Logistics Performance Index (LPI) developed and published biannually by the World Bank. It is based on a worldwide survey of global freight forwarders and express carriers. The LPI consists of both qualitative and quantitative indicators and measures the logistics efficiency of over 150 countries across 6 different areas: customs efficiency, logistics infrastructure, tracking and tracing ability, ease of international shipments, logistics services quality, shipment timeliness [Arvis et al. 2018].

The LPI and its indicators have been used in logistics research at an international level [Gogoneata 2008], at a regional level – in Sub-Saharan Africa [Shepherd 2016], and at a national level - in Singapore [Tan and Hilmola 2012]. Moreover, the LPI has been used in different governmental logistics initiatives, mostly as a benchmarking tool. The Finnish Ministry of Traffic and Communications has used the LPI as a dynamic comparative tool in its biannual Finnish State of Logistics Report [Solakivi et al. 2017], Oman uses the LPI as a benchmarking tool and as a target indicator within the framework of The Sultanate of Oman Logistics Strategy 2040 [Al-Futaisi 2015], similar to the Report of the Standing Committee on Transport, Infrastructure and Communities of Canada [Sgro 2019].

This precludes the use of the LPI as a tool for benchmarking country-level logistics systems against different countries, and as an instrument for prioritizing and choosing essential national logistics program directions in a systematic way.

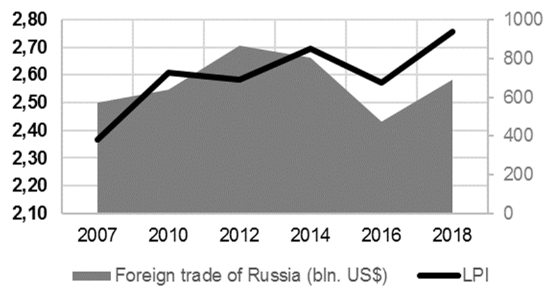
ANALYSIS

The Russian Federation is one of the main partners of the EU, APEC and the CIS [The Central Bank of the Russian Federation 2018]. Fuel and energy products prevail in the export structure, but Russia is also a major exporter of metal, machinery, equipment, chemical products, food products, and agricultural raw materials. Russia also imports machinery, equipment, textile products, pharmaceuticals, and food products.

Moreover, in a territorial sense, Russia is an important transit logistical link between China and Europe with a future project – the Belt and Road Initiative, predicted to develop this link even further [Titarenko et al. 2015]. Thus, the Russian Federation is a major participant in international trade, and the quality and effectiveness of Russia's logistics system are important for international trade.

In order to look at the problems in Russia's national logistics system and to create a systematic solution for its development, we have chosen the LPI as the primary research instrument.

First of all, we need to analyze the biannual LPI scores for the Russian Federation and compare it with the changes in Russia's foreign trade in 2007, 2010, 2012, 2014, 2016 and 2018 (years of LPI release) to determine the relevance of the index to this study (Figure 1). A correlation analysis is not possible, due to the small number of data points – 6. That amount is an insufficient sample size for any significant Pearson's correlation (significant at n≥25) [Bonett and Wright 2000]. This means only a general overview of LPI scores and Russia's foreign trade volumes can be performed.



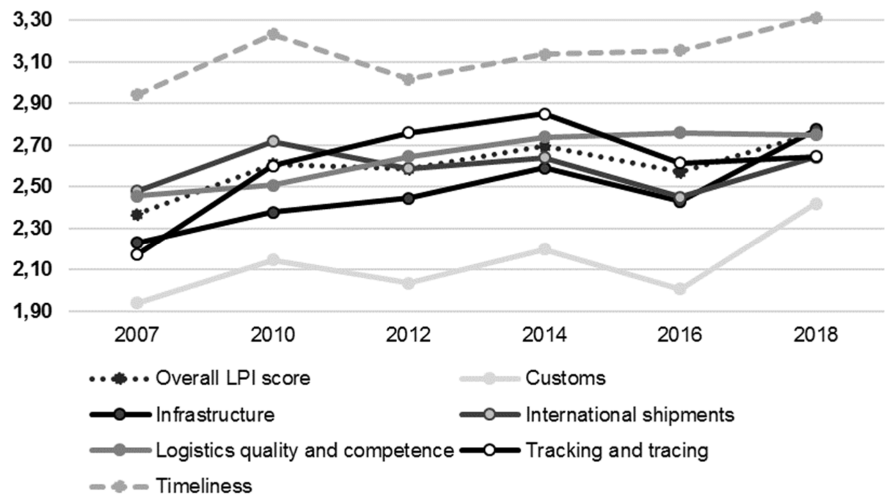
Source: Arvis et al. 2018; The World Bank

Fig. 1. Comparison of LPI scores and Russian foreign trade volumes (2007-2018)

As can be seen from the diagram, the dynamics of foreign trade and LPI scores for Russia are proportional for all observed periods except 2012 (there is a decrease in the LPI score for 2012, compared with an increase in foreign trade in 2012). It is assumed that this fact is associated with a change in indicator weights in all 6 areas of the LPI in 2014, since, firstly, before the 2014 release, indicator weights were distributed differently and the LPI methodology was only being formed and, secondly, 2014 marks the beginning of the parallel movement of the graph lines.

In this way, we can see that the LPI can be used in this study, being a widely used tool for benchmarking logistics aspects and being mostly comparable with foreign trade volumes through it also being a measure of logistics efficiency.

To begin with our analysis, it is necessary to look at all aspects of the LPI in detail over all published periods, as well as to identify positive and negative trends in Russia's logistics system (Figure 2).



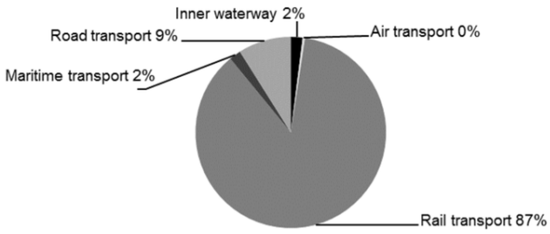
Source: Arvis et al. 2018

Fig. 2. LPI indicator scores for Russia (2007-2018)

It is worth noting that the overall situation in the Russian Federation has improved, although not by much. Starting from 2007, over the course of 12 years, the Russian Federation has improved its performance by 0,39 points, rising from the 99th place to the 75th, from the third quartile of the LPI to the second.

Further, it is necessary to consider the current logistic potential of the Russian Federation, to identify the main bottlenecks and trace their relationship with the corresponding indicator in the LPI and to develop recommendations that will increase Russia's position in this rating.

The least change can be observed for "International shipments", which may reflect some difficulties with cargo clearance procedures, which, in turn, lead to higher prices. This dynamic may also be indicative of possible barriers that prevent cargo from being transported at competitive prices. This includes the strong monopolization of the country's railway network and the size of the country's territory, which forces the country to heavily depend on railway lines for cargo transportation, which is reflected in the fact that the railway transport type prevails over the rest (Figure 3).



Source: Sabelnikova et al. 2018

Fig. 3. Transport type distribution in Russia (2018)

The "Timeliness" indicator remains the highest-rated aspect of Russia's logistics system. This fact may indicate either proper logistical planning in the Russian Federation (the time of cargo delivery from the sender to the recipient is correctly calculated), or the overall high quality of the cargo delivery system, which is unlikely, given the rather low ratings given for the quality of transport infrastructure ("Infrastructure" indicator) in Russia. It is likely that, given the nature of the LPI calculation, wherein only respondents from within Russia or neighboring countries are chosen, LPI respondents have few comparison points.

The most dynamic change can be observed for "Infrastructure", which probably indicates the implementation of measures to modernize and develop the transport infrastructure of the Russian Federation in recent years. A more detailed analysis of infrastructure connected to international trade can be found in section 3.2.

A stable low rating can be observed for "Customs", but it is necessary to note a sharp increase in the rating (2,42 in 2018 compared with 2,01 in 2016) in 2018. This fact can be related to the fact that the Customs Code Agreement of the Eurasian Economic Union (EAEU) from April 11th, 2017 entered into force on the 1st of January, 2018. The purpose of the Agreement was to ensure unified customs regulation in the Eurasian Economic Union, which includes establishing the procedure and conditions for the movement of goods across the customs border of the EAEU, their location and use on the customs territory of the EAEU or outside it, the procedure for performing customs operations related to the arrival of goods at the customs territory of the EAEU, their departure from the customs territory of the EAEU, temporary storage of goods, their customs declaration and release, other customs operations, the procedure for paying customs tariffs, special, anti-dumping, or countervailing duties, use and/or disposal of goods in the customs territory of the EAEC or beyond it. More precisely, this document introduced mandatory electronic declaration in the countries of the Customs Union, and also significantly simplified and accelerated the procedures and process of customs clearance.

The quality and supply of logistics services in the Russian Federation varies greatly and the assessment ("Logistics quality and competence") is stably average, but it is possible to identify some trends in this area, namely: the lack of a formed and unified 3PL market and the absence of system integrators at the 4PL level.

Outsourcing of transport services occupies 22% of the market in Russia or about a fifth of the entire transport and logistics industry. For comparison, 3PL - suppliers occupy 65% of the European market and 48% of the Chinese [TransRussia 2018]. It is important to note that the unsaturated nature of the market means that international firms have every opportunity to advance into Russia. 3PL, as an industry, has only recently taken root in Russia.

Misconceptions regarding the type of services offered and the fact that many Russian companies transport goods themselves are also hindering the development of the industry. While domestic firms are struggling to meet international service standards, foreign firms are moving forward in the Russian logistics industry and occupying open niches.

Regarding the last two areas of the LPI: "International logistics" and "Tracking and tracing", it is difficult to analyze these indicators at a country logistics level, since they are inextricably linked with others and the improvement of dependent systems could definitely affect the estimates. More competitive prices for the transport of goods directly depend on the quality of the logistics services provided within the country and the effectiveness of customs. At the same time, the ability to track cargo directly depends on two factors: the recipient's access to a system that notifies them of the cargo status and the presence of a tracking system with the carrier. Due to the fact that the Russian Federation is not among the countries with a high share of the population cut off from the Internet due to extremely high cost of access [ITU 2018], it is logical to assume that low ratings for this aspect in LPI are a consequence of the lack of a tracking system among carriers, and this is also directly related to the quality of the logistics services provided within the country.

With regard to the integration of Russia's logistics in international trade, we need to consider some international transport corridors separately. Bilateral movement of goods from Asia to Europe, from the Middle East to Scandinavia depends on the efficiency and functioning of these international transport corridors.

The Russian Federation is crisscrossed by several international transport corridors, with throughputs of hundreds of millions of tons of cargo per year. Three international transport corridors (part of the system of Crete, Helsinki or Pan-European corridors) pass through the territory of Russia, namely: I, II, IX, as well as the Northern Sea Route (NSR) along the Arctic coastline and part of the new International North-South Transport Corridor (INSTC).

The NSR passes through the Arctic waters of Russia, presenting a new way to transport huge cargoes by ship from Europe to Asia and vice versa. The shipping route had been mapped previously, but only recently has the technology become affordable enough and the environment safe enough to make the route viable option for container shipping. The NSR crosses the Barents, Kara, Laptev, East Siberian and Chukchi seas, comprises 40% less sailing distance and can reduce delivery time by up to 35% compared with the usual route using the Suez Canal [Furuichi and Otsuka 2013].

Corridor IX stretches from Helsinki in Finland to Alexandroupolis in Greece. The corridor follows the route: Helsinki - Vyborg - St. Petersburg - Moscow - Kyiv - Chisinau - Bucharest - Ruse - Dimitrovgrad – Alexandroupolis. The corridor includes railways, highways, ports in St. Petersburg, Kaliningrad, Vyborg, airports of the Leningrad and Moscow transport hubs, inland waterways, freight, and passenger terminal and is one of the longest Pan-European corridors.

Corridor II starts from Berlin in Germany and ends in Nizhny Novgorod in Russia, passing through Poland and Belarus. The corridor follows the route: Berlin - Poznan - Warsaw - Brest - Minsk - Smolensk - Moscow - Nizhny Novgorod. The development of the railway part of this corridor to the Far Eastern ports will significantly increase the size of international transit cargo transportation in the West-East traffic.

The Russian part of Corridor I that starts in Helsinki and ends in the Polish port of Gdansk, includes the seaport and airport in Kaliningrad, railways, and roadways from the border with Lithuania and from the border with Poland.

The INSTC is a proposed multimodal network of maritime, rail and road routes with a length of 7200 km for the transport of goods between Afghanistan, Armenia, Central Asia, and Europe [Hriday 2018]. The route mainly includes the transportation of goods from India, Iran, Azerbaijan, and Russia by sea, by rail, and by roadway. The purpose of the corridor is to expand trade relations between such large cities as Mumbai, Moscow, Tehran, Baku, Bandar Abbas, Astrakhan, Bandar Anzali and others. 3000 km of the route pass through the territory of Russia. Russia's territory is officially entered through the route by the Caspian Sea, but the major scope of the INSTC is trans-Asian.

The Trans-Siberian Railway also plays a special role in Russia's transit system. It covers 9289 km and is the longest railway in the world, which mainly serves for the transportation of containerized cargo from China to Finland and Germany.

In the west, the rail connects with Scandinavia through Finland and with the EU through the Baltic countries. Far in the east, the corridor connects Russia with China, Mongolia, and Korea. In 2015, the world's longest cargo railway route Harbin — Hamburg from China to Germany via Russia was launched on the basis of the Trans-Siberian Railway, reducing the delivery time for goods to 15 days [Pomfret 2019].

Our study and several other researchers' studies [Filina 2004; Sakuleva and Metjolkin 2015] of container movement through the Trans-Siberian Railway indicate the following barriers to the further development of transport links along the railway:

- Delivery time fluctuation;
- Unreasonably high terminal processing rates;
- Rolling stock obsolescence;
- Lack of an end-to-end tariff rate applicable in all directions from the port of departure to the port of destination.

The problems of attracting goods for transportation through the Trans-Siberian Railway are complex. Their solution primarily concerns the development of a competitive end-to-end freight rate, as well as the efficient handling of transit cargo in ports and at border stations with the cooperation of various railway, customs, maritime and other agencies.

With regard to the INSTC, our own and other research [Cvetkov et al. 2014] note that the main disadvantages are:

- The absence of direct rail links between Russia and Iran and the slow operation of customs in Russian ports;
- Since its very conceptualization, the INSTC has not been able to ensure widespread participation of private investors. This is due to many reasons, including US sanctions against Iran. Sanctions played a role in preventing some Western companies from entering the Iranian market, but this in no way prevented them from participating in a multi-country project, which in itself was not the subject of any form of sanctions. Large companies fear that there are big risks associated with the return on investment in project development;
- The different railway gauge between Russia, Azerbaijan, and Iran, the lack of some sections of the project, especially in Iran.

The Pan-European corridors suffer from problems that are outside the interests and sphere of influence of the Russian Federation, although some can be found in the country, namely:

- Extremely low throughput of highways;
- Inappropriate quality of transport routes;
- Large sections of non-electrified railway tracks.

The main constraints to the improvement and creation of new Arctic transport routes and the development of the Northern Sea Route are:

- Low development level of coastal infrastructure along its routes and underdevelopment (often complete absence) of railway infrastructure;
- Unclear conditions for carriers for receiving permits for passage of vessels along the Northern Sea Route;
- The need to create uniform tariffs for the provision of services for all carriers throughout the Northern Sea Route;
- Lack of involvement of major global carriers in the activities of the Northern Sea Route, which leads to problems in drawing up the schedule of vessels along Arctic routes;
- Coordination of the work of all ports of the Northern Sea Route.

Thus, after the analysis, it is necessary to identify and collect the main recommendations for improving the rank of the Russian Federation in the LPI rating.

RESULTS

To begin with, two development scenarios should be developed, based on the analysis of assessments of various aspects of Russia's logistics in the LPI depending on available resources, because that tool is designed to identify priority areas for the development of various logistics subsystems. Scenario A is a high-priority recommendation list that uses minimum resources for maximum effectiveness in a situation of resource scarcity and budgeting, while Scenario B can be implemented after Scenario A or parallel to it, dependent on available budget and resources.

Scenario A

Scenario A is considered the most important and implies:

– Support for timely delivery at the current LPI level;
– Thorough development of the country's customs system.

As can be seen from the previous paragraph, on-time deliveries are consistently the strongest side of logistics in the Russian Federation, therefore development (in the framework of this scenario) is not required, only a strategy for keeping the current level is advised. The following recommendations can be implemented as part of this strategy:

– Investment into the support of the current logistics infrastructure, more precisely into the aging Trans-Siberian Railway;
– Reduction of freight rates in order to avoid a detour of Russian Federation territory through southern countries, such as Kazakhstan;
– Modernization of rolling stock.

In the framework of this scenario, it is also taken into account that all indicators, except "Timeliness" and "Customs", are approximately at the same level, which indicates the need for improving and developing the lowest-valued indicator ("Customs") to achieve average scores.

Customs efficiency can be increased by:

– Improving customs regulation;
– Improving the level of training of customs personnel;
– Simplification, optimization, and computerization of processes related to certification and licensing in export-import operations;
– The development of free economic zones and the provision of preferences for more developed and actively developing countries.

Scenario B

Scenario B remains secondary and implies implementation and launch if scenario A goals are achieved or in parallel with it (if there are enough resources). In the framework of this scenario, the main recommendation that can be advised is the general development and support of a positive LPI score growth trend for "Infrastructure", "Logistics quality and competence", "Tracking and tracing", and "International shipments". To be more precise:

– Improvement of the investment attractiveness of the logistics industry in Russia;
– The accelerated formation of the 3PL-services market and the transition to the 4PL concept (creation of system integrators in the field of logistics, for example, large transport and logistics complexes in Yekaterinburg, Novosibirsk and/or Omsk);
– Improvement of the government regulation of the logistics industry;
– Creation of a system of reliable statistical reporting on logistics indicators;
– Improvement of the level of training for the logistics industry;
– Investment in the creation of new international logistics projects (The Belt and Road Initiative) and/or support of ongoing projects, for example, the INSTC.

It should be noted that several of the scenario recommendations correlate with the Russian Federation Transport Strategy 2030.

As part of its strategy, it is noted that one of the main problems of logistics in the Russian Federation is the low technical level and the poor state of infrastructure and production bases. Also, the document raises the problem of integration into international trade within the framework of restricting the access of domestic carriers to foreign infrastructure facilities with corresponding rising costs for owners of rolling stock and state prestige loss when conducting international trade.

CONCLUSIONS

In conclusion, if the development scenarios coincide with the development directions in the Russian Federation Transport Strategy 2030, then we can assume that the implementation of scenarios A and B will lead to similar results, namely:

- The total volume of freight traffic will increase from 12068,8 million tons in 2007 to 17858,0 million tons in 2030 (48%), cargo turnover will increase from 2,48 trillion ton-kilometers to 3,86 trillion ton-kilometers (55.6%).
- Transportation of goods in containers will increase by 2030 compared to 2007 by 6 times - up to 648 million tons. Goods transport by road will increase by 6.7 times (up to 361 million tons), by rail - by 5.6 times (up to 130 million tons), by maritime transport – by 5 times (up to 150 million tons), by inland water transport – by 17.5 times (up to 7 million tons). The cargo turnover of Russian seaports will increase in 2030 compared to 2007 by 2.3 times - up to 1025 million tons.
- The total international transportation of goods by Russian carriers, including the transportation of export, import and transit goods, as well as transportation abroad, will increase 1.6 times - up to 627 million tons.
- Transportation of transit goods through Russia will increase in 2030 compared with 2007 by 3.6 times - up to 100 million tons.

We believe these recommendations are implementable and reasonable and will lead to positive changes in Russia's national logistics system.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

Al-Futaisi A., 2015. Sultanate of Oman Logistics Strategy 2040. Muscat: Ministry of Transport and Communications.

Arvis J., Wiederer C., Shepherd B., Raj A., Dairabayeva K., Kiiski T. 2018. Connecting to Compete 2018: Trade Logistics in the Global Economy. Washington, DC: The World Bank. http://doi.org/10.1596/29971.

Beysenbaev R., 2018. The importance of country-level logistics efficiency assessment to the development of international trade British Journal for Social and Economic Research, 3(6), 13-20, http://doi.org/10.22406/bjser-18-3.6-13-20.

Bonett D., Wright T., 2000. Sample size requirements for estimating Pearson, Kendall and Spearman correlations. Psychometrika, 65 (1), 23-28, http://doi.org/10.1007/bf02294183.

Cvetkov V., Zoidov K., Medkov A., 2014. Formirovanie novoj jevoljucionnoj koncepcii uvelichenija gruzovoj bazy transportnyh koridorov Sever - Jug: sovremennoe sostojanie, geopoliticheskie uslovija i jekonomicheskie predposylki [The formation of new evolutionary conceptions of North-South corridor freight traffic: the current situation, geopolitical conditions and economic preconditions]. Regional'nye problemy preobrazovanija jekonomiki, 9(47), 229-246.

Dettmer B., Freytag A., Draper P., 2014. Air cargo beyond trade barriers in Africa. Journal of Economic Integration, 29 (1), 95-138, http://doi.org/10.11130/jei.2014.29.1.95.

Edirisinghe L., 2013. The Influence of Logistics Competence in International Trade in Sri Lanka: A Contemporary Study.

SSRN Electronic Journal, http://doi.org/10.2139/ssrn.3305996.

Filina V., 2004. Transport Logistics: Modern Problems and Development Trends. Studies on Russian Economic Development, 15(1), 70-84.

Furuichi M., Otsuka N., 2013. Cost Analysis of the Northern Sea Route (NSR) and the Conventional Route Shipping. In IAME. Marseille.

Gogoneata B. 2008. An analysis of explanatory factors of logistics performance of a country. The AMFITEATRU ECONOMIC journal, 10, 143-156.

Guner S., Coskun E., 2012. Comparison of impacts of economic and social factors on countries' logistics performances: a study with 26 OECD countries. Research in Logistics and Production, 2(4), 329-343.

Hriday S., 2018. Turning the international North-South corridor into a digital corridor. Sravnitelnaya politika [Comparative Politics], 9(4), 124-138.

ITU. 2018. Measuring the Information Society Report 2018 (1st ed.). Geneva: ICT Data and Statistics Division.

Luttermann S., Kotzab H., Halaszovich T.F., 2017. The Impact of Logistics on International Trade and Investment Flows. In The 29th NOFOMA conference Taking on Grand Challenges. Lund University: NOFOMA.

Ministry of Transport of the Russian Federation. 2008. Transportnaja strategija Rossijskoj Federacii na period do 2030 goda [Russian Federation Transport Strategy 2030]. Moscow, Russia: Ministry of Transport of the Russian Federation.

Pomfret R., 2019. The Eurasian Land Bridge: linking regional value chains along the New Silk Road. Cambridge Journal of Regions, Economy and Society, 12(1), 45–56, http://doi.org/10.1093/cjres/rsy030.

Sabelnikova M., Kuzmicheva L., Ageeva L., Akimova I., Akimova M., Kobrinskaja L., Savostjanova T., Uvarova G., 2018. Transport v Rossii [Transport in Russia]. Moscow, Russia.

Sakuleva T., Metjolkin P., 2015. Transsibirskaja magistral' kak odna iz sostavnyh chastej transportnoj infrastruktury nacional'noj jekonomiki Rossii [The Trans-Siberian Railway as one of the main components of Russia's national transport infrastructure] Vestnik universiteta, 7, 123-126.

Sgro J., 2019. Interim Report on Establishing a Canadian Transportation and Logistics Strategy. 42nd Parliament, 1st Session, House of Commons.

Shepherd B., 2016. Infrastructure, trade facilitation, and network connectivity in Sub-Saharan Africa. Journal of African Trade, 3(1-2), 1-22, http://doi.org/10.1016/j.joat.2017.05.001.

Solakivi T., Ojala L., Laari S., Lorentz H., Töyli J., Malmsten J., Viherlehto N., 2017. Finland State of Logistics 2016. Turun kauppakorkeakoulun julkaisuja.

Tan A., Hilmola O., 2012. Future of transshipment in Singapore. Industrial Management and Data Systems, 112(7), 1085-1100, http://doi.org/10.1108/02635571211255032

The Central Bank of the Russian Federation. 2018. External Trade of the Russian Federation in Services: Statistical Publication. Moscow: Central Bank of the Russian Federation.

Titarenko M., Petrovsky V., Portyakov V., Ostrovsky A., Kovalevskaya V., 2015. Development of Russian–Chinese Trade, Economic, Financial and Cross-Border Relations. Working Paper 20. Spetskniga, Moscow.

TransRussia. 2018. Transport and Logistics in Russia: Returning to Growth: A Market Insights report from TransRussia/ TransLogistica. TransLogistica.

NARODOWY SYSTEM LOGISTYCZNY ROSJI – GŁÓWNE KIERUNKI ROZWOJU

STRESZCZENIE. **Wstęp:** Celem pracy jest stworzenie rekomendacji poprawy narodowego system logistycznej Rosji. System ten został podstany analizie w oparciu o 6 wskaźników dynamicznych w okresie 11 lat. Należy wziąć pod uwagę, że wdrożenie pewnych rozwiązań na skalę państwową wymaga czasu oraz poniesienia określonych kosztów, co wyklucza obecnie rozwój w pełnej skali. Istotna jest prawidłowa ocena stanu aby określić, które obszary krytycznej narodowego systemu logistycznego są najbardziej niedorozwinięte w chwili obecnej jak również jakie określenie już przydzielonych zasobów na rozwój systemu logistycznego w mniejszej skali i w określonych obszarach.
Rozwój logistyki, w dobie obecnej międzynarodowej gospodarki, jest istotny dla każdego państwa. Rosja posiada potencjał do stanie się ważnych ogniwem transportowym pomiędzy Wschodem i Zachodem.
Metody: Narodowy system logistyczny Rosji został poddany analizie przy zastosowaniu 6 wskaźników zdefiniowanych przez Bank Światowy Bank. Pozwoliło to na wydzielenie problematycznych obszarów oraz wypracowanie planu rozwoju wraz z jego zaleceniami na poziomie państwowym.
Wyniki: Zalecenia dla rozwoju narodowego systemu logistycznego zostało zebrane na liście uwzględniającej ich priorytetowość dla dwóch scenariuszy wynikowych. Ze względu na mała dostępność możliwych zasobów konieczny jest ich podział i przydzielenie tylko do usunięcia części najistotniejszych wąskich gardeł.
Wnioski: Uzyskane scenariusze rozwoju wraz z warunkami integracji mają na celu rozwój narodowego system logistycznego Rosji w celu zwiększenia jej konkurencyjności na rynkach międzynarodowych.

Słowa kluczowe: Logistics Performance Index (LPI), Rosja, korytarze transport międzynarodowego, logistyka międzynarodowa, infrastruktura, państwowa polityka transportu

Ruslan Beysenbaev ORCID ID: https://orcid.org/0000-0002-1094-9338
Dostoevsky Omsk State University
Faculty of International Business
Prosp. Mira, d. 55-A, Omsk, Omsk Oblast 644077, **Russia**
e-mail: beysenbaevrusslan@yandex.ru

Yuri Dus
Dostoevsky Omsk State University
Faculty of International Business
Prosp. Mira, d. 55-A, Omsk, Omsk Oblast 644077, **Russia**
e-mail: beysenbaevrusslan@yandex.ru

LogForum

> Scientific Journal of Logistics <

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

2020, 16 (2), 219-227

http://doi.org/10.17270/J.LOG.2020.415

ORIGINAL PAPER

COST DEVELOPMENT IN LOGISTICS DUE TO INDUSTRY 4.0

Dagmar Čámská[1], Jiří Klečka[2]

1) Czech Czech Technical University in Prague, Prague, **Czech Republic**, 2) Czech University of Chemistry and Technology Prague, Prague, **Czech Republic**

ABSTRACT. **Background:** This paper is focused on the development of costs and their structure in logistics companies. Industry 4.0 should trigger significant changes in technologies, business or society where logistics as an area of entrepreneur activity is no exception. Some areas of logistics as storage and warehousing should be even pioneers. It is supposed that human labor has been/will be substituted by other production factors. This substitution should influence economic variables of companies and their overall performance. Challenges of Industry 4.0 will not only be exposed to companies but also to government. It is necessary to monitor the environment and describe changes.
Methods: Using published corporate financial statements the analysis is based on ratio analysis which describes cost structure and time series which show cost development on the level of individual companies operating in logistics. There are analyzed especially analytical indicators of selected cost items in terms of ratios, indicators of total costs and profitability.
Results: The computed cost structure and development were summarized and evaluated by descriptive statistics.
Conclusions: The obtained results show if and how significant there have been any changes in the level and structure of costs and profitability of logistics companies. Coming Industry 4.0 will have serious impact on business, government and individuals. This paper proves if the initiative Industry 4.0 can be already visible on the corporate data and results.

Key words: operating cost, cost structure, Czech Republic, CZ-NACE H, Industry 4.0.

A part of this study was presented as oral presentation at the „8th International Logistics Scientific Conference WSL FORUM 2019" in Poznan (Poland), 18th-19th of November 2019.

INTRODUCTION

Industry 4.0 is a term for a new development phase which does not affect only industry as previous industrial revolutions. Industry 4.0 can be characterized as a complex social change that causes changes in the thinking and attitude of the whole society. The term Industry 4.0 is not a world phenomenon [Lasi et al. 2014]. It originally came from Germany and therefore countries with close connections to Germany have taken the term. It is also possible to meet other terms such as smart industry.

At the current moment we are not standing on the edge, but in the center of this new development stage. Industry 4.0 has brought significant changes which do not affect only technologies. It must be emphasized that because of technological core current research has focused mainly on its technical fundamentals [Kiel et al. 2017]. Industry 4.0 is driven by nine technological shifts [Rüßmann et al. 2015], specifically Autonomous robots, Simulation, Horizontal and vertical system integration, The Industrial Internet of Things, Cybersecurity, The cloud, Additive manufacturing, Augmented Reality, Big data and analytics. These technological shifts are mainly connected with huge amount of

Citation: Čámská D., Klečka J., 2020. Cost development in logistics due to Industry 4.0. LogForum 16 (2), 219-227, http://doi.org/10.17270/J.LOG.2020.415

Received: 15.11.2019, Accepted: 24.02.2020, on-line: 30.03.2020.

investment mitigating the risk of losing competitive advantage. On one hand there are enormous costs and expenses, on the other hand it seems that the economic discussion is still in its infancy [Kiel et al. 2017]. It is still not discussed and investigated in detail although more and more companies have already implemented new technologies [Romberg 2016].

Many researchers base their works on general estimations published by Rüßmann et al. [2015] or Mckinsey Global Insititute [2015] or on case studies. Quantitative research is still rare in the area of productivity, accuracy or flexibility in manufacturing and related branches. There can be found pioneers as Dalenogare et al. [2018] using regression analysis and proving that some emerging technologies are more promising than the others in the case of the Brazilian companies, Brendel's [2015] effort to find evidence that the benefits of Industry 4.0 outweigh its costs or Erdei [2018] focusing on impact of new technologies, especially industrial robots, on productivity, employment and value added.

The consequences and impact on profit or value added are hardly in general focus. It should be changed because changes and technological shifts should be implemented because of their consequences and influence on business goals fulfilling. There is a serious risk that small and medium sized enterprises (SMEs) have not caught a wave of change and they will become victims [Sommer 2015]. Arcidiacono et al. [2019] proves that implementation of industry 4.0 is uneven among SMEs in the automotive industry.

A research gap has been clearly detected. There are not enough researches focusing on the impact of Industry 4.0 on economic variables and overall companies' performance. This paper should contribute to closing this gap in the area of logistics. The specific verified idea will be introduced in the following chapter which will also distinguish between Industry 4.0 and Logistic. 4.0. The following chapter is dedicated to indicators used for an analysis and description of a data sample. Obtained values of the selected indicators will be represented in chapter Results. Then part Conclusion contains discussion, limitations and possible future research tendencies.

LOGISTIC 4.0 AND PAPER IDEA

The previously presented technological changes of Industry 4.0 are mostly connected with investment in fixed assets tangible as well as intangible [Bettenhausen et al. 2010] and as well as in the area of logistics these investments are significant [Jereb 2017]. In the area of logistics these investments lead especially to RFID (Radio Frequency Identification), RTSL (Real Time Locating Systems), Cyber-Physical Systems, Internet of Things and Services and Big Data [Cyplik et al., 2019]. According to Acimovic et al. [2019] supply chain is affected by technologies of Industry 4.0 in the following areas: communication (real time interaction), merchandise manipulation (robotics and sensors), origin track (blocking technology), distribution of goods (self-driving vehicles) and off course data mining enabling Big data usage. Müller et al. [2018] sees positive effect from Industry 4.0 on Supply Chain in the form of flexibility, decreasing documentation efforts, usability of data, cost savings, traceability or decreasing of incorrect delivery.

There can be found authors as Cyplik et al. [2019] who distinguishes between Industry 4.0 and Logistics 4.0. Changing of providing logistic services is a response of Logistics 4.0 to Industry 4.0 [Maslaric et al. 2016]. Krykavsky et al. [2019] demonstrates the relevance of the implementation of Industry 4.0 into the practical activities which are complex. Therefore these activities consists of manufacturing, trading, logistic which are interconnected by networking in the process of delivering goods or services to their final customers. There are similarities of both concepts (Industry 4.0 and Logistics 4.0) but the obstacle is that it prevails thinking that Industry 4.0 is connected with production in a narrow sense and therefore logistics seems excluded. On the other hand Logistics 4.0 still remains less raised topic [Cyplik et al. 2019].

The aforementioned technological shifts and changes cause replacement of human labor [Rotman et al. 2013]. In other words part of workers' duties is transferred to modern machines [Barreto et al. 2017]. These machines are and will be more autonomous and it enables the increase of the quality of produced products and provided services [Gubán 2017]. On the other hand it leads to changes of labor market [Kergroach 2017] and wages inequalities [Moenning et al. 2019]. Majority of researchers justly only state that new technologies in logistics enable improvement in manufacturing, delivering time, cost effectiveness etc. leading to greater profit [as Acimovic et al. 2019]. Unfortunately they do not provide any proof for their statements as in the area of general Industry 4.0.

This paper's effort can be described as a proof of replacement labor by new technologies leading to higher profits. This kind of substitution has been and will be important to maintain and strengthen enterprise competitiveness. It is crucial for companies which belong to areas in which Industry 4.0 has emerged or will be implemented. The paper verifies on the real data, if the substitution of labor by new technologies has already occurred in the analyzed time period. The main attention is dedicated to economic effects brought by this substitution. The research is carried out on Czech enterprises belonging to storage and warehousing sector.

INDICATORS AND DATA SAMPLE

Using published corporate financial statements the conducted analysis is based on ratio analysis. The ratios of the classical financial analysis are too general and are not able to fulfil our purposes. The substitution of the considered type should be examined. It is necessary to describe cost structure and its development. The indicators used in this analysis combine the ratios of the classical financial analysis and the ratios of partial cost. Selected cost items are personal costs and depreciation plus amortization. Personal costs contain wages, salaries and insurance paid by an employer. The item depreciation and amortization represent adjustments to tangible and intangible fixed assets. If an enterprise grows there will be pressure on cost growth. It must be noted that in this case the costs grow absolutely but there is an enormous effort that their relative growth has to be smaller than the growth of sales. Usage of the ratios solves an issue of the absolute versus relative growth.

Following text has to describe the used ratios because of their specificity. Indicators and input variables are described in table and equations represent computation of the used indicators. Company's growth influences the level of investment. If the company wants to sustain its development it is necessary to restore its property and if they want to grow they have to invest more and increase the value of fixed assets. Equation 1 (indicator A) displays the first ratio called absolute change in depreciation and amortization over sales. Positive value of indicator A proves that the company has invested relatively more than it is the sales growth. The second analyzed cost item is personal costs. Equation 2 (indicator B) shows the second ratio called absolute change in personal costs over sales. Negative value of indicator B proves that the company has paid relatively less on wages than it is the sales growth. It must be noted that it is valid for relative values because wages and salaries increase in absolute values due to the company growth, inflation and labor market situation described as a limited labor supply.

On the one hand there is an effort of the investment on the other hand companies prefer to minimize costs. One possible solution leads to personal costs. Especially in the case of Industry 4.0 which replaces human labor with technology. Equation 3 (indicator C) works with the substitution of personal costs by investment in the fixed assets. It is expressed as the substitution of personal costs by depreciation and amortization over sales. It can be also rewritten as a difference between indicators A and B. Positive value of indicator C means the increasing difference between depreciation costs and personnel costs. The substitution of labor by investments is expressed here in financial terms.

Table 1. Variable specification

Used indicators and their description:
A – absolute change in depreciation and amortization costs over sales
B – absolute change in personal costs over sales
C – substitution of personal costs by depreciation and amortization over sales
D – absolute change in profitability
Used variables and their description:
DaP – depreciation and amortization (in CZK)
Sales – total revenues from selling finished goods, resold goods and services (in CZK)
PersC – personal costs (in CZK)
0 – base period (specifically 2014)
1 – current period (specifically 2017)

Source: own work

The main incentive of the companies for these changes is not Industry 4.0 itself but the fulfilling of the main enterprise goal. The main enterprise goal can be represented by an achieved profit as it is in the case of equation 4 (indicator D). Indicator D is focused on the absolute change in sales profitability caused by analyzed costs.

$$A = \frac{DaA_1}{Sales_1} - \frac{DaA_0}{Sales_0} \quad (1)$$

$$B = \frac{PersC_1}{Sales_1} - \frac{PersC_0}{Sales_0} \quad (2)$$

$$C = \left(\frac{DaA_1}{Sales_1} - \frac{PersC_1}{Sales_1}\right) - \left(\frac{DaA_0}{Sales_0} - \frac{PersC_0}{Sales_0}\right) \quad (3)$$

$$D = (-1) \times \left(\frac{DaA_1 + PersC_1}{Sales_1} - \frac{DaA_0 + PersC_0}{Sales_0}\right) \quad (4)$$

The aforementioned paper idea has to be verified on the real data and real companies. Therefore it is crucial to define a data sample. Branch Logistics consists of many different types of companies. Logistics in the sense of CZ-NACE H contains two main groups Transportation and Storage. Although Industry 4.0 has penetrated into all economic areas transportation is still at the beginning because autonomous vehicles remain pioneers for practice. On the other hand CZ-NACE 52 Storage and warehousing could be further because of automatic storage systems, software solutions, QR codes etc. This branch should be highly influenced by technological changes and the substitution of labor by fixed assets should occur.

The analysis has been conducted for the time period 2014-2017. It has a serious consequence that each company included in the sample must have available financial statements for the aforementioned time period. Czech enterprises are not always willing to publish their financial statements [Strouhal et al. 2014] and therefore the final sample consists of 52 enterprises. These enterprises had total sales in 2017 equal to 20,292,629,000 CZK (approximately 770,704,000 EUR). Following European Commission [2003] rules these companies can be divided according their size. Sales of large enterprises should exceed 50 million Euros (1,316,500,000 CZK). Medium sized enterprises have sales in the range 10 – 50 million Euros (263,300,000 - 1,316,500,000 CZK) and sales of small ones are below 10 million Euros (263,300,000 CZK). Table 2 shows a structure of the analyzed sample. It must be noted that the large enterprises have only 10% share on the sample but they contribute to 60% of total sales. On the other hand small companies create a backbone but their total contribution to sales exceeds only 10%.

Table 2. Structure of the analyzed sample

	Number of enterprises	Share on total sample	Total sales (CZK)	Share of sales on sample
Large enterprises	5	9.62%	11,827,819,000	58.29%
Medium enterprises	9	17.31%	6,150,407,000	30.31%
Small enterprises	38	73.08%	2,314,403,000	11.41%
All enterprises	52	100%	20,292,629,000	100%

Source: own work

RESULTS

This part is dedicated to obtained results. The results will be included in tables and interpreted. The first indicator displays absolute change in depreciation and amortization costs over sales. The results show that more than 25% of all companies without respect to their size (3rd quartile) achieved relative growth in depreciation and amortization to their sales. In the case of medium sized enterprises even more than half of companies (median). It means that these companies relatively massively invested in their fixed assets in the analyzed time period. It must be noted that some companies could already invest before the analyzed time period and that the indicator focuses on the relative growth to sales.

Table 3. Descriptive statistics of absolute change in depreciation and amortization costs over sales

	Full sample	Large enterprises	Medium enterprises	Small enterprises
Mean	-0.0052	0.0275	0.0125	-0.0138
Median	-0.0029	-0.0017	0.0022	-0.0033
Minimum	-0.0827	-0.0292	-0.0280	-0.0827
Maximum	0.1480	0.1480	0.1273	0.1480
1st quartile	-0.0214	-0.0213	-0.0109	-0.0302
3rd quartile	0.0052	0.0910	0.0161	0.0024
St. deviation	0.0392	0.0637	0.0430	0.0289
Trim mean	-0.0068	---	---	-0.0131

Source: own work

In the case of personal costs there are significant decreases measured to sales if we focus on minimum, 1st quartile but upper quartile reaches comparable results as the previous indicator. Cost items such as depreciation + amortization and personal costs should not be analyzed separately for our purpose. These items are interconnected when we talk about of replacement labor by new technologies therefore the indicator C looks at both indicators jointly. It will bring the most significant results.

Table 4. Descriptive statistics of absolute change in personal costs over sales

	Full sample	Large enterprises	Medium enterprises	Small enterprises
Mean	-0.0099	-0.0175	0.0179	-0.0155
Median	-0.0058	0.0021	0.0231	-0.0159
Minimum	-0.2762	-0.1111	-0.0434	-0.2762
Maximum	0.1362	0.0410	0.0909	0.1362
1st quartile	-0.0422	-0.0845	-0.0035	-0.0426
3rd quartile	0.0294	0.0397	0.0280	0.0234
St. deviation	0.0794	0.0589	0.0343	0.0876
Trim mean	-0.0075	---	---	-0.0125

Source: own work

Mean proves that personal costs are substituted by depreciation and amortization massively in the full data sample although median has slight worse results. In total 23 enterprises (3 large, 2 medium and 18 small) achieved positive replacement. The positive replacement ranges from 0.15 to 26.48 percentage points. On the other hand 29 enterprises (56%) show negative substitution that personal costs increased more than depreciation and amortization measured over sales.

Table 5. Descriptive statistics of substitution of personal costs by depreciation and amortization

	Full sample	Large enterprises	Medium enterprises	Small enterprises
Mean	0.0047	0.0450	-0.0053	0.0017
Median	-0.0013	0.0918	-0.0230	-0.0007
Minimum	-0.1861	-0.0402	-0.0860	-0.1861
Maximum	0.2648	0.1070	0.1433	0.2648
1st quartile	-0.0395	-0.0357	-0.0417	-0.0450
3rd quartile	0.0410	0.1023	0.0267	0.0267
St. deviation	0.0835	0.0661	0.0653	0.0877
Trim mean	0.0033	---	---	-0.0004

Source: own work

The negative replacement ranges from -0.04 to -18.61 percentage points. It has several explanations. First these enterprises do not fulfill our expectations of investing in fixed assets and new technologies. Second the labor market development is not helpful because limited labor supply pushes up nominal wages and salaries.

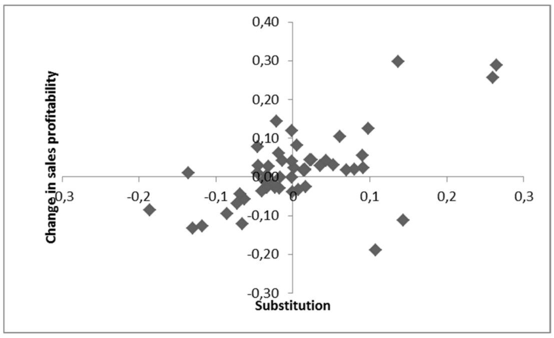
The last indicator D focuses on the profitability change observed in our data sample. Minimum and 1st quartile proves negative impact on the profitability then there is change around mean and medium into positive impact. It is crucial to show the dependency between the discussed replacement and sales profitability. Figure 1 fits our purposes the best.

Table 6. Descriptive statistics of absolute change in sales profitability

	Full sample	Large enterprises	Medium enterprises	Small enterprises
Mean	0.0152	-0.0100	-0.0304	0.0293
Median	0.0174	0.0240	-0.0269	0.0221
Minimum	-0.1891	-0.1891	-0.1113	-0.1336
Maximum	0.2981	0.1246	0.0169	0.2981
1st quartile	-0.0328	-0.1129	-0.0623	-0.0295
3rd quartile	0.0429	0.0759	0.0043	0.0562
St. deviation	0.0934	0.1034	0.0422	0.0966
Trim mean	0.0136	---	---	

Source: own work

The figure displays that positive replacement of labor by investment leads mainly to positive impact on profit. On the other hand the negative replacement leads mainly to negative impact on profit. Specific numbers describing the reality say 19 enterprises of 23 with positive replacement achieved increase of sales profitability and the range was from 1.69 to 29.81 percentage points. 18 enterprises of 29 with negative replacement achieved decrease in profitability whose range was from -0.06 to -13.36 percentage points.



Source: own work

Fig. 1. Absolute change in sales profitability due to substitution of personal costs by depreciation and amortization

CONCLUSIVE REMARKS

This paper verified if the initiative Industry 4.0 can be already visible on the corporate data and achieved profits in the area of logistics. It is not a surprising result that there are more companies with undesired development with the respect to Industry or Logistics 4.0. It just supports findings of the others that the infusion of new technologies in the logistic is not wide and especially small sized enterprises would suffer from this lately. The used indicators described financial sources needed for used human labor or for used machine labor. It leads to the economic reflection of the human labor replacement by machines (robots) and other new technologies. The analysis proved that the enterprises showing the desired development of this replacement can achieve higher profitability. On the other hand the enterprises supporting human labor instead of investments in fixed assets and therefore in new technologies increased their probability of the negative impact on the profitability.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The paper is one of the outputs of the research project "Financial characteristics of enterprise in bankruptcy" registered at Grant Agency of Academic Alliance under the registration No. GAAA 10/2018.

REFERENCES

Acimovic S., Stajic N., 2019, Digital supply chain: leading technologies and their impact on industry 4.0 [in:] 19th international scientific conference Business Logistics in Modern Management, 75-90.

Arcidiacono F., Ancarani A., Di Mauro, C., Schupp F., 2019. Where the rubber meets the road. Industry 4.0 among SMEs in the automotive sector, IEEE Engineering Management Review, http://doi.org/10.1109/EMR.2019.2932965.

Barreto L., Amaral A., Pereira T., 2017. Industry 4.0 implications in logistics: an overview, Procedia Manufacturing, 13, 1245-1252, http://doi.org/10.1016/j.promfg.2017.09.045.

Bettenhausen K.D., Oesterle M., Zuehlke D., 2010. SmartFactory The intelligent Factory of the Future in the Life Cycle Contributions to the Further Development of Automation [in:] 11th Branch Meeting of the Measurement and Automation Technology - Automation 2010, 257-260.

Brendel T., 2019. Industry 4.0 – More costs than benefits?, Zeitschrift fuer Wirtschaftlichen Fabrikbetrieb, 114(1-2), 68-71, http://doi.org/10.3139/104.112042.

Cyplik P., Oleskow-Szlapka J., Tobola A., Adamczak M., 2019. Building a model for assessing the maturity of Polish enterprises in terms of logistics 4.0 assumption [in:] 19th international scientific conference Business Logistics in Modern Management, 105-120.

Dalenogare L.S., Benitez G.B., Ayala N.F., Frank A.G., 2018. The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics, 204, 383-394, http://doi.org/10.1016/j.ijpe.2018.08.019.

Erdei E., Popp J., Oláh J., 2018. Comparison of time-oriented methods to check manufacturing activities and an examination of their efficiency, LogForum, 14(3), 371-386, http://doi.org/10.17270/J.LOG.2018.290.

European Commission, 2003. Commission Recommendation EU 2003/61/ES. Available on the Internet: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:124:0036:0041:EN:PDF (9/28/2019)

Gubán M., Kovács G., 2017. INDUSTRY 4.0 Conception, Acta Technica Corviniensis-Bulletin of Engineering, 10(1), 111-114.

Jereb B., 2017. Mastering logistics investment management, Transformations in Business & Economics, 16(1), 100-120.

Kergroach S., 2017. Industry 4.0: New Challenges and Opportunities for the Labour Market, foresight and gover-nance, 11(4), 6-8, http://doi.org/10.17323/2500-2597.2017.4.6.8.

Kiel D., Müller J.M., Arnold C., Voigt K.I., 2017. Sustainable industrial value creation: Benefits and challenges of industry 4.0, International Journal of Innovation Management, 21(8), http://doi.org/10.1142/S1363919617400151

Krykavskyy Y., Pokhylchenko O., Hayvanovych N., 2019. Supply chain development drivers in industry 4.0 in Ukrainian enterprises, OECONOMIA COPERNICANA, 10(2), 273-290, http://doi.org/10.24136/oc.2019.014.

Lasi S., Fettke P., Kemper H.G., Feld T., Hoffmann M., 2014. Industry 4.0, Business & Information Systems Engineering, 6(1), 239-242, http://doi.org/10.1007/s12599-014-0334-4.

Maslaric M., Nikoličic S., Mirčetic D., 2016. Logistics Response to the Industry 4.0: the Physical Internet, Open Engineering, 6(1), 511-517, http://doi.org/10.1515/eng-2016-0073.

Moenning A., Maier T., Zika G., 2019. Economy 4.0-Digitalisation and Its Effect on Wage Inequality, Jahrbucher fur Nationalokonomie und Statistik, 239(3), 363-398, http://doi.org/10.1515/jbnst-2017-0151.

McKinsey Global Institute, 2015. The Internet of Things: Mapping the Value Beyond the Hype, Available on the Internet: http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=706B4E4BA86659F79206FC558BB5D371?doi=10.1.1.729.7846&rep=rep1&type=pdf (07/15/2019).

Müller J.M., Voight K.I., 2018. The impact of Industry 4.0 on Supply Chains in Engineer-to-Order-Industries – An Explanatory Case Stucy, IFAC PapersOnline, 51(11), 122-127, http://doi.org/10.1016/j.ifacol.2018.08.245.

Romberg A., 2016. The operative implementtation of industry 4.0 is increasing rapidly in Germany, Productivity management, 21(1), 61-64.

Rotman D., 2013. How Technology Is Destroying Jobs, Technology Review, 116(4), 28-35.

Rüßmann M., Lorenz M., Gerbert P., Waldner M., Justus J., Engel P., Harnisch M., 2015. Industry 4.0: The future of productivity and growth in manufacturing industries, Boston Consulting Group, Available on the Internet: https://www.bcg.com/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries.aspx (08/21/2019).

Sommer L., 2015. Industrial revolution - Industry 4.0: Are German manufacturing SMEs the first victims of this revolution?, Journal of Industrial Engineering and Management, 8(5), 1512-1532, http://doi.org/10.3926/jiem.1470.

Strouhal J., Gurtvis N., Nikitina-Kalamae M., Li T.W., Lochman A.L., Born K., 2014. Are companies willing to publicly present their financial statements on time? Case of Czech and Estonian TOP100 Companies. Proceedings [in:] The 7th International Scientific Conference on Managing and Modelling of Financial Risks Modelling of Financial Risks, 731-738.

ROZWÓJ KOSZTÓW W LOGISTYCE JAKO POCHODNA INDUSTRY 4.0

STRESZCZENIE. **Wstęp:** W pracy poruszane jest zagadnienie rozwoju kosztów oraz ich struktury w przedsiębiorstwach logistycznych. Wdrożenie Industry 4.0 pociąga za sobą istotne zmiany w technologiach, biznesie oraz środowisku dla wszystkich rodzajów firm, w tym również logistycznych. Niektóre obszary logistyki jak magazynowanie powinny być nawet pionierami we wdrażaniu Industry 4.0. Ma to bezpośredni wpływ na zmienne ekonomiczne i ich ogólną kondycję. Wyzwania, jakie stawia Industry 4.0 dotyczą nie tylko firm ale również dla rządu. Niezbędne jest monitorowanie środowiska oraz opis zachodzących zmian.

Metody: Dane do analizy pochodzą z publikowanych zeznań finansowych korporacji. Sama analiza opiera się na analizie porównawczej tych sprawozdań, opisujących strukturę kosztów oraz rozwój kosztów na poziomie indywidualnych przedsiębiorstw działających w branży logistycznej. Szczególnej analizie poddano wskaźniki analitycznej wybranych pozycji kosztowych, jak również dokonano analizy całości kosztów i zyskowności.
Wyniki: Uzyskana struktura kosztów została podsumowana i oszacowana statystyką opisową.

Wnioski: Uzyskane wyniki wskazują czy i jak istotne są zmiany w poziomie i strukturze kosztów oraz zyskowności przedsiębiorstw logistycznych. Nadchodzący Industry 4.0 będzie miał poważny wpływ na biznes, zarówno na poziomie rządu jak i poszczególnych przedsiębiorstw. W pracy udowodniono, że inicjację Industry 4.0 można już zauważyć w wynikach firm.

Słowa kluczowe: koszt operacyjny, struktura kosztów, Czechy, CZ-NACE H, Industry 4.0.

Dagmar Čámská
Czech Technical University in Prague
Prague, **Czech Republic**
e-mail: dagmar.camska@email.cz

Jiří Klečka
University of Chemistry and Technology Prague
Prague, **Czech Republic**

LogForum

> Scientific Journal of Logistics <

2020, 16 (2), 229-237

http://doi.org/10.17270/J.LOG.2020.381

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

RANKING OF OPPORTUNITIES FOR IMPLEMENTING THE OMNICHANNEL CONCEPT

Hubert Wojciechowski, Łukasz Hadaś

Poznań University of Technology, Poznań, **Poland**

ABSTRACT. **Background:** The paper is devoted to implementation of the omnichannel concept using the ranking of opportunities. Opportunities were obtained from a SWOT/TOWS analysis and Thurstone's method is used for ranking. The SWOT/TOWS analysis is one of the most basic analytical methods and the result of this analysis indicates a general strategy. Based upon previous authors' experiences in using SWOT/TOWS, we can conclude that this analysis is often insufficient for decisions to be taken, as it lacks information on what factors should be prioritized over others in implementing the chosen strategy. Further analysis is required to confirm the next steps should be in implementing corporate strategy, and this analysis is performed using different methods.

Methods: Based on the previously developed SWOT/TOWS analysis, the authors created an algorithm for making decisions in logistics in terms of implementing the concept of omnichannel. In the methodology, an algorithm merging SWOT/TOWS analysis with Thurstone's method is presented. The results of this paper show how making decisions in logistics can be more accurate using Thurstone's method in conjunction with SWOT/TOWS analysis. Thurstone's method is used to sort all factors in implementing the omnichannel concept.

Results: A grouped list of opportunities from the most critical to the least crucial correspond with the present state of the market. Using Thurstone's method together with SWOT/TOWS analysis will result in a more complete set of data to use in the decision-making process in implementing the omnichannel concept. Combining the results of the two analyses creates a methodology for ranking opportunities for implementing the omnichannel concept.

Conclusions: The method for making decisions in implementing the omnichannel concept presented here gives more information for managers than using each of these analysis separately. The main advantage of using both analyses is that risk is reduced during implementation and a list of factors is produced that can be used in the following decisions.

Key words: omnichannel, e-commerce, decision-making, SWOT, TOWS.

A part of this study was presented as oral presentation at the „8th International Logistics Scientific Conference WSL FORUM 2019" in Poznan (Poland), 18th-19th of November 2019.

INTRODUCTION

The process of implementing new management concepts that are to significantly affect the competitive position of an enterprise requires strategic analysis. The key here is to identify opportunities and threats of the implementation process. Such knowledge allows you to plan activities that will lead to success by using the most important opportunities and reducing or eliminating key threats. Managers in the analysis process usually reach for well-known tools. One such tool is SWOT / TOWS strategic analysis [Pickton 1998, de Houben 1999, Dyson 2004]. This analysis provides the image of the company (its strengths and weaknesses) and its surroundings (opportunities and threats) and then allows an overall strategy of operation to be selected. In the decision-making process necessary for effective implementation of a selected strategy in relation to the entire company or the analysed area of operation

Citation: *Wojciechowski H., Hadaś Ł., 2020. Ranking of opportunities for implementing the omnichannel concept. LogForum 16 (2), 229-237, http://doi.org/10.17270/J.LOG.2020.381*

Received: 03.09.2019, Accepted: 24.02.2020, on-line: 30.03.2020.

(e.g. distribution logistics), general guidelines resulting from the SWOT / TOWS analysis are usually not sufficient.

Omnichannel is described in "Competing in the age of omnichannel retailing" as an evolution, where the distinctions between physical and online retailing will vanish, turning the world into a showroom without walls [Brynjolfsson, Yu Jeffrey, Mohammad 2013]. A similar definition is presented by Baird and Kilcourse [2011], Rigby [2011] and Beck and Rygl [2015]. Based on these definitions, the omnichannel criteria is that the customers should not see any difference using any of the retail channels available. Retail channels can be used in different sequences. The customer can first search for information online and then go to the store. This process is called webrooming [Flavian et al. 2016]. The other sequence of using retail channels is to first gather information in physical stores and then buy online, which is called showrooming [Neslin et al., 2014]. However, it is common not only to use one retailer channel, but to use different channels of multiple retailers for planning and preparation purposes before purchasing [Chiou et al., 2012, Chiu et al., 2011]. All retailers' actions have one common aim – to let the customer have the best possible experience during the process of purchasing [Blom et al., 2017, Huré et al., 2017, Lemon and Verhoef, 2016, Sit et al., 2018]. Each retail channel is determined by many factors [Harris et al., 2018, Verhoef et al., 2007]. Usually it is a strategic decision for a company to determine what channel should be prioritized by allocating necessary resources to this channel.

When implementing the omnichannel concept, the validity of opportunities for implementing the omnichannel can be assessed differently by each expert, especially bearing in mind that in the literature it is emphasized that the process of integrating customer service channels is difficult to implement, costly and risky [de Carvalho 2014]. Most often, all the negative effects of transformation affect the customer's perception of the company and, as a result, the competitive position of the company [Bell 2014].

A valuable complement to the analysis can be the Thurstone method [Sagan 2009]. The skilful combination of SWOT / TOWS analysis and the Thurstone method allows better effects to be achieved in the decision-making process in the form of fuller information to be used while implementing the strategy.

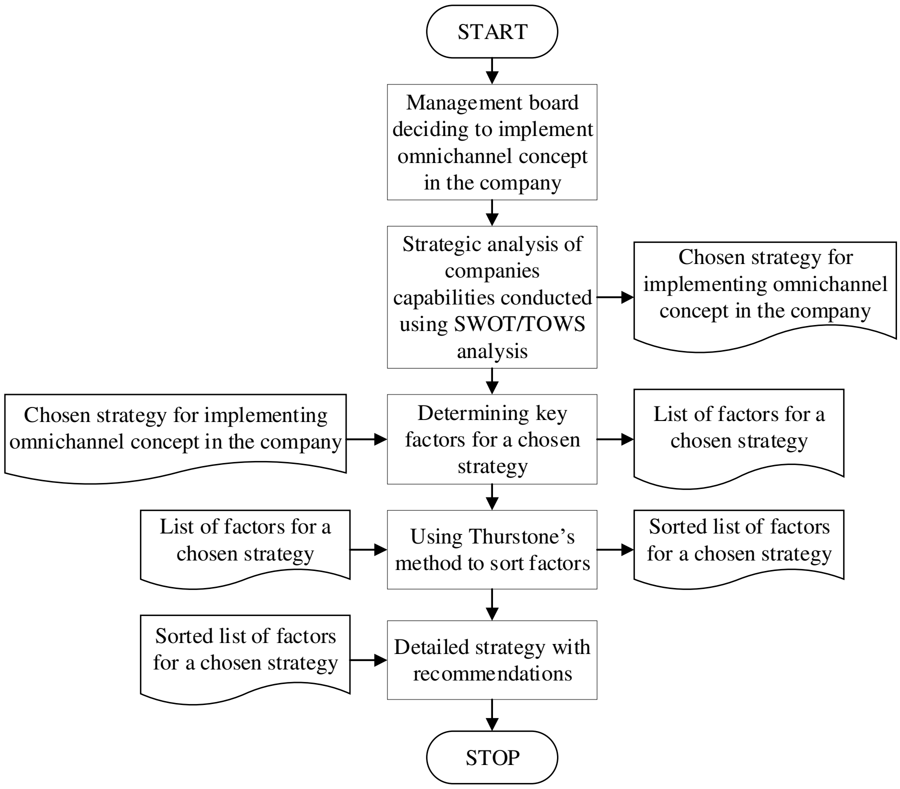
The article presents a case of such an analysis carried out in order to implement the omnichannel concept in distribution. The omnichannel approach in enterprises consists in unifying standards for each customer service channel, especially in the field of distribution and improving customer satisfaction in each service channel [Piotrowicz 2014]. In the article, the authors use the results of previous surveys carried out on a group of specialists from enterprises and clients that provided a generalized comparison of opportunities and threats regarding implementation of the omnichannel concept [Wojciechowski, Hadas 2018]. To analyse opportunities and threats, questionnaire surveys were used, because the aim was to obtain recommendations for the logistics and sales departments of various companies, not to analyse a single case study. As a final result, SWOT / TOWS analysis was used to determine which strategy should be used to implement the concept in the enterprise for diagnosed external factors (opportunities and threats) [Wojciechowski, Hadas 2018].

The results obtained provide the basis for further analysis presented in this article, because, as mentioned above, the use of the SWOT / TOWS analysis is insufficient, due to there being no information on which factors require more and which less attention in the implementation process. The Thurstone method was chosen to deepen the analysis. After completing the work, the analysis methodology was also formulated as a way of combining SWOT / TOWS analysis with the Thurstone method in the decision process.

METHODOLOGY OF ANALYSIS

The process of determining the rank of opportunities for implementing the omnichannel concept was carried out according to the following methodology (Fig. 1). In the first step, based on the results of the survey and according to the classical

SWOT/TOWS methodology, a strategy for implementing the omnichannel concept was chosen. In the second step, on the basis of expert assessments, the Thurstone method was used to create a ranking of opportunities that should be used in the process of implementing the concept.



Source: own work

Fig. 1. Methodology of determining the ranking opportunities for implementation the omnichannel concept

The SWOT / TOWS analysis shows that an enterprise that decides to implement the omnichannel concept in its distribution should use an aggressive strategy, i.e. maxi-maxi [Wojciechowski, Hadas 2018], in order to achieve the best possible effect. This aggressive strategy consists in making the greatest possible use of emerging market opportunities, taking over similar enterprises, concentrating the entire company's efforts on using only opportunities with the greatest potential and strengthening its own position on the market. All of these activities should be carried out by the company using the chances which result from the SWOT / TOWS analysis. However, this analysis does not make it possible to easily determine which chances can give the best results and how many resources should be devoted to each opportunity. Therefore, using the Thurstone method in the strategy implementation process can provide valuable information for managers. On this basis, and using the results obtained as to the choice of strategy and the ranking of the opportunities, the decisions regarding the next actions in the field of exploiting the opportunities are more accurate.

The starting point for the Thurston analysis was the list of opportunities and threats presented in the article: Wojciechowski Hubert, and Lukasz Hadas, "Possibilities of Implementing Omnichannel Concept in Distribution-Opportunities and Threats".

The assumptions of the Thurston pair comparison method consist in making each expert determine which of the factors in a pair is more important. Such action is required for each pair, i.e. in the case described it is 8 factors, which results in 28 pairs for one expert to compare. In this article, it was decided to use the data collected from the questionnaire survey and compared the answers given by each of the experts in pairs. The method used is based on the original Thurston method, but changes have been made to the comparison logic and the use of the formula for comparison. The Thurston method of pairwise comparisons produces a ranking of the criteria tested.

The Thurstone method allows factors to be sorted, in this case opportunities, from the most to the least important ones. On this basis, the company gains the knowledge of how many resources it should devote to the use of individual opportunities to gain a competitive advantage.

RANKING OPPORTUNITIES

During the research, experts took part in a survey. Expert were chosen from companies based on their general knowledge, and the strengths, weaknesses, opportunities and threats to the companies they work for. Based on results of the survey, 33 responses from experts were taken into consideration. Each expert determined whether each of the opportunities and threats used in the implementation process of omnichannel concept opportunities is critical (5), very important (4), important (3), not important (2) or not important (1). Table 1 presents the results of the survey.

Opportunities:

O1. Possibility of better monitoring customers' behaviours and using data collected in order to improve marketing strategy.
O2. Potential lower costs of single deliveries.
O3. Possibility of adjusting latest technology to changing market needs.
O4. Customers can change their daily shopping habits to use smart home devices instead.
O5. Using autonomous cars in distribution
O6. Potentially lower distribution costs using omnichannel in comparison to traditional distribution, or even costless distribution if digital distribution is used.
O7. More customers can be reached, because more channels are available.
O8. Faster delivery, especially when distribution can be done right at customer's house.

Table 1. Opinions collected from 33 experts on opportunities and threats (1- least important, 5 - most important)

	O1	O2	O3	O4	O5	O6	O7	O8
1	4	2	5	4	2	5	5	4
2	5	3	5	3	3	3	4	5
3	5	4	4	5	2	2	4	3
4	4	5	5	4	4	5	5	4
5	5	5	4	4	4	5	5	5
6	4	3	2	3	4	4	3	3
7	3	3	3	3	2	3	4	3
8	5	3	5	5	5	4	5	5
9	4	3	5	5	5	4	5	5
10	4	4	5	4	3	4	5	3
11	2	2	2	2	3	3	3	3
12	5	5	5	5	2	5	5	5
13	5	4	5	4	5	3	5	3
14	4	3	4	3	4	4	3	3
15	5	5	4	3	4	4	5	4
16	3	2	5	4	3	5	4	4
17	5	2	5	3	3	4	4	5
18	4	5	5	5	4	5	5	4
19	5	5	4	5	4	5	4	5
20	5	2	5	4	2	5	5	4
21	4	3	2	3	4	4	3	3
22	5	2	2	3	4	5	5	2
23	3	3	3	3	2	2	4	3
24	5	3	5	5	4	4	5	5
25	4	3	4	5	5	4	5	5
26	4	5	5	2	3	4	5	3
27	2	2	3	2	3	3	3	3
28	3	4	3	3	4	5	5	3
29	5	5	5	5	2	5	5	5
30	5	4	5	4	5	3	5	3
31	5	4	3	2	3	1	5	5
32	4	3	5	3	4	4	3	3
33	3	3	5	3	3	5	5	3

Source: own work

Using the Thurstone method [Sagan 2009], the next step after the experts have answered the criteria weights is to develop a table of proportions, which is calculated using the formula:

$$f(n,m) = \frac{\sum_{i=1}^{j} \operatorname{sgn}(n_i - m_i)}{\sum_{i=1}^{j} \operatorname{sgn}|n_i - m_i|}$$

$$\operatorname{sgn}(x) = \begin{cases} 0, & when\ x <= 0,\ x \in R \\ 1, & when\ x > 0 \end{cases}$$

n - the base criterion

m - the criterion against which the base criterion is compared
i - expert's number

Aspect calculations allow information to be obtained about the validity of one criterion over another. The resulting table of proportions after applying the formula looks as follows.

Table 2. Table of proportions

	O1	O2	O3	O4	O5	O6	O7	O8
O1	0,00	0,18	0,56	0,22	0,23	0,44	0,64	0,29
O2	0,82	0,00	0,70	0,63	0,54	0,71	0,95	0,57
O3	0,44	0,30	0,00	0,27	0,26	0,35	0,69	0,35
O4	0,78	0,38	0,73	0,00	0,52	0,65	0,90	0,57
O5	0,77	0,46	0,74	0,48	0,00	0,73	0,84	0,64
O6	0,56	0,29	0,65	0,35	0,27	0,00	0,70	0,39
O7	0,36	0,05	0,31	0,10	0,16	0,30	0,00	0,17
O8	0,71	0,43	0,65	0,43	0,36	0,61	0,83	0,00

Source: own work

The next stage of the method is to determine the validity of each criterion using the formula [Mierzwiak 2015]:

$$W_n = \frac{Z_n - Z_{min}}{Z_{max} - Z_{min}} + 1$$

Z_n - arithmetic mean for the nth column
W_n - the validity of the nth criterion, expressed by the formula
Z_{min} - the minimum value Zn
Z_{max} - the maximum value of Zn

The results obtained are presented in Table 3.

Table 3. List of W_n and Z_n results

Z_n	0,20	0,10	0,20	0,12	0,11	0,18	0,25	0,14
W_n	0,73	0,10	0,71	0,21	0,17	0,57	1,00	0,35
Criterion	O1	O2	O3	O4	O5	O6	O7	O8
O1	0,00	0,07	0,21	0,09	0,09	0,17	0,24	0,11
O2	0,29	0,00	0,25	0,23	0,20	0,26	0,33	0,22
O3	0,17	0,12	0,00	0,11	0,10	0,14	0,25	0,14
O4	0,28	0,14	0,26	0,00	0,20	0,24	0,32	0,22
O5	0,28	0,18	0,27	0,18	0,00	0,26	0,30	0,24
O6	0,21	0,11	0,24	0,13	0,11	0,00	0,26	0,15
O7	0,14	0,02	0,12	0,04	0,06	0,12	0,00	0,06
O8	0,26	0,16	0,24	0,16	0,14	0,23	0,30	0,00
Min Z_n	0,10							
Max Z_n	0,25							

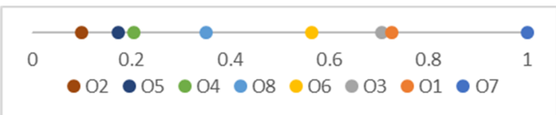
Source: own work

After developing the results of W_n, they were normalized in the range to 1 and presented sorted in Table 4 and Figure 2.

Table 4. Sorted results for the value Wn

O7	1
O1	0,726659
O3	0,70695
O6	0,565029
O8	0,350816
O4	0,205318
O5	0,173814
O2	0,1

Source: own work



Source: own work

Fig. 2. Ranking of opportunities for implementing the omnichannel concept

Table 4 and Figure 1 presents the results of calculations, and usually data is presented in tables. However, in this case, the authors have decided to show results in both figure and table forms. The graphical representation of the data makes the grouping of opportunities easier to notice.

INTERPRETATION OF RESULTS

The result obtained from the Thurstone method shows which opportunities are more important than others. Confirming the aim of this paper outlined in the abstract, the study's novelty lies in its creating a ranked list of opportunities that are significant in implementing the omnichannel concept. The result of SWOT/TOWS method alone is insufficient to make a decision about the action within the designated strategy, because it is from combining SWOT / TOWS and Thurstone methods that information can be obtained on what actions are necessary to achieve the goal.

Based on the data collected, it can be concluded that information is the most important resource, because two chances (O7 and O1), which relate to the information possessed by the company, make up a total of 51.46% of the weight of all odds. The next three chances (O3, O6 and O8) refer to already proven solutions in the field of logistics, transport and technology. They represent 42.87% of all odds. The last group of opportunities (O4, O5 and O2) refers to unpopular technologies used by enterprises, therefore due to the possible risk of lack of success in using these opportunities when implementing the omnichannel concept in distribution, these chances gained only 5.67% of the weight of all odds.

CONCLUSIONS

Analysing these results, we can see that the opportunities to use (Fig. 2) create certain groups (according to the criterion of similar rank). The dominant one is the chance (07) "More customers can be reached, because more channels are available", which is understandable, because it coincides with the main strategic goal. Two more chances form a group of similar rank:

– Possibility of adjusting latest technology to changing the market's necessity,
– Possibility of better monitoring of customers' behaviours.

According to these results, the 3 most important opportunities concentrate on issues related to the market, i.e. directly achieving the goals of implementing the omnichannel strategy using modern information technologies. In the group of these factors, there is both the opportunity to reach a larger group of customers (a characteristic feature of multi-channel customer service solutions - multichannel) and the use of modern IT technologies to monitor customer behaviour. Customer behaviour monitoring is the basis for adapting business operations to current customer preferences in terms of service (the omnichannel concept feature). Adapting the latest technologies to the changing market requirements in the omnichannel concept is often performed by creating or extending existing applications, especially for mobile devices. Such applications allow one to monitor consumer behaviour and send news about availability and promotions regarding recently viewed articles at the right time. The continuous development of such applications results in less user anonymity, but often also a better shopping experience.

A clearly weaker group of opportunities to use, in the opinion of the respondents, are those directly related to the logistics aspects of customer service, such as:

– Potentially lower distribution costs, or even costless distribution if digital distribution is used,
– Faster delivery, especially when they can be done right at the customer's house.

Therefore, can one assume that the physical distribution organization is of secondary importance in achieving the success of the omnichannel implementation strategy? Probably not, because efficient logistics secures the physical implementation of deliveries in accordance with the 7R rule. Without proper logistics solutions, it will not be possible to achieve satisfactory results in terms of customer service. The results obtained should be interpreted in such a way that the first (most important) group of chances in implementing the omnichannel strategy determines the direction of activities and the second group is to support their implementation.

On the other hand, the least important chances currently, in the opinion of the respondents, are the chances to use:

– Customers can change their daily shopping habits to use smart home devices instead,
– Using autonomous cars in distribution,
– Potential lower costs of single deliveries.

As we can see, these are issues related to physical distribution (autonomous cars, costs of single deliverers) and customer behaviour (daily shopping). Their relatively low rating may be due to the fact that these are potentially distant opportunities. For this reason, they are treated as less important, because they can be used in the past and not in current activities. To sum up, in the implementation of the omnichannel strategy, there is a group of opportunities that should be properly used, i.e. appropriate to their importance for the success of the strategy adopted. Their diverse rank is important for decision-makers who plan the implementation process. The results presented here are an important indication in this respect.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This article was funded by Poznań University of Technology, Faculty of Engineering Management [project number: 11/140/SBAD/4168].

REFERENCES

Baird N., Kilcourse B., 2011. Omni-channel fulfillment and the future of the retail supply chain. Benchmark Report, March.

Beck N., Rygl D., 2015. Categorization of multiple channel retailing in multi-, cross-, and omni-channel retailing for retailers and retailing. Journal of Retailing and Consumer Services 27: 170–178. http://doi.org/10.1016/j.jretconser.2015.08.001

Bell D.R., Gallino S., Moreno A., 2014, How to win in an omnichannel world, MIT Sloan Management Review, 56(1), 45.

Blom A., Lange F., Hess Jr. R.L., 2017. Omnichannel-based promotions' effects on purchase behavior and brand image. Journal of Retailing and Consumer Services, 39, 286-295. http://doi.org/10.1016/j.jretconser.2017.08.008

Brynjolfsson E., Yu J.H., Rahman M.S., 2013. Competing in the age of omnichannel retailing. MIT Sloan Management Review.

Chiou J.S., Wu L.Y., Chou S.Y., 2012. You do the service but they take the order. Journal of Business Research, 65(7), 883-889, http://doi.org/10.1016/j.jbusres.2011.06.035

Chiu H.C., Hsieh Y.C., Roan J., Tseng K.J., Hsieh J.K., 2011. The challenge for multichannel services: Cross-channel free-riding behavior. Electronic Commerce Research and Applications, 10(2), 268-277. http://doi.org/10.1016/j.elerap.2010.07.002

de Carvalho J.L.G., Campomar M.C., 2014. Multichannel at retail and omni-channel: Challenges for Marketing and Logistics. Business and Management Review, 4(3), 103-113.

Dyson R.G., 2004, Strategic development and SWOT analysis at the University of Warwick. European journal of operational research, 152(3), 631-640, http://doi.org/10.1016/S0377-2217(03)00062-6

Flavián C., Gurrea R., Orús C., 2016. Choice confidence in the webrooming purchase process: The impact of online positive reviews and the motivation to touch. Journal of Consumer Behaviour, 15(5), 459-476, http://doi.org/10.1002/cb.1585

Harris P., Riley F.D.O., Hand C., 2018. Understanding multichannel shopper journey configuration: An application of goal theory. Journal of Retailing and Consumer Services, 44, 108-117, http://doi.org/10.1016/j.jretconser.2018.06.005

Houben G., Lenie K., Vanhoof K., 1999. A knowledge-based SWOT-analysis system as an instrument for strategic planning in small and medium sized enterprises. Decision support systems, 26(2), 125-135, http://doi.org/10.1016/S0167-9236(99)00024-X

Huré E., Picot-Coupey K., Ackermann C.L., 2017. Understanding omni-channel shopping value: A mixed-method study. Journal of Retailing and Consumer Services, 39, 314-330, http://doi.org/10.1016/j.jretconser.2017.08.011

Lemon K.N., Verhoef P.C., 2016. Understanding customer experience throughout the customer journey. Journal of marketing, 80(6), 69-96.

Mierzwiak R., 2015. Metoda zarządzania jakością warunków pracy w przedsiębiorstwie produkcyjnym [The method of managing the quality of working conditions in a production company], PhD dissertation, Poznań.

Neslin S.A., Jerath K., Bodapati A., Bradlow E.T., Deighton J., Gensler S., Lee L., Montaguti E., Telang R., Venkatesan R., Verhoef P.C., 2014. The interrelationships between brand and channel choice. Marketing Letters, 25(3), 319-330. http://doi.org/10.1007/s11002-014-9305-2

Pickton D.W., Wright S., 1998, What's swot in strategic analysis? Strategic change, 7(2), 101-109, http://doi.org/10.1002/(SICI)1099-1697(199803/04)7:2<101::AID-JSC332>3.0.CO;2-6

Piotrowicz W., Cuthbertson R., 2014. Introduction to the special issue information technology in retail: Toward omnichannel retailing. International Journal of Electronic Commerce, 18(4), 5-16, http://doi.org/10.2753/JEC1086-4415180400

Rigby D. 2011. The future of shopping. Harvard Business Review 89(12): 65–76.

Sagan, Adam, 2009. Analiza preferencji konsumentów z wykorzystaniem programu Statistica–analiza conjoint i skalowanie wielowymiarowe [Analysis of consumer preferences using the Statistica program - conjoint analysis and multidimensional scaling], StatSoft Polska Sp. z.o.o, 3-22.

Sit J.K., Hoang A., Inversini A., 2018. Showrooming and retail opportunities: A qualitative investigation via a consumer-experience lens. Journal of Retailing and Consumer Services, 40, 163-174, http://doi.org/10.1016/j.jretconser.2017.10.004

Verhoef P.C., Neslin S.A., Vroomen B., 2007. Multichannel customer management: Understanding the research-shopper phenomenon. International journal of research in marketing, 24(2), 129-148, http://doi.org/10.1016/j.ijresmar.2006.11.002

Wojciechowski H., Hadas L., 2018, Possibilities of Implementing Omnichannel Concept in Distribution–Opportunities and Threats, Business Logistics in Modern Management, 337-353.

RANGOWANIE SZANS WE WDRAŻANIU KONCEPCJI OMNICHANNEL

STRESZCZENIE. **Wstęp:** Głównym celem tego artykułu jest pokazanie rankingu szans dla wdrożenia koncepcji omnichannel wraz z metodologią analizy. Badane szanse uzyskano z analizy SWOT/TOWS. Natomiast do opracowania rankingu szans zastosowano metodę Thurstone'a. Analiza SWOT/TOWS jest jedną z najbardziej podstawowych metod analitycznych. Wynik tej analizy wskazuje jedynie ogólną strategię, jaką powinno obrać przedsiębiorstwo. Na podstawie poprzednich doświadczeń autorów w stosowaniu SWOT/TOWS można stwierdzić, że analiza zwykle nie wystarcza do podjęcia trafnej decyzji. Brakuje informacji o tym, jakie szanse należy wykorzystać lub jakie zagrożenia należy ograniczać w pierwszej kolejności podczas wdrażaniu wybranej strategii. W celu zwiększenia skuteczności wdrożenia strategii wyznaczonej przez analizę SWOT/TOWS przez przedsiębiorstwo należy przeprowadzić dalsze analizy korzystając z różnych metod.
Metody: Autorzy tego artykułu chcieliby pokazać, w jaki sposób podejmowanie decyzji w logistyce może być bardziej efektywne przy użyciu metody Thurstone'a wraz z analizą SWOT/TOWS. Metoda Thurstone'a posłużyła do wzbogacenia analizy SWOT/TOWS.
Wyniki: Rezultatem artykułu jest posortowana i pogrupowana lista szans od najbardziej do najmniej kluczowych. Zastosowanie metody Thurstone'a wraz z analizą SWOT/TOWS dostarcza pełniejszy zestaw danych do wykorzystania w procesie decyzyjnym we wdrażaniu koncepcji omnichannel.

Wnioski: Przedstawiona metodyka podejmowania decyzji we wdrażaniu koncepcji omnichannel daje menedżerom więcej informacji niż stosowanie każdej analizy osobno. Główną zaletą korzystania z obu analiz jest zmniejszenie zwiększenie szans udanego wdrożenia, dzięki uzyskaniu listy szans wraz z ich rangą, które należy uwzględnić w procesie podejmowania decyzji o sposobie realizacji koncepcji omnichannel.

Słowa kluczowe: Omnichannel, e-commerce, podejmowanie decyzji, SWOT; TOWS

Łukasz Hadaś ORCID ID: https://orcid.org/0000-0001-9271-8738
Poznań University of Technology
Faculty of Engineering Management
Strzelecka 11, 60-965 Poznań, **Poland**
e-mail: lukasz.hadas@put.poznan.pl

Hubert Wojciechowski ORCID ID: https://orcid.org/0000-0002-1061-4191
Poznań University of Technology
Strzelecka 11, 60-965 Poznań, **Poland**
e-mail: hubert.wojciechowski@put.poznan.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (2), 239-250

http://doi.org/10.17270/J.LOG.2020.432

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

TIME PERIOD BASED COPRAS-G METHOD: APPLICATION ON THE LOGISTICS PERFORMANCE INDEX

Burcu Adiguzel Mercangoz, Bahadir Yildirim, Sultan Kuzu Yildirim

Istanbul University, Istanbul, **Turkey**

ABSTRACT. **Background:** Logistics is vital for the trades of countries. The inputs such as raw materials and energy that is needed for production and also the outputs of these processes are transported and distributed effectively as a result of an efficient logistics process. In order to measure the logistics performance of countries, The World Bank (WB) is publishing an index entitled Logistics Performance for every two years.

Methods: The main value of this study is to provide logistics performance scores of the selected countries for a selected time period. Thus, periodic evaluations can be done for a selected time period. The grey numbers are used for determining a new dataset for a time period and implement to Complex Proportional Assessment of Alternatives (COPRAS) method. 28 European Union (EU) member states plus 5 EU Candidate Countries are ranked by using the COPRAS-Grey (COPRAS-G) method according to their logistics performance scores. In order to see if the ranking calculated by COPRAS-G is representing the past index data, the bilateral comparisons of the rankings are investigated by using the Spearman Rank and Kendall's Tau Correlation methods.

Results: The results showed that the dataset obtained by using grey numbers represent the LPI scores of the countries for the selected time period. Although there are slight differences between the Spearman and Kendall correlation coefficients, the ultimate result is the same. The ranking calculated by COPRAS-G has the strongest relationship with all rankings published by WB.

Conclusions: By using the grey numbers combined with the COPRAS-G method, the LPI of Countries can be evaluated for a time period.

Key words: COPRAS-G, logistics performance, multi criteria decision making, grey numbers, correlation analysis.

INTRODUCTION

With the rise of world trade as a result of globalization, firms and countries have entered into a race to gain a competitive advantage. This process has increased the importance of each activity in the supply chain. Logistics activities, which form an important part of the supply chain, are an effective area for companies and countries to create competitive advantage [Civelek, 2015]. Logistics activities have great prospects in the company profitability and the country's economy in this sense. The development of countries in the field of logistics makes them indispensable part of the global trade. They become a master hub in the supply chain and also the preferred hub. As a result, logistics become one of the main drivers of the countries' economies. Thus, performance of the logistics needs to be calculated and improved. The logistics performance of the countries and the companies are evaluated by some different metrics. This study focused on evaluating the country's logistics performance. The World Bank (WB) publishes the Logistics Performance Index (LPI) that is used for ranking and sorting the countries according to their logistics performances. The data is obtained from professionals that are working at international logistics companies all around the world. There are six indicators used for evaluating the performance of countries. The

Citation: *Mercangoz B.A., Yildirim B., Yildirim S.K., 2020. Time Period Based COPRAS-G Method: Application on the Logistics Performance Index. LogForum 16 (2), 239-250, http://doi.org/10.17270/J.LOG.2020.432*

Received: 03.01.2020, Accepted: 02.03.2020, on-line: 30.03.2020.

definitions of these indicators are shown in Table 1.

Table 1. Definition of Logistics Performance Index Indicators

LPI Indicators	Definitions
Customs	The efficiency of customs and borders
Infrastructure	The quality of trade and transport infrastructure
International Shipping	The ease and cost-folding level of international shipping arrangements
Logistics Quality and Competence	The competence and quality of logistics services
Tracking and Tracing	Ability to monitor international shipments
Timeliness	Timely availability of shipment to arrival

Source: World Bank [2018]

The Multi-Criteria Decision making methods support the decision making process that has more than one criterion. For deciding which alternative to choose from a set of alternatives decision making process is used. Also, there is not only one criterion affecting the decision making process every time. There can be conflicting criteria that make the decision process harder. Indeed, for most cases, every alternative provides the criteria at the different level. Therefore, a concession needed to be formed. Multi-Criteria Decision Making (MCDM) methods support decisions for considering more than one criterion.

In some cases where the decision criteria cannot be expressed with an exact number, it is possible to use a certain interval for the evaluation by expressing it in fuzzy or grey numbers. This study aims to make an evaluation of 5-term index data. The dataset was formed with intervals using grey numbers. The following research questions were examined.

Research Question 1: When the LPI scores are evaluated for a certain period of time, can the results obtained by the proposed model accurately represent the period covered?

Research Question 2: Which countries are effective on the field of logistics, according to the results of the periodic evaluation with the proposed COPRAS-G method?

The study is organized in four sections. At the following part of the study, the literature is reviewed by examining the studies that are related to LPI scores and the studies related to application areas of the COPRAS-G method. At the “Methodology” part of the study, Grey Number Theory and the COPRAS-G method is explained in detail. The data, application steps and the results of the study are given in the third part. In order to see if the proposed model is an effective tool to represent the selected period, the correlation analysis is applied in the discussions section. The conclusions and the suggestions for the further studies take place in the last part of the study.

LITERATURE REVIEW

The literature review section is in twofold: (i) Studies Related with the Logistics Performance Index Scores of the Countries, and (ii) Studies Related with the Application Areas of COPRAS Method.

Studies Related with the Logistics Performance Index Scores of the Countries

Bentyn [2015] examines changes of LPI scores of Poland along with its EU membership process. He found out that there has been a significant development in all indicators of LPI over the selected period. Solakivi et al [2014] examined LPI of Finland. They compared Finland’s logistics performance with its neighbor countries. Also similar studies are conducted to evaluate the logistics performance of countries separately such as Brazil [Faria et al. 2015], England [Khan, Qianli, 2017], Turkey [Iris, Tanyas, 2011; Yaprakli, Unalan, 2017], Malaysia [Bakar, Jaafar, 2016; Nur Fadiah et al. 2017]. Jumadi and Zailani [2010] examined logistics performance by using LPI and compare its performance with other countries and also its situation within the OECD countries. Dekker et al. [2016] examined the LPI score of Costa Rica to produce strategies and alternatives.

Hoekman and Nicita [2011] considered the various indices related to trade and applied them to developing countries. They search for various kinds of trade costs that have importance on logistics performance and they found the importance of logistics performance in increasing trade. Yildirim and Adiguzel Mercangoz [2019], used Additive Ratio ASsesment [ARAS] Grey method to evaluate the Logistics performance of OECD countries.

Marti et al. [2014] studied the value of each LPI indicators on trade for emerging economies to investigate the total trade in these economies. Similar to their study, Celebi [2017] conducted a study on determining the effects of LPI on international trade. Puertas et al. [2014] analyzed the importance of logistics performance in relation to EU exports between the years 2005 and 2010. According to the results of their study, Competence and Tracking component of LPI is found as the component that needs greater importance for those years. Marti et al. [2017] investigated the potential differences to be observed with the use of different income and geographical area in their studies. They found out that the logistics performance largely depends on income and geographical area. The countries that are highly dominated by the EU, are in the group of best performers. Candemir and Celebi [2017] analyzed the role of logistics sector in economic development.

On the other hand, there are some studies conducted for identifying the relations between LPI and some other economical indexes. For instance, Cemberci et al. [2015] studied the efficacy of the Global Competitiveness Index (GCI) on the LPI by using hierarchical regression analysis on each of the components of the LPI. Similar to their study, Civelek et al. [2015] used the same model for analyzing the effect of LPI on GCI and the Gross Domestic Product [GDP]. The bilateral relations were statistically significant. Gani [2017] explored that the overall logistics performance is positively and statistically related to exports and imports in his study. Different from others, Uca et al. [2016] performed hierarchical regression analysis between LPI and Corruption Perception Index (CPI) and Foreign Trade Volume (FTV). Onsel Ekici et al. [2016] concerned with the GCI and the LPI. Differently, they do not assume that the relationship is linear and used an artificial neural network (ANN) model to investigate the relation between the GCI and the LPI. Some indicators of GCI that may effect on LPI components are selected in their study. Erkan [2014] investigate the relationship between the indicators of GCI and LPI related to the "infrastructure" indicator. 113 countries are included in a regression analysis to investigate the significant relation between overall LPI score and each of the selected components. Vaillancourt and Haavisto [2015] addressed to the importance of logistics performance for humanitarian context. They investigate the relationship between the logistics performance of the country and the disaster impact for epidemic, flood and storm.

Studies Related with the Application Area of COPRAS Method

Chatterjee and Chakraborty [2013] used COPRAS method to solve a gear material selection problem and compare the results with the results obtained by using ARAS method. Bayrakci & Aksoy [2019] evaluate the performance of individual pension companies that manage individual pension investments, which are considered as long-term investment instruments, in comparison with ARAS and COPRAS methods in their study. COPRAS method is also used in the field of Learning Management System (LMS) [Bakhouyi et al. 2016], location selection problem [Arslan et al. 2018].

COPRAS method is used with grey theory in order to cope with the uncertainty. Zavadskas et al. [2008] determined the values at intervals and used COPRAS-G for selecting effective versions of the external walls construction. Zolfani et al. [2012] used COPRAS-G method for selecting a supplier problem. Like their studies, Chatterjee and Kar, [2018] used COPRAS-G method for supplier selection problem. In order to check the reliability of the results, spearman's correlation analysis is used between the ranking results of proposed method with VIKOR-G, ARAS-G and TOPSIS-G. Liou et al. [2016] used a hybrid model that deals with the dependent relationships between various criteria and uncertain information from decision makers. They used Decision-making Trial and Evaluation Laboratory (DEMATEL), influential network relationship map (INRM), DEMATEL-based, Analytical Network Process (ANP) and COPRAS-G methods. Tavana, et al. [2013] proposed a hybrid model and integrates the ANP with fuzzy set theory and the COPRAS-G method for the social media platform selection problem in a fuzzy environment. Aghdaie et al. [2013] proposed a hybrid model and integrate the Step-wise Weight Assessment Ratio Analysis [SWARA] and COPRAS-G method for machine tool evaluation and selection considering the company strategies, recourses and policies for the organizations. Nguyen et al. [2014] used fuzzy ANP and COPRAS-G for evaluating machine tools taking into account of the interactions between the criteria. The results are compared with the other MCDM methods. Zhang et al. [2018] proposed a method for making wisely choice about the green building investment by using AHP and COPRAS-G methods. Mousavi-Nasab and Sotoudeh Anvari, [2017] reviewed the literature for material selection problem and found out that COPRAS and TOPSIS mostly used methods for material selection problem in general. Pancholi and Bhatt [2018] used COPRAS-G for the maintenance-planning problem. Bitarafan et al. [2012] used COPRAS-G for crisis management. A study about the coal-fired thermal power plants is conducted by Adhikary et al. 2014. The grey numbers are used to deal with the uncertain data; the criteria against each alternative are expressed in grey number instead of crisp values.

COPRAS method is also used with fuzzy theory. Garg et al. [2019] used fuzzy theory in order to make the selection of websites for e-learning platforms in educational organizations. Cakir and Ozdemir [2018] used fuzzy COPRAS in order to select suitable six-sigma project from eleven alternatives.

As a result of the literature survey, to the best of our knowledge, there isn't any study calculating the Logistics Performance Index by using COPRAS-G method for a selected time period. Thus, this study constitutes a different application area of the COPRAS-G technique in the literature.

METHODOLOGY

COPRAS method was first introduced by Zavadskas et. al [1994] and Zavadskas and Kaklauskas [1996]. In COPRAS method, for conflicting weighted criteria, the alternatives are compared, and their utility degree is determined [Zavadskas et al., 2008]. The calculated utility degree is used for evaluating complex processes of both maximizing and minimizing criteria values. The method assumes direct and proportional dependence of significance and priority of investigated alternatives, finally selects the best decision considering both the ideal and the ideal-worst solutions.

Different from the COPRAS method the COPRAS-G method uses the grey numbers. Grey numbers are part of Grey System theory, which is a new method for studying problems where partial information is known. Grey system theory was initiated by Julong [1982] where "grey" means poor, incomplete, and uncertain of knowledge. Grey system theory use “black” to indicate unknown information, “white” the completely known information, and “grey” the partially known and partially unknown information [Liu and Lin, 2010]. Grey numbers are useful when dealing with a system containing limited information. In this study, we used the grey number to refer the countries as upper and lower limits of LPI scores.

Applied COPRAS-G steps below proposed by Zavadskas et. al. [2008]:

Step 1. Selecting the set of the most important criteria and types of criteria as cost or benefit, describing the alternatives.

Step 2. Constructing the grey decision-making matrix

$$\otimes X = \left[\left[\underline{x}_{ij};\overline{x}_{ij}\right]\right]_{mxn} = \begin{bmatrix} [\underline{x}_{11};\overline{x}_{11}] & [\underline{x}_{12};\overline{x}_{12}] & \cdots & [\underline{x}_{1n};\overline{x}_{1n}] \\ [\underline{x}_{21};\overline{x}_{21}] & [\underline{x}_{22};\overline{x}_{22}] & \cdots & [\underline{x}_{2n};\overline{x}_{2n}] \\ \vdots & \vdots & \ddots & \vdots \\ [\underline{x}_{m1};\overline{x}_{m1}] & [\underline{x}_{m2};\overline{x}_{m2}] & \cdots & [\underline{x}_{mn};\overline{x}_{mn}] \end{bmatrix} \quad i=1,2,\ldots,m \quad j=1,2,\ldots,n \tag{1}$$

Step 3. Normalizing the grey decision-making matrix

$$\tilde{\underline{x}}_{ij} = \frac{\underline{x}_{ij}}{\frac{1}{2}\left(\sum_{i=1}^{m}\underline{x}_{ij}+\sum_{i=1}^{m}\overline{x}_{ij}\right)} = \frac{2\underline{x}_{ij}}{\sum_{i=1}^{m}\underline{x}_{ij}+\sum_{i=1}^{m}\overline{x}_{ij}} \tag{2}$$

$$\tilde{\bar{x}}_{ij} = \frac{\bar{x}_{ij}}{\frac{1}{2}\left(\sum_{i=1}^{m}\underline{x}_{ij} + \sum_{i=1}^{m}\bar{x}_{ij}\right)} = \frac{2\bar{x}_{ij}}{\sum_{i=1}^{m}(\underline{x}_{ij} + \bar{x}_{ij})} \quad (3)$$

Step 4. Calculating the weighted normalized grey decision matrix. The weighted normalized values are calculated by using equation (4) and (5), respectively:

$$\hat{\underline{x}}_{ij} = \tilde{\underline{x}}_{ij} \cdot w_j \quad (4)$$

$$\hat{\bar{x}}_{ij} = \tilde{\bar{x}}_{ij} \cdot w_j \quad (5)$$

$$\otimes\hat{X} = \left[\left[\hat{\underline{x}}_{ij};\hat{\bar{x}}_{ij}\right]\right]_{mxn} = \begin{bmatrix} [\hat{\underline{x}}_{11};\hat{\bar{x}}_{11}] & [\hat{\underline{x}}_{12};\hat{\bar{x}}_{12}] & \cdots & [\hat{\underline{x}}_{1n};\hat{\bar{x}}_{1n}] \\ [\hat{\underline{x}}_{21};\hat{\bar{x}}_{21}] & [\hat{\underline{x}}_{22};\hat{\bar{x}}_{22}] & \cdots & [\hat{\underline{x}}_{2n};\hat{\bar{x}}_{2n}] \\ \vdots & \vdots & \ddots & \vdots \\ [\hat{\underline{x}}_{m1};\hat{\bar{x}}_{m1}] & [\hat{\underline{x}}_{m2};\hat{\bar{x}}_{m2}] & \cdots & [\hat{\underline{x}}_{mn};\hat{\bar{x}}_{mn}] \end{bmatrix} \quad i=1,2,...,m \;\; j=1,2,...,n \quad (6)$$

Step 5. Calculating the sums and of criterion values, whose , benefit criteria (larger numbers are more preferable); , cost criteria (smaller numbers are more preferable):

$$S_{+i} = \frac{1}{2}\sum_{j=1}^{k}\left(\hat{\underline{x}}_{ij} + \hat{\bar{x}}_{ij}\right) \quad i=1,2,...,m \;\; j=1,2,..,k \quad (7)$$

$$S_{-i} = \frac{1}{2}\sum_{j=k+1}^{n}\left(\hat{\underline{x}}_{ij} + \hat{\bar{x}}_{ij}\right) \quad i=1,2,...,m \;\; j=k+1,k+2,...,n \quad (8)$$

Step 6. Calculating the relative significance of each alternatively the expression:

$$Q_i = S_{+i} + \frac{S_{-\min} \cdot \sum_{i=1}^{m} S_{-i}}{S_{-i} \cdot \sum_{i=1}^{m}\left(\frac{S_{-\min}}{S_{-i}}\right)} \quad i=1,2,...,m \quad (9)$$

Step 7. Calculating the utility degree of each alternative by the formula so calculate performance index P,

$$P_i = \left[\frac{Q_i}{Q_{\max}}\right] \cdot 100\% \quad i=1,2,...,m \quad (10)$$

APPLICATION AND RESEARCH RESULTS

At the first survey that is published in 2007, there were 7 indicators used to calculate the LPI, thus the data from the year 2007 is not considered in this study. The data set of the study is consisted of five Logistic Performance Index published by the World Bank.

5-Period LPI data were used as initial data. The maximum and minimum values of the 5-year data for each country were converted into the upper and lower limits of the grey numbers to be used in the decision matrix. Thus, grey numbers belonging to 7 indicators representing each country were formed.

28 EU plus 5 EU Candidate Countries are taken as alternatives. Seven indicators (Customs, Infrastructure, International Shipping, Logistics Quality & Competence, Tracking & Tracing, Timeliness) constitute the criterion set of the study. The importance of the criteria in the decision matrix was obtained from the study conducted by Yildirim and Adiguzel Mercangoz [2019]. In their study, weights of the criteria were calculated by Fuzzy Analytic Hierarchy Process (fuzzy-AHP) method by taking expert opinions. The importance of the criteria is shown in Table 2.

Table 2. Importance Weightings of Indicators

Criteria	C#	W	%
Customs	C1	0,14	14%
Infrastructure	C2	0,39	39%
International Shipping	C3	0,08	8%
Logistics Quality & Competence	C4	0,14	14%
Tracking & Tracing	C5	0,07	7%
Timeliness	C6	0,19	19%

Source: Yildirim and Adiguzel Mercangoz [2019]

The grey performance values calculated for the countries and the criterion weights are combined in the grey decision matrix and shown in Table 3.

The performance values in the decision matrix were normalized by using Equation (5) and (6). After this process, weighted normalized decision matrix was obtained by using criterion weights with the help of Equation (7) and (8). The optimization direction is maximum in all seven indicators in the decision matrix. For this reason, S+ values are calculated by using Equation (10). Calculated S+ values are used in Equation (12) to calculate Q values for all country alternatives. Finally, values were calculated by Equation (13) and the countries are ranked according to these values. The country rankings obtained by the Q and P scores is shown in Table 4.

Table 3. Grey Decision Matrix

Weights	0.14	0.39	0.08	0.13	0.07	0.19
	C1	C2	C3	C4	C5	C6
Australia	[3.49, 3.79]	[3.64, 4.18]	[3.26, 3.88]	[3.56, 4.18]	[3.83, 4.36]	[3.79, 4.37]
Belgium	[3.66, 3.85]	[3.98, 4.12]	[3.31, 4.05]	[3.98, 4.13]	[4.05, 4.22]	[4.20, 4.43]
Bulgaria	[2.40, 2.97]	[2.30, 4.19]	[2.93, 3.31]	[2.85, 3.10]	[2.72, 3.16]	[3.18, 4.04]
Croatia	[2.62, 3.07]	[2.36, 4.19]	[2.93, 3.12]	[2.53, 3.21]	[2.82, 3.2]	[3.22, 3.59]
Cyprus	[2.88, 3.11]	[2.89, 4.19]	[2.80, 3.21]	[2.72, 3.17]	[2.54, 3.51]	[3.31, 3.79]
Czech Republic	[2.95, 3.58]	[2.96, 4.19]	[3.01, 3.75]	[3.27, 3.72]	[3.17, 3.84]	[3.40, 4.16]
Denmark	[3.58, 3.93]	[3.75, 4.07]	[3.46, 3.70]	[3.74, 4.14]	[3.36, 4.18]	[3.92, 4.41]
Estonia	[2.51, 3.41]	[2.75, 4.19]	[2.82, 3.34]	[2.82, 3.27]	[2.95, 3.25]	[3.23, 4.08]
Finland	[3.82, 4.01]	[3.52, 4.12]	[3.41, 3.85]	[3.72, 4.14]	[3.31, 4.32]	[3.80, 4.28]
France	[3.59, 3.71]	[3.96, 4.01]	[3.30, 3.73]	[3.75, 3.87]	[3.89, 4.02]	[4.02, 4.37]
Germany	[3.87, 4.12]	[4.26, 4.44]	[3.66, 3.86]	[4.09, 4.31]	[4.05, 4.27]	[4.32, 4.48]
Greece	[2.38, 3.36]	[2.88, 4.19]	[2.69, 3.30]	[2.69, 3.23]	[2.98, 3.59]	[3.32, 3.85]
Hungary	[2.82, 3.35]	[3.08, 4.19]	[2.78, 3.44]	[2.87, 3.35]	[2.87, 3.82]	[3.41, 4.06]
Ireland	[3.36, 3.8]	[3.29, 3.84]	[3.40, 3.83]	[3.54, 3.94]	[3.62, 4.13]	[3.76, 4.47]
Italy	[3.34, 3.47]	[3.72, 3.85]	[3.21, 3.65]	[3.62, 3.77]	[3.73, 3.86]	[4.03, 4.13]
Latvia	[2.71, 3.22]	[2.52, 4.19]	[2.72, 3.38]	[2.64, 3.29]	[2.79, 3.55]	[2.88, 4.06]
Lithuania	[2.73, 3.42]	[2.58, 4.19]	[2.79, 3.49]	[2.85, 3.49]	[2.73, 3.68]	[3.60, 4.14]
Luxembourg	[3.53, 4.04]	[3.63, 4.24]	[3.37, 4.24]	[3.67, 4.01]	[3.61, 4.12]	[3.90, 4.80]
Malta	[2.65, 3.00]	[2.89, 4.19]	[2.70, 3.23]	[2.80, 3.01]	[2.56, 3.15]	[3.01, 3.79]
Netherlands	[3.85, 4.12]	[4.15, 4.29]	[3.61, 3.94]	[4.05, 4.22]	[4.02, 4.17]	[4.15, 4.41]
Poland	[3.12, 3.30]	[2.98, 4.19]	[3.22, 3.68]	[3.26, 3.58]	[3.32, 3.54]	[3.80, 4.52]
Portugal	[3.17, 3.37]	[3.17, 4.19]	[3.02, 3.83]	[3.15, 3.71]	[3.38, 3.72]	[3.84, 4.13]
Romania	[2.36, 3,00]	[2.25, 4.19]	[2.99, 3.32]	[2.68, 3.20]	[2.90, 3.39]	[3.22, 4.00]
Slovak Republic	[2.79, 3.28]	[2.99, 4.19]	[2.84, 3.41]	[3.07, 3.16]	[2.84, 3.54]	[3.14, 3.94]
Slovenia	[2.59, 3.42]	[2.65, 4.19]	[2.84, 3.34]	[2.90, 3.51]	[3.16, 3.51]	[3.10, 3.82]
Spain	[3.40, 3.63]	[3.58, 4.19]	[3.11, 3.83]	[3.62, 3.83]	[3.54, 3.96]	[4.00, 4.12]
Sweden	[3.68, 4.05]	[4.03, 4.27]	[3.39, 4.00]	[3.90, 4.25]	[3.82, 4.38]	[4.26, 4.45]
United Kingdom	[3.73, 3.98]	[3.95, 4.21]	[3.63, 3.77]	[3.92, 4.05]	[4.00, 4.13]	[4.19, 4.37]
Albania	[2.07, 2.43]	[2.14, 4.19]	[2.48, 2.84]	[2.39, 2.65]	[2.15, 2.67]	[3.01, 3.58]
Macedonia. FYR	[2.21, 2.55]	[2.47, 4.19]	[2.38, 2.84]	[2.36, 2.76]	[2.32, 2.82]	[2.79, 3.13]
Montenegro	[2.17, 2.83]	[2.30, 4.19]	[2.22, 3.15]	[2.31, 2.72]	[2.37, 2.76]	[2.65, 3.33]
Serbia	[2.19, 2.6]	[2.30, 4.19]	[2.63, 3.41]	[2.55, 3.02]	[2.67, 3.07]	[2.80, 3.55]
Turkey	[2.71, 3.23]	[3.08, 4.19]	[3.06, 3.41]	[3.05, 3.64]	[3.09, 3.77]	[3.63, 3.94]

Source: own work

Table 4. Ranking Countries According to LPI Scores Calculated by COPRAS-G

Countries	Q	P	Rank	Countries	Q	P	Rank
Germany	0.036	100%	1	Turkey*	0.03	82%	17
Netherlands	0.036	98%	2	Hungary	0.029	81%	18
Sweden	0.035	97%	3	Slovak Republic	0.029	80%	19
United Kingdom	0.035	96%	4	Lithuania	0.029	80%	20
Belgium	0.035	95%	5	Estonia	0.028	78%	21
Luxembourg	0.034	94%	6	Slovenia	0.028	78%	22
France	0.034	93%	7	Greece	0.028	78%	23
Denmark	0.034	92%	8	Cyprus	0.028	78%	24
Australia	0.033	92%	9	Latvia	0.028	76%	25
Finland	0.033	92%	10	Malta	0.028	76%	26
Spain	0.033	90%	11	Romania	0.027	75%	27
Italy	0.032	89%	12	Bulgaria	0.027	75%	28
Ireland	0.032	88%	13	Croatia	0.027	74%	29
Portugal	0.031	85%	14	Serbia*	0.026	71%	30
Poland	0.031	85%	15	Macedonia, FYR*	0.025	69%	31
Czech Republic	0.03	84%	16	Montenegro*	0.025	68%	32
				Albania*	0.025	68%	33

* Turkey, Serbia, Macedonia, FYR, Montenegro, and Albania are official Candidate Countries to become member states of the EU.
Source: own work

From Table 4. it can be seen that Germany ranked 1 for the selected period. Germany, Netherlands, Sweden, Belgium, and the United Kingdom can be seen as the main drivers of logistics of EU Countries. 12 EU countries have a ranking after Turkey. As Turkey compared within the EU candidate countries, it can be seen that EU candidate countries except Turkey are located at the end of the EU countries. Turkey ranked 17. Turkey has an important difference in candidate countries according to its ranking.

DISCUSSIONS

In order to see if the results obtained by the proposed model are effective to represent the selected period, the correlation analysis are applied. LPI rankings published by WB and ranking calculated by COPRAS-G are investigated by using by rank correlation tests. Once the ranking results are unsatisfied the parametric relation analyses conditions, Spearman Rank and Kendall's Tau Correlation Analysis are applied in order to find out the relations between the rankings. The results of the Spearman Rank and Kendall's Tau Correlation Analysis can be seen from Table 5. Although there are slight differences between the Spearman and Kendall correlation coefficients, the ultimate result is the same.

Table 5. Non-Parametric Correlations Matrix

			2018	2016	2014	2012	2010	COPRAS-G
Kendall's Tau_b	2018	Correlation Coefficient	1,000	,742**	,758**	,750**	,723**	,803**
		Sig. (2-tailed)	.	,000	,000	,000	,000	,000
	2016	Correlation Coefficient	,742**	1,000	,803**	,682**	,860**	,864**
		Sig.	,000	.	,000	,000	,000	,000
	2014	Correlation Coefficient	,758**	,803**	1,000	,705**	,830**	,864**
		Sig.	,000	,000	.	,000	,000	,000
	2012	Correlation Coefficient	,750**	,682**	,705**	1,000	,670**	,758**
		Sig.	,000	,000	,000	.	,000	,000
	2010	Correlation Coefficient	,723**	,860**	,830**	,670**	1,000	,852**
		Sig.	,000	,000	,000	,000	.	,000
	COPRAS-G	Correlation Coefficient	,803**	,864**	,864**	,758**	,852**	1,000
		Sig.	,000	,000	,000	,000	,000	.
Spearman's rho	2018	Correlation Coefficient	1,000	,890**	,907**	,905**	,883**	,936**
		Sig.	.	,000	,000	,000	,000	,000
	2016	Correlation Coefficient	,890**	1,000	,945**	,862**	,963**	,973**
		Sig.	,000	.	,000	,000	,000	,000
	2014	Correlation Coefficient	,907**	,945**	1,000	,877**	,954**	,966**
		Sig.	,000	,000	.	,000	,000	,000
	2012	Correlation Coefficient	,905**	,862**	,877**	1,000	,854**	,903**
		Sig.	,000	,000	,000	.	,000	,000
	2010	Correlation Coefficient	,883**	,963**	,954**	,854**	1,000	,967**
		Sig.	,000	,000	,000	,000	.	,000
	COPRAS-G	Correlation Coefficient	,936**	,973**	,966**	,903**	,967**	1,000
		Sig.	,000	,000	,000	,000	,000	.

** Correlation is significant at the 0.01 level (2-tailed)

Source: own work

In comparison with the relationships between the ranking calculated by COPRAS-G and the ones calculated by WB is stronger than relationships calculated within the yearly rankings calculated by WB. The ranking calculated by COPRAS-G has the strongest relationship with all rankings published by WB. According to the results, the proposed model can be used as an effective decision making method that provides evaluation opportunity for a certain period, rather than a single year data.

CONCLUSIONS AND FUTURE RESEARCHES

It is tried to eliminate the uncertainty confronted due to the nature of decision problems, the lack of complete knowledge, by using grey system theory in this study. The main value the proposed method is to give an opportunity to evaluate the Logistics Performances of the countries for a selected period. Different from other studies, grey numbers are used to represent the performances of the selected countries by intervals obtained from the past datasets. The countries are ranked according to their evaluated LPI scores for this period.

This study also provides a different application area of COPRAS-G method. COPRAS-G method is used to evaluate the logistics performance of the countries. The criteria weights can be determined by MCDM methods such as Analytic Network Process (ANP), Stepwise Weight Assessment Ratio Analysis (SWARA), Factor Relationship (FARE), The Decision Making Trial and Evaluation Laboratory (DEMATEL), Entropy Weight Method and further analysis can be performed comparatively. Grey numbers obtained from the mean and standard deviations can be used instead of max-min performances for forming the data set. The study can be repeated using analyzes with new approaches such as Evaluation Based on Distance from Average Solution (EDAS) and Weighted Aggregated Sum Product Assessment (WASPAS) which are similar to the COPRAS method.

With the proposed method, it is considered that decision makers are presented with general ranking that includes and represents all published statistics rather than a single term. Periodic comparisons can be made with performance indexes that can be formed with more data. It will be useful to compare the results by making calculations for more than one period using grey numbers in the following years.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The author(s) received no financial support for the research, authorship, and/or publication of this article.

REFERENCES

Adhikary D.D., Bose G.K., Dipankar B., Mitra S., 2014. Multi criteria FMECA for coal-fired thermal power plants using COPRAS-G. International Journal of Quality & Reliability Management; 31(5), 601-614. http://doi.org/10.1108/IJQRM-04-2013-0068

Aghdaie M.H., Zolfani S.H., Zavadskas E.K., 2013. Decision making in machine tool selection: An integrated approach with SWARA and COPRAS-G methods. Economics of Engineering Decisions, 24(1), 5-17. http://doi.org/10.5755/j01.ee.24.1.2822

Arslan R., Bircan H., Eleroglu H., 2018. Optimally rating of biogas, compost, vermicompost facilities to be installed in Yozgat Province with ARAS and COPRAS methods. Turkish Journal of Agriculture - Food Science and Technology 6 (12),1844-1852. http://doi.org/10.24925/turjaf.v6i12.1844-1852.2319

Bakar M.A.A, Jaafar H.S., 2016. Malaysian logistics performance: A manufacturer's perspective. In Peoceedings of the 6th International Research Symposium in Service Management. Procedia . 571-578. http://doi.org/10.1016/j.sbspro.2016.05.442

Bakhouyi A., Dehbi R., Talea M., 2016. Multiple criteria comparative evaluation on the interoperability of LMS by applying COPRAS method, 2016 Future Technologies Conference (FTC), 361-366. http://doi.org/10.1109/FTC.2016.7821635

Bayrakci E., Aksoy E., 2019. Comparative Performance Assessment with Entropy Weighted ARAS and COPRAS Methods of Private Pension Companies, Business and Economics Research Journal, 10(2), 415-433.

Bentyn Z., 2015. Changes of Logistics Performance in Poland as a Result of Integration with the European Union States. We Wrocławiu Research Papers of Wrocław University of Economics, 407.

Bitarafan M., Zolfani S.H., Arefi S.L., Zavadskas E.K., 2012. Evaluating the construction methods of cold-formed steel structures in reconstructing the areas damaged in natural crises, using the methods AHP and COPRAS-G, Archives of Civil and Mechanical Engineering 12, 3, September 2012, 360-367.

Cakir E., Ozdemir M., 2018. Alti Sigma Projelerinin Bulanik Copras Yöntemiyle Degerlendirilmesi: Bir Üretim Isletmesi Ornegi (Six Sigma Projects Evaluation Using Fuzzy Copras Method: A Case Of Manufacturing Company), Verimlilik Dergisi 2018, 1 (1) 7-40.

Candemir Y., Celebi D., 2017. An Inquiry into the Analysis of the Transport & Logistics Sectors' Role in Economic Development. Transportation Research Procedia, 25, 4692-4707. http://doi.org/10.1016/j.trpro.2017.05.317

Celebi D., 2017. The Role of Logistics Performance in Promoting Trade. Maritime Economics & Logistics, 21, 3, 307-323. http://doi.org/10.1057/s41278-017-0094-4

Çemberci M., Civelek M.E., Canbolat N., 2015. The Moderator Effect of Global Competitiveness Index on Dimensions of Logistics Performance Index. Procedia-Social and Behavioral Sciences, 95(2015) 514-1524. http://doi.org/10.1016/j.sbspro.2015.06.453

Chatterjee P., Chakraborty S., 2013. Gear material selection using complex proportional assessment and additive ratio assessment-based approaches: a comparative study. International Journal of Materials Science and Engineering, 1(2), 104-111. http://doi.org/10.12720/ijmse.1.2.104-111

Chatterjee K., Kar A.S., 2018. Supplier Selection in Telecom Supply Chain Management: A Fuzzy-RASCH Based COPRAS-G Method, Technological and Economic Development of Economy, 24, 2: 765–791.

Civelek M.E., Uca N., Cemberci M., 2015. The Mediator Effect of Logistics Performance Index on the Relation between Global Competitiveness Index and Gross Domestic Product. European Scientific Journal 11 (3): 368–375. Available at SSRN: https://ssrn.com/abstract=3338312

Dekker M.J., Looff E.J., Roelofsen D.S., Roekel W.S., 2016. Improving the Logistical Situation of Costa Rica. Delf Uiversity of Technology Report.

Erkan B., 2014. The Importance and Determinants of Logistics Performance of Selected Countries. Journal of Emerging Issues in Economics, Finance and Banking, 3(6), 1237-1254.

Faria R.N.D., Souza C.S.D., Vieira J.G.V., 2015. Evaluation of Logistic Performance Indexes of Brazil in the International Trade. Revista de Administração Mackenzie 16 (1) 213–235.

Gani A., 2017. The Logistics Performance Effect in International Trade. The Asian Journal of Shipping and Logistics, 33, 4, 279-288. http://doi.org/10.1016/j.ajsl.2017.12.012

Garg R., Kumar R., Garg S., 2019. MADM-Based Parametric Selection and Ranking of E-Learning Websites Using Fuzzy COPRAS, IEEE Transactions on Education, 62, 1, February 2019.

Hoekman B., Nicita A., 2011. Trade Policy, Trade Costs, and Developing Country Trade. World Development 39(12), 2069–2079.

Iris C., Tanyas M., 2011. Analysis of Turkish Logistics Sector and Solutions Selection to Emerging Problems Regarding Criteria Listed in Logistics Performance Index (LPI). International Journal of Business and Management Studies, 3, 1, 93-102.

Julong D., 1982. Control problems of Grey Systems, System and Control Letters, 5, 288-94.

Jumadi H., Zailani S., 2010. Integrating Green Innovations in Logistics Services Towards Logistics Services Sustainability: A Conceptual Paper. Environmental Research Journal 4(4), 261-271.

Khan S., Qianli D., 2017. Does National Scale Economic and Environmental Indicators Spur Logistics Performance? Evidence from UK. Environmental Science and Pollution Research 24 (34) 26692-26705. http://doi.org/10.1007/s11356-017-0222-9

Liou J.J.H., Tamošaitienė J., Zavadskas E.K., Tzeng G.H., 2016. New hybrid COPRAS-G MADM Model for improving and selecting suppliers in green supply chain management. International Journal of Production Research, 2016, 54, 1, 114–134. http://doi.org/10.1080/00207543.2015.1010747

Liu S., Lin Y., 2010. Introduction to Grey Systems Theory. In: Grey Systems. Understanding Complex Systems, vol 68. Springer, Berlin, Heidelberg.

Martí L., Puertas R., García L., 2014. The Importance of the Logistics Performance Index in International Trade. Applied Economics 46 (24): 2982–2992. http://doi.org/10.1080/00036846.2014.916394

Martí L., Martín J.C. Puertas R., 2017. A DEA-Logistics Performance Index. Journal of Applied Economics, 20, 1, 169-192. http://doi.org/10.1016/S1514-0326(17)30008-9

Nguyen H.T., Dawal S.Z.M., Nukman Y., Aoyama, H., 2014. A hybrid approach for fuzzy multi-attribute decision making in machine tool selection with consideration of the interactions of attributes. Expert Systems with Applications, 41, 6, May 2014, 3078-3090. http://doi.org/10.1016/j.eswa.2013.10.039

Nur Fadiah M.Z., Wahab S.A., Mamun A.A., 2017. Logistics Capability, Logistics Performance, and The Moderating Effect of Firm Size: Empirical Evidence From East Coast Malaysia. Journal of Developing Areas, 51, 2, 171-182. http://doi.org/10.1353/jda.2017.0038

Onsel Ekici, S., Kabak, O., Ulengin F., 2016. Linking to Compete: Logistics and Global Competitiveness Interaction. Transport Policy 48:117-128. http://doi.org/10.1016/j.tranpol.2016.01.015

Pancholi N., Bhatt M., 2018. FMECA-Based Maintenance Planning through COPRAS-G and PSI, Journal of Quality in Maintenance Engineering, 2018, 24, 2, 224-243. http://doi.org/10.1108/JQME-03-2017-0015

Puertas R., Martí L. García L., 2014) Logistics Performance and Export Competitiveness: European Experience. Empirica, 41 (3) 467–480. http://doi.org/10.1007/s10663-013-9241-z

Mousavi-Nasab S.H., Sotoudeh Anvari A., 2017. A comprehensive MCDM-based approach using TOPSIS, COPRAS and DEA as an auxiliary tool for material selection problems. Materials & Design. May 2017, 121, 237-253, 17. http://doi.org/10.1016/j.matdes.2017.02.041

Solakivi T., Ojala L., Laari S., Lorentz H., Toyli J., Malmsten J., Viherlehto N., 2015. Finland State of Logistics 2014. Turun Kauppakorkeakoulun Julkaisuja Sarja E-1:2015.

Tavana M., Momeni E., Rezaeiniya N., Mirhedayatian S.M., Rezaeiniya H., 2013. A Novel Hybrid Social Media Platform Selection Model using fuzzy ANP and COPRAS-G. Expert System with Applications 40(14): 5694-5702. http://doi.org/10.1016/j.eswa.2013.05.015

Uca N., Ince H., Sumen H., 2016. The Mediator Effect of Logistics Performance Index on the Relation Between Corruption Perception Index and Foreign Trade Volume. European Scientific Journal 12(25) 37-45. https://hdl.handle.net/11467/1573

Vaillancourt A., Haavisto I., 2015. Country Logistics Performance and Disaster Impact. Disasters 40(2), 262-283. https://doi.org/10.1111/disa.12146

Yapraklı T.S. Unalan M., 2017. The Global Logistics Performance Index and Analysis of the Last Ten Years Logistics Performance of Turkey. Ataturk University Journal of Economics & Administrative Sciences, 31, 3, 589-606.

Yildirim B.F., Adiguzel Mercangoz B., 2019. Evaluating the Logistics Performance of OECD Countries by Using Fuzzy AHP and

ARAS-G. Eurasian Economic Review, 1-19. http://doi.org/10.1007/s40822-019-00131-3

Zavadskas E.K., Kaklauskas A., Sarka V., 1994. The new method of multicriteria complex proportional assessment of projects, Technological and Economic Development of Economy, 1(3): 131–139.

Zavadskas E.K., Kaklauskas A., 1996. Determination of an Efficient Contractor by using the new Method of Multi Criteria Assessment. In Langford, D. A.; Retik, A. (eds.) Interna. Symposium for "The Organization and Management of Construction". Shaping Theory and Practice, 2: Managing the Construction Project and Managing Risk. CIB W 65; London, Weinheim, New York, Tokyo, Melbourne, Madras. - London: E and FN SPON, 94-104.

Zavadskas E.K., Kaklauskas A., Turskis Z., Tamosaitiene J., 2008. Selection of the Effective Dwelling House Walls by Applying Attributes Values Determined at Intervals. Journal of Civil Engineering and Management, 14(2), 85-93. http://doi.org/10.3846/1392-3730.2008.14.3

Zavadskas E.K., Turskis Z., Tamošaitienė J., Marina V., 2008. Multicriteria Selection of Project Managers by Applying Grey, Technological and economic development 14(4): 462–477. http://doi.org/10.3846/1392-8619.2008.14.462-477

Zhang Y, Tan Y., Li N., Liu G., 2018. Decision-Making in Green Building Investment Based on Integrating AHP and COPRAS-Grey Approach, In Proceedings of the International Conference on Construction and Real Estate Management 2018, :65-71. http://doi.org/10.1061/9780784481738.008

Zolfani S.H., Chen I.S., Rezaeiniya N., Tamosaitiene J., 2012. A Hybrid MCDM Model Encompassing AHP and Copras-G Methods for Selecting Company Supplier in Iran. Technological and Economic Development of Economy, 18(3): 529-543. http://doi.org/10.3846/20294913.2012.709472

METODA OKRESOWA COPRAS-G: ZASTOSOWANIE WSKAŹNIKA SPRAWNOŚCI LOGISTYCZNEJ (LPI)

STRESZCZENIE. Wstęp: Logistyka jest istotną częścią handlu wielu krajów. Wkład w postaci surowców oraz energii jest niezbędny w procesie produkcji, wymaga on jednak najczęściej transportu, tak samo jak i wyroby finalne uzyskanie w procesie produkcji, zrealizowanego w efektywny sposób jako element całego procesu logistycznego. W celu pomiaru tego procesu w różnych krajach, Bank Światowy publikuje w okresach dwuletnich dane dotyczące aktywności logistycznych.

Metody: Podstawowym celem tej pracy jest dostarczenie oceny działalności logistycznej wybranych krajów w wybranym okresie czasu. Liczby szare są stosowane do określenia danych dla danego okresu oraz zastosowania metody Complex Proportional Assessment of Alternatives (COPRAS). Stworzono ranking sprawności logistycznej obejmujący 28 państw członkowskich UE oraz 5 państw kandydujących do EU. W celu oszacowania poprawności danych wyliczonych przy pomocy metody COPRAS, wykonano podwójne porównanie otrzymanych rankingów przy użyciu metod Spearman Rank oraz korelacji Kendalla Tau.

Wyniki: Uzyskane wyniki pokazują, że dane otrzymane poprzez użyciu liczb szarych reprezentują dane LPI badanych krajów w wybranym okresie. Występujące różnice, ujawnione w postaci współczynników korelacji Spearman i Kendall, nie są istotne. Ranking uzyskany w oparciu o metodę COPRAS-G wykazuje silną korelację ze wszystkimi rankingami publikowanymi przez Bank Światowy.

Wnioski: Wskaźnik LPI dla wybranych krajów na założony okres został wyliczony poprzez zastosowanie liczb szarych w połączeniu z metodą COPRAS-G.

Słowa kluczowe: COPRAS-G, sprawność logistyczna,wielokryterialne podejmowanie decyzji, szare liczby, analiza korelacji

Burcu Adiguzel Mercangoz ORCID ID: https://orcid.org/0000-0003-2250-1052
Faculty of Transportation and Logistics
Istanbul University
I.U.C. Avcilar Campus, 34320 Avcilar, Istanbul, **Turkey**
e-mail: burcua@istanbul.edu.tr

Bahadır F. Yildirim ORCID ID: https://orcid.org/0000-0002-0475-741X
Faculty of Transportation and Logistics
Istanbul University
I.U.C. Avcilar Campus, 34320 Avcilar, Istanbul, **Turkey**
e-mail: bahadirf.yildirim@istanbul.edu.tr

Sultan KUZU YILDIRIM ORCID ID: https://orcid.org/0000-0001-6577-1584
School of Business
Istanbul University
I.U.C. Avcilar Campus, 34320 Avcilar, Istanbul, **Turkey**
e-mail: sultan.kuzu@istanbul.edu.tr

LogForum

> Scientific Journal of Logistics <

2020, 16 (2), 251-260

http://doi.org/10.17270/J.LOG.2020.436

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

A DECISION MAKING SUPPORT SYSTEM IN LOGISTICS COOPERATION USING A MODIFIED VIKOR METHOD UNDER AN INTUITUINISTIC FUZZY ENVIRONMENT

Anna Tatarczak

Maria Curie-Skłodowska University in Lublin, Lublin, **Poland**

ABSTRACT. **Background:** This paper proposes a novel hybrid group decision making methodology to solve a coalition-formation problem for cooperative replenishment with multiple firms to achieve operational efficiency. We consider a case of horizontal cooperation between firms, and we investigate the profitability of horizontal cooperation when designing collaborative contracts.
Methods: This study presents the application of a hybrid approach for group decision support for the coalition -formation problem. Multi-criteria decision making (MCDM) and intuitionistic fuzzy set (IFS) theory have been integrated to provide group decision support under consensus achievement. In addition, this study employs the entropy method to identify the weights of the decision makers.
Results: The proposed integrated approach has been further studied through an illustrative example. The decision procedure used here is simply structured so that it may easily be implemented with a computer.
Conclusions: This research may be beneficial to decision makers, researchers and organizations in helping them to understand project based evaluation in order to design and plan better horizontal cooperation.

Key words: Coalition formation, logistics cooperation multi-criteria decision analysis, group decision making, Shapley value, VIKOR.

A part of this study was presented as oral presentation at the „8th International Logistics Scientific Conference WSL FORUM 2019" in Poznan (Poland), 18th-19th of November 2019.

INTRODUCTION

Horizontal logistics collaboration offers a great opportunity for companies to reduce their distribution costs. By forming a coalition, companies have the potential to become more profitable. However, the selection of a coalition structure is a difficult task for decision makers. The decision maker needs to identify and choose the best possible partner(s) in order to carry out a joint plan with respect to many criteria. The aim of this paper is to propose a novel hybrid group decision making methodology to solve coalition-formation problem.

Drivers of horizontal collaboration and multi - criteria analyses in a coalition structure are studied in the literature, and may be categorized into four main groups according to their objectives as follows:

- **Cost reduction**. Horizontal cooperation reduces the costs of non-core activities, e.g. organizing safety training, joint fuelling facilities [Cruijssen et al. 2007]. Moreover, horizontal cooperation reduces purchasing costs, e.g. vehicles, onboard computers, fuel [Cruijssen et al. 2007].

Citation: Tatarczak A., 2020. A decision making support system in logistics cooperation using a modified Vikor method under an intuituinistic fuzzy environment. LogForum 16 (2), 251-260, http://doi.org/10.17270/J.LOG.2020.436
Received: 10.01.2020, Accepted: 09.03.2020, on-line: 30.03.2020.

- **Service improvement**. Collaborative relationships improve the quality of the service provided at lower costs, e.g. in terms of speed, frequency of deliveries, geographical coverage, reliability of delivery times [Cruijssen et al. 2007, Ghaderi et al. 2016].
- **Market position**. Alliances are a useful tool with which to expand the available fleet, along with its service range and geographic coverage, and, as a result, to increase their customer reach [Gou et al. 2014].
- **Emission reduction**. Among the main motivating factors for companies to engage in a horizontal logistics coalition is the achievement of a higher degree of sustainability e.g. reduced emission of greenhouse gases and other undesirable substances [Soysal et al. 2018].

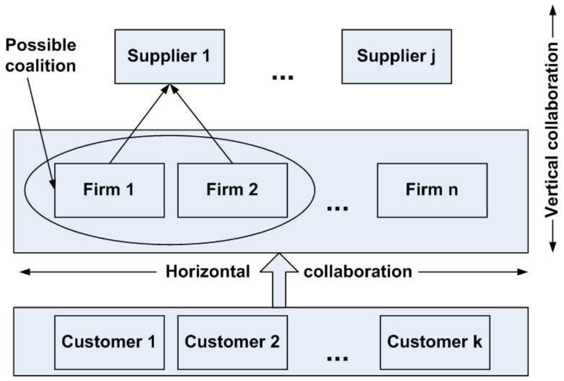
As a result of the aforementioned drivers of collaboration, firms attempted to join their orders by forming alliances. In order to contract coalition structure and prevent conflict situations in future coalitions, we address the following research issues:

1. Which criteria to choose for collaboration partner evaluation?
2. How to generate criteria and alternative ratings? How to specify the weights of criteria and decision makers objectively?
3. Which multi-criteria method to choose for collaboration partner evaluation?

Multiple criteria decision making (MCDM) methods provide an effective means of assisting decision makers to choose the best alternative given multiple criteria. In MCDM problems, a group decision matrix is established by aggregating the individual evaluation of each decision maker (DM) with the aim of finding a group satisfactory solution that is most preferred by the DMs [Cali and Balaman 2019]. VIKOR is a well-known and widely-used multiple attribute decision making method. The major advantage of the VIKOR method is that it may be used to trade off the maximum group utility of the majority and the minimum individual regret of the opponent [Wan et al., 2013, Tavana et al., 2016].

The fuzzy sets theory introduced by Zadeh [1965] has been very successful in dealing with problems involving uncertainty. Zadeh [1965] and Zhao et al. [2015] proposed the concept of the hesitant fuzzy set (HFS), which permits its membership to have a set of possible values. Fuzzy set theory may be used to model imprecision in MCDM problems. Atanassov [1986] extended the HFS considering the nonmembership degree and hesitation degree as well as the membership degree and proposed IFS theory.

In this paper, we address the problem of coalition-formation for cooperative replenishment with multiple firms to achieve operational efficiency, as it is presented in Figure 1. The selection of the most suitable partner(s) with respect to numerous conflicting criteria becomes a more challenging and difficult problem. Our goal is to identify the best partner(s) or the alliance.



Source: Jouida et al., 2017

Fig. 1. The business context considering collaboration and coalition-formation

In order to adopt a reliable and practical decision making model, we propose a hybrid MCGDM approach based on the integration of the IFS and VIKOR method with the aid of the entropy method and Shapley value to evaluate the weights of DMs and criteria by utilizing linguistic variables.

The paper is organized as follows. In Section 2, we introduce the concept of IFSs ,fuzzy measures, the entropy method, and Shapley value. The conceptual framework of the adopted research methodology is described in Section 3. In Section 4 an illustrative example is given. Finally, we conclude and discuss the direction of future works in Section 5.

PRELIMINARIES

IFSs

Definition 1. *[Zhao et al. 2015]. Given a fixed set $X = \{x_1, x_2, \dots, x_n\}$, then a hesitant fuzzy set (HFS) on X is in terms of a function that when applied to X returns a set of* $[0,1]$.

For convenience, Wei [2012] completed the original HFS definition by including the HFS mathematical representation as follows:

$$A = \{< x,\ h_A(x) > | x \in X\}$$

where $h_A(x)$ is a set of some values in $[0,1]$, and denotes the possible membership degree of the element $x \in X$ to the set A. For the sake of simplicity, $h(x) = h_A(x)$ is called a hesitant fuzzy element (HFE).

Definition 2. *[Atanassov 1986]. Given a fixed set $X = \{x_1, x_2, \dots, x_n\}$ then an IFS A in X is represented as*

$$A = \{< x,\ \mu_A(x), v_A(x) \quad > | x \in X\}$$

where the functions $\mu_A(x): X \to [0,1]$ represent the membership degree and non-membership degree of the element $x \in X$ to A subset of X and for every $x \in X$ in the following condition:

$$0 \le \mu_A(x) + v_A(x) \le 1.$$

In this paper, the hesitant normalized Hamming distance is used to measure the difference between the evaluation values of the alternatives. This measurement is defined as follows.

Definition 3. *[Zhang and Wei 2013]. Let h_1 and h_2 be two HFEs on $X = \{x_1, x_2, \dots, x_n\}$ then the hesitant Normalized Hamming distance measurement between h_1 and h_2 is defined as follows:*

$$||h_1 - h_2|| = \frac{1}{l}\sum_{j=1}^{l} |h_{1\sigma(j)} - h_{2\sigma(j)}|,$$

where $l(h)$ indicates the number of elements in h, and is defined as the length of HFE.

Shapley value

Definition 4. *[Shapley and Shubik 1953] Let μ be a fuzzy measurement on the set $X = \{x_1, x_2, \dots, x_n\}$. The Shapley index for every $j \in X$ is defined by*

$$\varphi_j = \sum_{K \subset X \setminus x_j} \frac{(n-|K|-1)!|K|!}{n!} [\mu(K \cup \{x_j\}) - \mu(K)] \quad (1)$$

where n and K are the number of criteria in X and $|K|$ respectively.

The Shapley value of μ is the vector $\varphi(\mu) = [\varphi_1, \varphi_2, \dots, \varphi_n]$.

The Shapley value φ_j returns the average value of the contribution $x_j \in X$ alone in all coalitions. Thus, a basic property of the Shapley value is that $\varphi_1 + \varphi_2 + \dots + \varphi_n = 1$.

Linguistic variables

Linguistic variables are variables of values which are not numbers but words or, more generally, linguistic labels off fuzzy sets [Zadeh 1983]. In our study, the weights of DMs are obtained based on those variables which are shown in Table 1.

Table 1. Number of regular destinations and passenger traffic in 2013

Linguistic variables	Intuitionistic fuzzy numbers
Extremely good (EG)/ extremely high (EH)	(1.00; 0.00; 0.00)
Very very good (VVG)/ very very high (VVH)	(0.90; 0.10; 0.00)
Very good (VG)/ very high (VH)	(0.80; 0.10; 0.10)
Good (G)/ high (H)	(0.70; 0.20; 0.10)
Medium good (MG)/ medium high (MH)	(0.60; 0.30; 0.10)
Fair (F)/medium (M)	(0.50; 0.40; 0.10)
Medium bad (MB)/medium low (ML)	(0.40; 0.50; 0.10)
Bad (B)/low (L)	(0.25; 0.60; 0.15)
Very bad (VB)/very low (VL)	(0.10; 0.75; 0.15)
Very very bad (VVB)/very very low (VVL)	(0.10; 0.90; 0.00)

Entropy concept

The concept of entropy in information theory was firstly proposed by Shannon [1948] which presented an equation to measure the uncertainty in information based on probability theory. The formulation of IF-entropy is depicted in the following equation.

$$E(A) = -\frac{1}{nln2}\sum_{j=1}^{n}[\mu_A(x_i)ln\mu_A(x_i) + v_A(x_i)lnv_A(x_i) - (1-\pi_A(x_i))\ln(1-\pi_A(x_i)) - \pi_A(x_i)ln2], \quad (2)$$

Consider an MCGDM problem where $A = \{a_1, a_2, \dots, a_m\}$ are the alternative sets to choose, $X = \{x_1, x_2, \dots, x_n\}$ are the criteria set, h_{ij} is the rating of alternatives a_i $(i = 1,2,\dots,m)$ with respect to criteria x_j $(j = 1,2,\dots,n)$.

Alternative a_i is represented as an A-IFS of the following form:

$$a_i = \{\langle x_j, X_{ij} | x_j \in X\rangle\}$$

where $X_{ij} = (\mu_{ij}, v_{ij})$. X_{ij} defines the degrees of satisfaction and dissatisfaction of the *i*th alternative regarding to the *j*th criterion respectively denoted by μ_{ij}, and v_{ij}, where $0 \le \mu_{ij} + v_{ij} \le 1$, $\pi_{ij} = 1 - \mu_{ij} - v_{ij}$, $i = 1,2,\dots,m$, $j = 1,2,\dots,n$. π_{ij} is the hesitancy degree of the *i*th alternative regarding to *j*th criterion.

DECISION SUPPORT SYSTEM

This section presents a detailed description of the proposed decision system in logistics cooperation. Companies have a lack of efficient and effective systems to conduct horizontal cooperation. The proposed approach is easy to implement the algorithm, moreover it is practical and provides solutions with incomplete quantitative information. The proposed model was applied to a practical case in logistics industry.

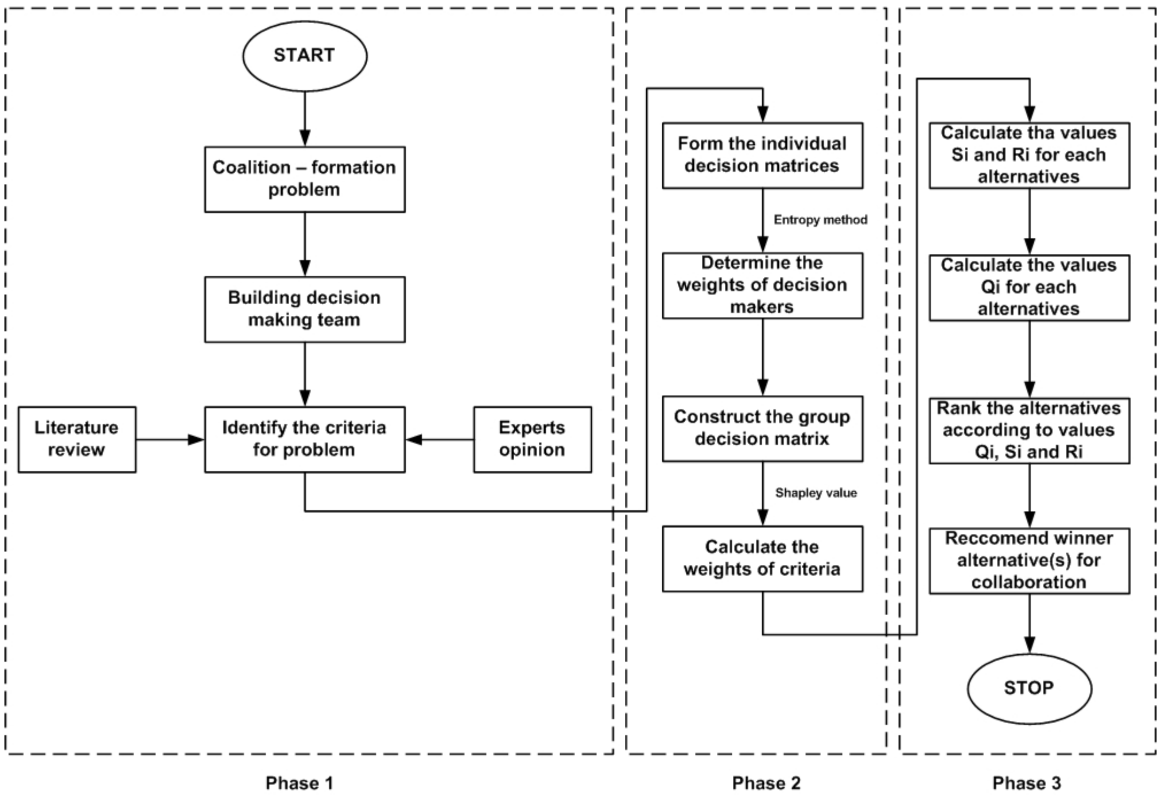


Fig. 2. Schematic diagram of the proposed model

In the proposed group decision model, the computational process takes place in three phases. Initially, the weights of the DMs and the weights of decision criteria are determined using the entropy method and Shapley value respectively. The second task is to generate the ranking of the logistics coalition-formation problem using fuzzy VIKOR. The suggested algorithm is presented in Figure 2 and explained subsequently.

Phase I

In this study, the criteria for coalition-formation problem were identified through literature review (Section 1) and validated by the company experts via nominal group technique for making an objective and unbiased decision [Delbecq et al. 1975].

Phase II

In the first step, assume that each expert provides his/her judgments on each factor as a linguistic term. Since linguistic terms are not mathematically operable, the next step is to make a standardization of expert evaluations by transforming them according Table 1. Therefore each individual decision matrix is formed according to evaluation of each DM. However, all DMs may not have the same weight in the decision process. The importance level of the experts is considered as linguistic terms. The weighted method used in this study is proposed by Calı and Balaman [2019]. The entropy of the kth DM is calculated as follows

$$E(R^{(k)}) = -\frac{1}{mnln2}\sum_{j=1}^{n}\sum_{i=1}^{m}[\mu_{ij}ln\mu_{ij} + v_{ij}lnv_{ij} - (1-\pi_{ij})\ln(1-\pi_{ij}) - \pi_{ij}ln2],$$

where $R^{(k)}$ indicates individual IF-decision matrix of E_k, $j = 1,2,\dots,n$, $i = 1,2,\dots,m$. Here if $\mu_{ij} = 0, v_{ij} = 0, \pi_{ij} = 1$,; then $\mu_{ij}ln\mu_{ij} = 0$, $v_{ij}lnv_{ij} = 0$, respectively.

Then, calculate the degree of divergence for each $R^{(k)}$ as following equation $d_{R^{(k)}} = 1 - E(R^{(k)})$. Finally, calculate the weights of DMs w_k using the following equation: $w_k = \frac{d_{R^{(k)}}}{\sum_{k=1}^{K} d_{R^{(k)}}}$. After the individual preferences are converted into priorities, these preferences of the group of decision makers are aggregated so as to estimate the collective preferences. The aggregation of the individual judgments are calculated by the equation

$$r_{ij} = \left[1 - \prod_{k=1}^{K}\left(1-\mu_{ij}^{(k)}\right)^{w_k}, \prod_{k=1}^{K}\left(v_{ij}^{(k)}\right)^{w_k}, \prod_{k=1}^{K}\left(1-\mu_{ij}^{(k)}\right)^{w_k} - \prod_{k=1}^{K}\left(v_{ij}^{(k)}\right)^{w_k}\right]. \quad (3)$$

As a result the group decision matrix $R = (r_{ij})_{m\times m}$ is constructed, where $r_{ij} = (\mu_{ij}, v_{ij}, \pi_{ij})$ indicates the evaluation value of ith alternative with reference to jth criterion according to group evaluation. The final step in this phase is to calculate the weights of criteria. The weights are obtained based on the Shapley value by applying equation (1).

Phase III

Once the weights of criteria are obtained, a modified VIKOR approach is proposed for conducting the ranking process. In order to determine the positive ideal solution (PIS) and the negative ideal solution (NIS): $A^+ = \{h_1^+, h_2^+, h_3^+, h_4^+\}$, $A^- = \{h_1^-, h_2^-, h_3^-, h_4^-\}$. The average score S_i and the worst group score R_i for each alternative are determined as follows:

$$S_i = \sum_{j=1}^{n}\varphi_j\frac{||h_j^+ - h_{1j}||}{||h_j^+ - h_j^-||}, \qquad R_i = \max_{x_j}\frac{||h_j^+ - h_{1j}||}{||h_j^+ - h_j^-||}\varphi_j$$

where φ_j are the weight of the separate criterion x_j contribution based on a different combination of sub-criteria and expressed by their relative importance in decision making. The best alternative to this method is determined on the basis of the overall ranking index Q_i by the following relationship:

$$Q_i = v\frac{S_i - S^*}{S^- - S^*} + (1-v)\frac{R_i - R^*}{R^- - R^*}$$

where S_i and R_i denote the average and the worst group score of alternative i, respectively,

$$S^* = \min_i S_i, \qquad S^- = \max_i S_i, R^* = \min_i R_i, \\ R^- = \max_i R_i$$

and υ represents the significance of the strategy, the value of which is usually set to 0.5.

Rank the alternatives by sorting the values S_i, R_i and Q_i in descending order. The larger the index value, the better the performance of the alternatives. The results are three ranking lists that may be used to propose and validate a compromise solution.

Obtain a compromise solution to the alternatives $A^{'}$, which is best ranked by the measure Q (minimum), if the following two conditions should be satisfied:

$\Delta 1.$ Acceptable advantage $Q(A^{''}) - Q(A') \geq \frac{1}{m-1}$, where $A^{''}$ is the alternative with the second position in the ranking list by Q, and m is the number of alternatives.

$\Delta 2.$ Acceptable stability in decision making the alternatives $A^{'}$ should also be the best ranked by S_i or/and R_i which indicates that this compromise solution is stable within a decision making process.

If the condition Δ1*:* is not satisfied, $A^{(M)}$ is determined by the relation $Q(A^M) - Q(A') \geq \frac{1}{m-1}$, for maximum M (the positions of these alternatives are "in closeness"). Thus, all alternatives $A^{'}, A^{''}, \ldots, A^{(M)}$ are the compromise solutions. If the condition Δ2*:* is not satisfied, then both alternatives $A^{'}$ and $A^{''}$ are compromise solutions.

EXPERIMENTAL SETUP

Case background

A logistics company was chosen for the case study. The company was chosen due to their willingness to incorporate horizontal cooperation practices into their operations as well as their experience in the field. The company wishes to select the best coalition for logistics cooperation. After pre-assessment, a list of potential coalitions was identified for further assessment. To assess the best coalition structure, a panel consisting of three experts was formed. All of the of experts were chosen based on their reputation, performance, and also on the basis of their experience.

Coalition-structure selection based on extended VIKOR

Step 1. Determination of the goal, alternatives and criteria

The coalition in the example is any group of two or more companies that agree to work together temporarily in a partnership to achieve a common goal. It is further assumed that only one coalition may exist at any one time. Suppose there are three possible coalition structures a_i (i=1,2,3) to be evaluated. It is necessary to compare these coalition structures to select the most important of them from the point of view of their relative importance, taking into account the criteria suggested as drivers of horizontal collaboration: cost reduction (x_1); service improvement (x_2); market position (x_3); and emission reduction (x_4). Selection of these criteria were based on the reviewed literature (in Section 1), which were confirmed by DMs opinions.

Step 2. Construction of individual decision matrix

At the beginning of the evaluation process, each DM evaluated the alternatives with reference to each criterion using linguistic variables and afterward these ratings were converted to intuitionistic fuzzy numbers, presented in Table 2.

Table 2. The individual decision matrices with IFNs

		x_1	x_2	x_3	x_4
		$\mu\ v\ \pi$	$\mu\ v\ \pi$	$\mu\ v\ \pi$	$\mu\ v\ \pi$
$R^{(1)} =$	a_1	(0.7, 0.2, 0.1)	(0.8, 0.1, 0.1)	(0.8, 0.1, 0.1)	(0.7, 0.2, 0.1)
	a_2	(0.6, 0.3, 0.1)	(0.5, 0.4, 0.1)	(0.2, 0.3, 0.5)	(0.1, 0.75, 0.15)
	a_3	(0.1, 0.75, 0.15)	(0.25, 0.6, 0.15)	(0.4, 0.5, 0.1)	(0.5, 0.4, 0.1)
$R^{(2)} =$	a_1	(0.7, 0.2, 0.1)	(0.8, 0.1, 0.1)	(0.7, 0.2, 0.1)	(0.5,0.4, 0.1)
	a_2	(0.6, 0.3, 0.1)	(0.5, 0.4, 0.1)	(0.6, 0.3, 0.1)	(0.4, 0.5, 0.1)
	a_3	(0.5, 0.4, 0.1)	(0.7, 0.2, 0.1)	(0.8, 0.1, 0.1)	(0.6, 0.3, 0.1)
$R^{(3)} =$	a_1	(0.5, .4, 0.1)	(0.7, 0.2, 0.1)	(0.6, 0.3, 0.1)	(0.6, 0.3, 0.2)
	a_2	(0.4, 0.5, 0.1)	(0.5, 0.4, 0.1)	(0.7, 0.2, 0.1)	(0.4, 0.5, 0.1)
	a_3	(0.5, 0.4, 0.1)	(0.8, 0.1, 0.1)	(0.8, 0.1, 0.1)	(0.7, 0.2, 0.1)

Step 3. Expert weights calculation

To calculate the weights of the DMs, first entropy values was used based on equation. Then, the divergence values are specified using and finally, the weight of each DMs are obtained using equation. Table 3 shows the degree of importance of the DMs.

Table 3. The results of entropy method for weights of DMs

	DM1	DM2	DM3
Entropy values	0.128	0.082	0.120
Divergences	0.872	0.918	0.880
Weights	0.327	0.344	0.330

Step 4. Construction of the group decision matrix.

All individual evaluations are aggregated based on equation (3) as is shown in Table 4.

Table 4. The group decision matrices with IFNs

		x_1	x_2	x_3	x_4
		$\mu\ v\ \pi$	$\mu\ v\ \pi$	$\mu\ v\ \pi$	$\mu\ v\ \pi$
$R =$	a_1	(0.64, 0.25, 0.65)	(0.77, 0.13, 0.77)	(0.71, 0.18, 0.72)	(0.61, 0.29, 0.58)
	a_2	(0.54, 0.36, 0.54)	(0.50, 0.40, 0.50)	(0.54, 0.26, 0.48)	(0.32, 0.57, 0.31)
	a_3	(0.39, 0.49, 0.39)	(0.65, 0.23, 0.66)	(0.71, 0.17, 0.73)	(0.61, 0.29, 0.61)

Step 5. Prioritizing criteria

This step starts with determination of the criteria correlation. To accomplish this, each DM was provided with a questionnaire and was asked to estimate the importance of each factor. The fuzzy measure of criteria x_j $(j = 1, 2, 3, 4)$ of X is as follows:

$$\mu(\emptyset) = 0,$$

$$\mu(x_1) = 0.35, \mu(x_2) = 0.3, \mu(x_3) = 0.22, \mu(x_4) = 0.2,$$

$$\mu(x_1, x_2) = 0.7, \mu(x_1, x_3) = 0.65, \mu(x_1, x_4) = 0.62, \mu(x_2, x_3) = 0.55, \quad \mu(x_2, x_4) = 0.45, \mu(x_3, x_4) = 0.4$$

$$\mu(x_1, x_2, x_3) = 0.82, \mu(x_1, x_2, x_4) = 0.79, \mu(x_1, x_3, x_4) = 0.7, \mu(x_2, x_3, x_4) = 0.65,$$

$$\mu(x_1, x_2, x_3, x_4) = 1.$$

Using equation (1), the Shapley value for criteria can be obtained as follows:

$$\varphi(x_1) = 0.355, \varphi(x_2) = 0.277, \varphi(x_3) = 0.203, \varphi(x_4) = 0.165.$$

Step 6. Calculate the values S_i and R_i for each alternatives

Determine the ideal and negative-ideal solution:

$$A^{+} = \{h_1^+, h_2^+, h_3^+, h_4^+\} = \{0.65, 0.77, 0.73, 0.61\},$$

$$A^{-} = \{h_1^-, h_2^-, h_3^-, h_4^-\} = \{0.25, 0.13, 0.17, 0.29\}.$$

Next, we compute S_i and R_i as below:

$$S_1 = \sum_{j=1}^{4} \varphi_j \frac{||h_j^+ - h_{1j}||}{||h_j^+ - h_j^-||} = 0.344, S_2 = 0.499, S_3 = 0.437.$$

$$R_1 = \max_{x_j} \frac{||h_j^+ - h_{1j}||}{||h_j^+ - h_j^-||} \varphi_j = 0.119, R_2 = 0.150, R_3 = 0.199.$$

Step 7. Calculate the values Q_i for each alternatives

Let $v = 0.5$, we compute

$$Q_i\ (i = 1,2,3){:}\ Q_1 = 0.000, \quad Q_2 = 0.691, \quad Q_3 = 0.802.$$

Step 8. Rank the alternatives according to values Q_i, S_i and R_i.

The Q_i, S_i and R_i values are sorted in decreasing order and three different rankings are presented in Table 5. Coalition a_1 is in the first position of the ranking lists considering *S; R* and *Q* values. The condition given by 4 is tested

$$Q(a_2) - Q(a_1) = 0.691 > 0.5.$$

Therefore, the condition (4) of acceptable advantage is satisfied. Consequently, coalition a_1 is chosen as he most appropriate coalition partner(s) for the company according to the methodology developed.

Table 5. The ranking

	a_1	a_2	a_3	Ranking	Compromise solution
S	0.344	0.499	0.437	$a_1 < a_3 < a_2$	a_1
R	0.119	0.150	0.199	$a_1 < a_2 < a_3$	a_1
$Q(v = 0.5)$	0.000	0.691	0.802	$a_1 < a_2 < a_3$	a_1

CONCLUSIONS

Existing research concerning horizontal logistics cooperation has mainly focused on assessing costs and benefits and their allocation to individual collaborating partners [Defryn et al. 2019]. However, the main interest of the potential collaborating firms is to figure out how the collaborating groups should be formed [Jouida et al. 2017]. In order to response to this question, in this paper a general solution framework is presented for optimising decisions in a horizontal logistics cooperation. Specifying, we present an effective model using modified VIKOR techniques for evaluating the best coalition partner(s) in a logistics alliance in an intuitionistic environment. In order to accommodate the criteria, the Shapley value is selected to obtain the relative weight of criteria.

The coalition-formation concept fits well in the real-world case of collaborative transportation that motivated our research. Group decision-making concerning the selection of the coalition partner(s) may help managers to face the problems that directly affect the viability of their organization. This research may be beneficial to decision makers, researchers and organizations in helping them to understand project based evaluation in order to design and plan better horizontal cooperation. Further studies may include situations where the information is in the form of an interval-valued intuitionistic fuzzy number.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The work was supported by National Science Center Poland under grant no. 2018/02/X/HS4/02777.

REFERENCES

Atanassov K., 1986. Intuitionistic fuzzy sets. fuzzy sets and systems 20 (1), 87-96, http://doi.org/10.1016/s0165-0114(86)80034-3.

Boran F.E., Gen¸c. S., Kurt M., Akay D., 2009. A multi-criteria intuitionistic fuzzy group decision making for supplier selection with topsis method. Expert Systems with Applications 36, 11363-11368, http://doi.org/10.1016/j.eswa.2009.03.039.

Calı S., Balaman S.Y., 2019. A novel outranking based multi criteria group decision making methodology integrating electre and vikor under intuitionistic fuzzy environment. Expert Systems with Applications 119, 36-50, http://doi.org/10.1016/j.eswa.2018.10.039.

Cruijssen F., Cools M., Dullaert W., 2007. Horizontal cooperation in logistics: opportunities and impediments. Transportation Research Part E: Logistics and Transportation Review 43, 129-142, http://doi.org/10.1016/j.tre.2005.09.007.

Defryn C., Sorensen K., Dullaert W., 2019. Integrating partner objectives in horizontal logistics optimisation models. Omega 82, 1-12, http://doi.org/10.1016/j.omega.2017.11.008

Delbecq A.L., Van de Ven A.H., Gustafson D.H., 1975. Group techniques for program planning: A guide to nominal group and Delphi processes. Scott Foresman, http://doi.org/10.1093/sw/21.4.338.

Ghaderi, H., Dullaert, W., Amstel, W.P.V., 2016. Reducing lead-times and leadtime variance in cooperative distribution networks. International Journal of Shipping and Transport Logistics 8, 51-65, http://doi.org/10.1504/ijstl.2016.073316 .

Gou Q., Zhang J., Liang L., Huang Z., Ashley A., 2014. Horizontal cooperative programmes and cooperative advertising. International Journal of Production Research 52, 691-712, http://doi.org/10.1080/00207543.2013.827809.

Jouida S.B., Krichen S., Klibi W., 2017. Coalition-formation problem for sourcing contract design in supply networks. European Journal of Operational Research 257, 539-558.

Shannon C.E., 1948. A mathematical theory of communication. Bell system technical journal 27, 379-423, http://doi.org/10.1016/j.ejor.2016.07.040.

Soysal M., Bloemhof-Ruwaard J.M., Haijema R., van der Vorst J.G., 2018. Modeling a green inventory routing problem for perishable products with horizontal collaboration. Computers & Operations Research 89, 168-182, http://doi.org/10.1016/j.cor.2016.02.003.

Tavana M., Yazdani M., Di Caprio D., 2017. An application of an integrated anp-qfd framework for sustainable supplier selection. International Journal of Logistics Research and Applications 20, 254-275, http://doi.org/10.1080/13675567.2016.1219702.

Wan S.P., Wang Q.Y., Dong J.Y., 2013. The extended vikor method for multiattribute group decision making with triangular intuittionistic fuzzy numbers. Knowledge-Based Systems 52, 65-77, http://doi.org/10.1016/j.knosys.2013.06.019

Wei G., 2012. Hesitant fuzzy prioritized operators and their application to multiple attribute decision making. Knowledge-Based Systems 31, 176-182, http://doi.org/10.1016/j.knosys.2012.03.011

Zadeh L.A., 1965. Fuzzy sets. Information and control 8, 338-353, http://doi.org/10.1016/s0019-9958(65)90241-x.

Zadeh L.A., 1983. Linguistic variables, approximate reasoning and dispositions. Medical Informatics 8, 173-186, http://doi.org/10.3109/14639238309016081

Zhang N., Wei G., 2013. Extension of vikor method for decision making problem based on hesitant fuzzy set. Applied Mathematical Modelling 37, 4938-4947, http://doi.org/10.1016/j.apm.2012.10.002.

Zhao N., Xu Z., Liu F., 2015. Uncertainty measures for hesitant fuzzy information. International Journal of Intelligent Systems 30, 818-836, http://doi.org/10.1002/int.21714.

SYSTEM WSPARCIA DECYZJI W WSPÓŁPRACY LOGISTYCZNEJ Z WYKORZYSTANIEM ZMODYFIKOWANEJ METODY VIKOR W ROZMYTYM ŚRODOWISKU

STRESZCZENIE. **Wstęp:** W artykule zaproponowano nową metodologię podejmowania decyzji dotyczących tworzenia koalicji między wieloma firmami w celu osiągnięcia wydajności operacyjnej. Rozważany jest przypadek horyzontalnej współpracy między firmami, a następnie badana jest opłacalność współpracy horyzontalnej przy projektowaniu umów o współpracę.
Metody: W pracy przedstawiono zastosowanie podejścia hybrydowego do wspomagania decyzji grupowych w przypadku problemu koalicji. Zintegrowano wielokryterialne podejmowanie decyzji (MCDM) i intuicyjną teorię zbiorów rozmytych (IFS), aby zapewnić grupowe wsparcie decyzji przy osiągnięciu konsensusu. Ponadto zastosowano metodę entropii do identyfikacji wag osób podejmujących decyzje.
Wyniki: Proponowane zintegrowane podejście zostało poddane dalszej analizie za pomocą przykładu. Zastosowana tutaj procedura decyzyjna ma prostą strukturę, dzięki czemu można ją łatwo wdrożyć za pomocą komputera.
Wnioski: Badania te mogą być korzystne dla decydentów, badaczy i organizacji, pomagając im zaprojektować i zaplanować współpracę horyzontalną.

Słowa kluczowe: tworzenie koalicji, współpraca logistyczna, analiza decyzji wielokryterialnych, grupowe podejmowanie decyzji, wartość Shapleya, VIKOR.

Anna Tatarczak ORCID ID: https://orcid.org/0000-0001-8573-5791
Maria Curie-Skłodowska University in Lublin
Pl. Marii Curie-Skłodowskiej 5/1115
20-031 Lublin, **Poland**
e-mail: anna.tatarczak@poczta.umcs.lublin.pl

LogForum
> Scientific Journal of Logistics <
2020, 16 (2), 261-269
http://doi.org/10.17270/J.LOG.2020.401
http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X
ORIGINAL PAPER

LOGISTICS MATURITY MODEL IN THE SERVICE INDUSTRY: STATE OF ART AND RESEARCH IMPLICATIONS

Monika Kosacka-Olejnik
Poznan University of Technology, Poznan, **Poland**

ABSTRACT. **Background:** Contemporary, logistics is regarded as a key factor in business success, which results in the emergence of the Logistics maturity concept. In the current literature, there is still lack of efforts to systematically review the state of the art of logistics maturation. Therefore, the aim of the paper was to address this gap by investigating the academic signs of progress in logistics maturity of service companies according to a developed literature review procedure.
Methods: The literature review method was used to verify current knowledge on the logistics maturity model, with the use of the developed method for literature review research.
Results: The literature review procedure was developed and used to analyze and categorize papers within the logistics maturity topic for identification of the logistics maturity, existing models, their structure and areas of maturity assessment. This study presents the research gap in logistics maturity models for the service industry.
Conclusions: Expected results of the research will contribute to the systematization of knowledge on the logistics processes realization in the service industry, so it will affect the state of theoretical knowledge of economics, management, and logistics. Findings of this review may be used as the basis for logistics maturity model development as well as a guideline for making a literature review.

Key words: logistics maturity, literature review, state of art, service industry.

INTRODUCTION

The competitiveness of companies require „mature logistics" as logistics has been perceived as a source of the competitiveness or key competence [Christopher 2016] and a major source of cost. Therefore, logistics has become an increasing area of strategic concern for companies, which compete in the turbulent environment.

Logistics is considered in a paper as a sum of undertaken processes aimed at efficient flow management into and out of a business in order to meet customers' requirements. Thus, logistics has several different fields of emphasis, including procurement, distribution, warehousing, reverse logistics, which are equally important. Considering the growing importance of logistics, there have been made some attempts to manage it and assess it. The increasing importance level of logistics has resulted in the term "logistics maturity", which took roots in the concept of process maturity.

Maturity models have been explored in the literature, resulting in many papers, also reviews e.g. made by Lacerda and von Wangenheim [2018]. Since these days, the publication amount of maturity-related topics has been steadily risen, resulting in new models dedicated to a specific sector or area. This growing diversity and scale of papers on maturity has made the field of maturity model research more and more confusing and interesting, at the same time.

Citation: Kosacka-Olejnik M., 2020. Logistics maturity model in the service industry: State of art and research implications. LogForum 16 (2), 261-269, http://doi.org/10.17270/J.LOG.2020.401
Received: 06.11.2019, Accepted: 21.01.2020, on-line: 30.03.2020.

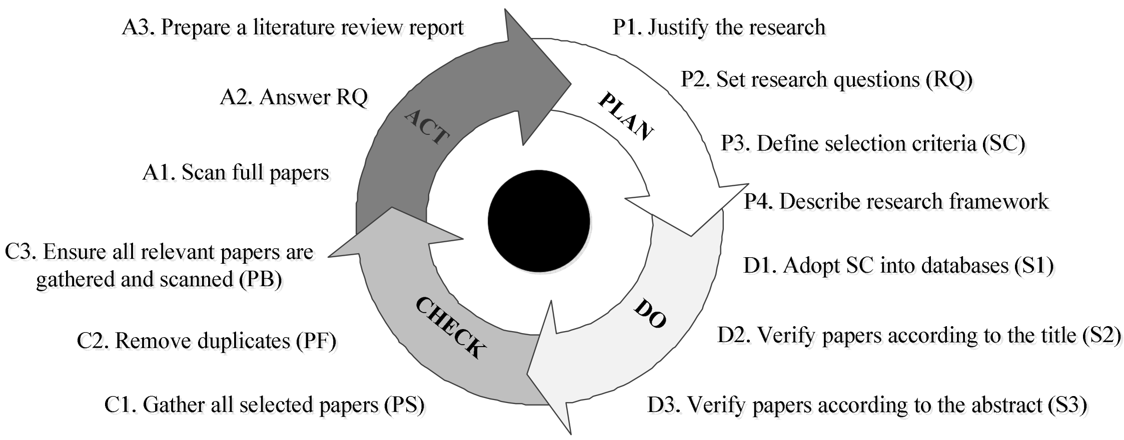
Considering the above, authors assumed that logistics maturity model becomes necessary to be analyzed in a systematic way to describe what is state-of-art on that topic as the overall state of the art of research on logistics, maturity has so far been rather limited.

The major objective of the paper was to provide an overview of the current state of the art on the logistics maturity model. The research was carried out in the framework of the project entitled: "Research on logistics maturity of service companies", realized in Poland (Project ID: 2016/21/D/HS4/02116). To achieve major objective of the paper, there was determined a literature review procedure.

The remainder of the paper is organized as follows. The research methodology is briefed in Section 2. Section 3 presents the methodology applied in this work. In Section 4 there are included answers for research questions used in Section 3. Section 4 provides a brief conclusion to this paper regarding the main findings and future research directions.

REVIEW METHODOLOGY

The aim of this study was to obtain an overview of the logistics maturity model. Therefore, it was assumed, that systematic literature reviews as proposed by Kitchenham [2004] or Denyer and Tranfield [2009] is an appropriate approach for gaining comprehensive insights. Owing to the fact, that there has not been identified one common approach to the literature review, author decided to prepare a procedure useful for literature review on the specific topic, within PDCA (Planning (P), Doing(D), Checking (C) and Acting (A)) method framework. As a result, the revision procedure was performed, following four major stages presented in Fig. 1.



Source: own work

Fig. 1. Literature review procedure

Regarding Fig. 1, the major focus of the first stage of research is research planning (P). Following Kitchenham [2004], it was claimed, that the key activity for the literature review is to justify that it is required. For justifiable reasons, the research questions should be established (hereafter: RQ), which are considered in a paper as a pre-requisite for the literature review success. As a consequence of the conducted literature research obtaining answers for RQ is expected. Finally, as the last step of the planning stage, there should be determined selection criteria (hereafter: SC). The most often used selection criteria include keywords, Boolean operators, search fields, time window, language, publication type, subject area, inclusion/exclusion criteria. Finally, the framework for the searching should be established, considering review executors, time of research (dynamic changes in publications) and used databases adequate from the perspective of the research scope, however in the author's opinion one repository is not enough.

Regarding Fig. 1, the major focus of the second stage of research is research doing (D), which requires papers selection according to specified requirements (SC). Firstly, SC should have been adopted into databases. It is noteworthy that, databases useful for the literature review offer different possibilities in selection criteria adoption on the initial selection, so research executors should describe search strings for each of the used databases. On the basis of the result of initial selection, a set of papers S1 is gathered, which is further verified in the scope of criteria fulfillment on the level of paper's title, and later on the level of paper's abstract.

With reference to Fig. 1, in the next stage of research the focus is put on checking papers and ensuring relevant works for further analysis. When a few databases are used, all satisfying results should be combined into one set of papers (set PS). In the next step, duplicates should have been excluded to get papers assigned to be fully screened (set PF). To ensure all relevant papers for further analysis, the snowball rule should be used so if there are some additional references, they should be added and verified (set PB).

Following Fig. 1, in the next stage there should be made an analysis of papers on the level of full paper content in order to answer RQ. The final step of this stage of a research is a research report. Research findings should be a summary of the current state of knowledge in the area of the problem under investigation.

LITERATURE RESEARCH ON LOGISTICS MATURITY MODEL IN THE SERVICE INDUSTRY – RESEARCH DESCRIPTION

Following the literature review procedure (Fig. 1), the literature research on the logistics maturity model was executed.

Considering the framework of the presented paper there was justified need to provide an overview on the current state of the art on the logistics maturity models as a part of research on logistics maturity of service companies, realized in Poland (Project ID: 2016/21/D/HS4/02116). The objective of this review was to elicit the state of the art on logistics maturity models. In this respect, to obtain an overview of the existing models the following research questions (RQ) were defined (Table 1).

Table 1. Research questions

Question ID	Description
RQ1	Is logistics maturity (as a whole) is a research subject?
RQ2	How to define the logistics maturity?
RQ3	How available logistics maturity models are built?
RQ4	Were existing models verified?
RQ5	Are there solutions dedicated for the research on logistics maturity in service companies, considering various sectors of services?

Source: own work

Considering the RQ (Table 1), there were defined SC as presented in the Table 2.

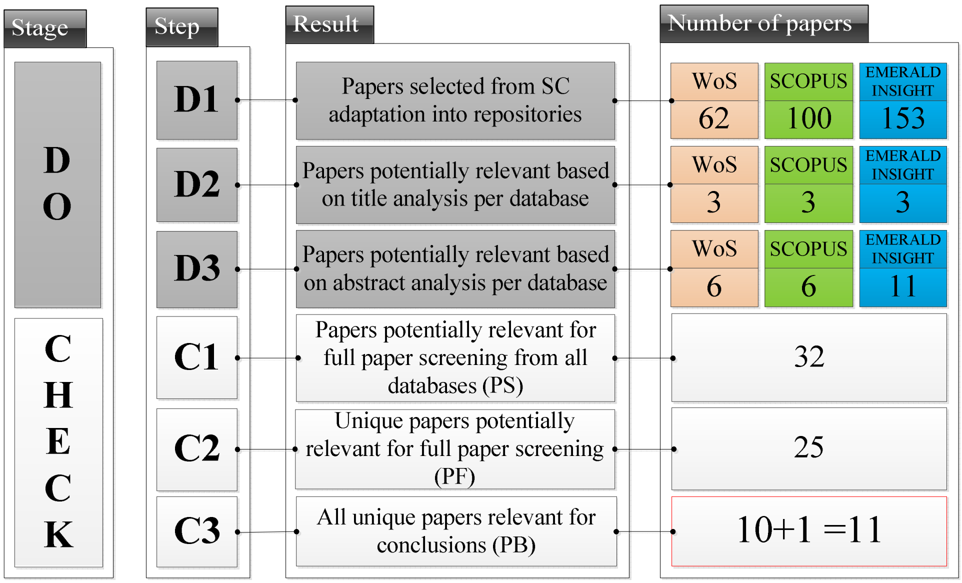
The searching framework included: time (August 2017), research executor (author of the paper) and scientific databases ("Web of Science", "Scopus", "Emerald Insight").

Following Fig. 1, in the second and third stage of research, there were selected papers for full screening by SC adoption into databases used in the research. The results of these stages in numbers were presented in Fig. 2.

Table 2. Selection criteria used in research on logistics maturity model

Criterion	Description
Keywords	• Related to subject: maturity, maturation, growth, evolution • Related to the logistics: logistics, logistic • Including an assessment conext: assessment, measurement, measures, assess, evaluation, evaluate • Considering: Method used for research on maturity: model, method, tool
Boolean operators	AND, OR
Search fields	title, kewords, abstract,
Time window	Till 2017
Language	English
Publication type	No limits
Subject areas	Engineering, economics, management, business, social Sciences, decision-making.
Inclusion criteria	I1: Studies regarding the evaluation of logistics processes using the maturity model. I2: Logistics maturity is being investigated on the company's level

Source: own work



Source: own work

Fig. 2. Papers selection for full screening

After an SC application into repositories, considering all required modifications of SC, there were 315 papers obtained from step D1 (set S1).

With reference to the Fig.1, in the next step all papers from the previous step were analyzed considering the title, in the scope of requirements related to logistics maturity topic fulfillment (step D2, Fig. 2). As a consequence, 9 papers from all repositories met these requirements (set S2).

Some of the papers required further analysis at the abstract level and 23 (set S3) of them were accepted after step D3 (Fig. 2).

As a consequence, there was obtained a set of 32 papers (set PS) from all databases gathered within step C1 (Fig. 2) however, it had to be cleared of 7 duplicates (step C2), which resulted in a set of 25 papers (set PF) intended for full paper scanning. It accounted for 8% of all publications searched by introduction SC during the initial selection S1.

In the author's opinion it is essential to make some conclusions only on those works which are related to RQ, so the set of publications intended for conclusions was reduced by 56%. Consequently, 11 papers: [Janse et al., 2010, Eadie et al., 2011, Battista et al., 2012, Bemelmans et al., 2013, Cao, Jiang 2013, Battista, Schiraldi, 2013, Jellouli, Abdelkadhi, 2013; Mazur, Stachowiak, 2014, van Lith et al., 2015, Benmoussa et al., 2015, Tontini et al., 2016], were included in fourth stage of research (one paper was added according to snowball rule). Based on those 11 papers, answers for RQ were obtained.

LITERATURE RESEARCH ON LOGISTICS MATURITY MODEL IN THE SERVICE INDUSTRY – RESEARCH RESUTS

RQ1: Is logistics maturity a research subject?

As a result of the literature review, it was stated that the logistics maturity has been the subject of scientific research, the interest rate is minor (only 11 publications). It is noteworthy, that in more than 70% of publications, logistics was considered in a narrow context, so researchers have taken up issues related to the maturity of selected logistics area e.g. distribution, supply, reverse logistics or supply chain-related issues. Considering research results, only one model makes possible to assess the maturity of the whole logistics system described by Battista et al. [2012] and Battista & Schiraldi [2013]. In the author's opinion, this confirms the ongoing research gap in this area, which should be a premise to undertake research to overcome the gap.

RQ2: How to define the logistics maturity?

Only in three papers, there was a logistics maturity model [Battista et al. 2012, Battista, Schiraldi, 2013, Jellouli, Abdelkadhi, 2013], so they were recognized as adequate to find the definition of logistics maturity. Unfortunately, even in these studies, there was no clear definition of logistics maturity, only a framework of existing maturity models. Owing to that fact, it was claimed that there has been identified a research gap. What is more, even in the case of a vast majority of rest papers analyzed in this paper, there was a lack of maturity definition in the context of a particular maturation object. There were identified only definitions of purchasing maturity in [van Lith at al. 2015] and [Bemelmans et al. 2013].

It was claimed, that the reason for the lack of logistics maturity definition is the fact that it has not been a well-recognized issue. Researchers intuitively use references to other existing models, defining a framework for models developed by them, recognizing this as sufficient, but without definition, their understanding may be difficult or even not possible. In the authors' opinion, issues with definition as well as a small number of papers on logistics maturity may result from problems related to the adaptation of maturity models in logistics.

RQ3: How available logistics maturity models are built?

In order to answer to RQ3, all 11 papers were analyzed considering the structure of the maturity model, expressed by maturity levels number and the assessment dimension as well as the used framework and research methodology to build the model (Table 3).

Regarding Table 3, it was stated that the reference model has an impact on the number of maturity levels. It is noteworthy that, 100% of selected studies presented maturity levels as an element of maturity model. However, numbers of maturity levels vary between 4 and 10, but 5 maturity levels is the most common value. Limit of the maturity levels number seems to be justified from the point of view of factors determining a given level description. The more levels, the harder the model's description.

Considering the Table 3, it was stated that CMM and CMMI standard have been seen as those reference models which play a dominant role in maturity model determination (60% of all maturity models described in the paper). Taking that into consideration it was assumed that, researchers do not reinvent the wheel, so they use well-known frameworks. The key for the CMMI model is the representation of the maturity model in a graduated form, where a specific level of maturity corresponds to the degree of meeting the requirements in a given range. These requirements can be described using both variable values as well as linguistically from the perspective of certain assessment parameters state. Justification for CMMI model used as a maturity model framework was presented in [Veldman & Klingenberg 2009].

Table 3. Logistics maturity model specification

Reference	No of maturity levels	Assessment dimension	CMMI/CMM Framework	Research methodology
[Tontini et al., 2016]	4	Materials management, Purchasing process, Supplier evaluation, Procurement planning	Other	literature review, experts method, survey
[van Lith et al., 2015]	10	8 strategic processes and 6 enabling processes in purchasing	Other	literature review, case study, interview
[Benmoussa et al., 2015]	6	Processes identified by mapping	CMMI	literature review, case study
[Bemelmans et al., 2013]	6	14 aspects of procurement	Other	literature review, interview
[Eadie et al., 2011]	5	12 KPA related to the barriers and drivers for procurement	CMM	literature review, experts method, survey, interview, statistical analyzis
[Mazur and Stachowiak, 2014]	5	Organization	CMMI	literature review, survey, observation
[Cao and Jiang, 2013]	5	Storage, Transportation, Cost, Time	CMM	literature review, mathematical modelling
[Janse et al., 2010]	4	Business strategy, Reverse supply chain management strategy and goals, Spare part management , Secondary markets and remarketing, Process recovery	CMMI	literature review, case study, survey, interview
[Battista & Schiraldi, 2013], [Battista et al.,2012]	5	4 dimensions according to SCOR (without reverse logistics)	CMMI	literature review, interview, brainstorming
[Jellouli and Abdelkadhi,2013]	4	Logistics, but no detailed data	No data	literature review, experts method, survey

Source: own work

With reference to research methodology, the literature review method was indicated as necessary, owing to the fact that it was used in each considered paper. It proves that knowledge is essential for developing a new model, even if existing models are used as a framework. Moreover, very often there are also used interviews and surveys as maturity the level is usually determined by the evaluation of answers, check-list points or assessed statements (usually on a Likert scale) in a self- or external evaluation (in 50% of models). In the author's opinion, it is relevant to use various methods, techniques, and tools, which should be adequate for the purpose of the research. It was stated, that research methodology should be adequate to the research object so the research instruments should be selected in such a way to allow an objective and unambiguous assessment of the company's logistics maturity.

Taking into consideration the assessment's dimensions, it was found that there has not been identified one clearly dominant approach. Moreover, it is worth noting that the dimensions of this assessment are a consequence of the logistics area. In the author's opinion, as far as the logistics maturity model is concerned, all logistics areas (logistics systems) should be included in the assessment dimensions, which have been missing in the identified logistics maturity models.

To sum up, in the author's opinion each maturity level should be identified by requirements indicated at an adequate level, not descriptions of levels, as this may raise doubts during the maturity research. It should be noticed that the logistics maturity model may have an evolutionary character, so reaching the higher level must be preceded by the achievement of the lower level however, it is not a precondition.

RQ4: Were existing models verified? & RQ5 Are there solutions dedicated for the research on logistics maturity in service companies, considering various sectors of services?

In order to answer the last questions, there was made an analysis of papers according to their practical verification and potential to the adaptation to service industry (Table 4).

Table 4. Logistics maturity model development – models' verification and application to services

Reference	Verification	Sector	Service adaptation	Remarks
[Tontini et al., 2016]	YES	Metal-mechanic, medical services	YES	
[van Lith et al., 2015]	YES	Construction	YES	
[Benmoussa et al., 2015]	YES	Furniture	Adaptable	Tests required
[Bemelmans et al., 2013]	Partially	Construction	Yes	Model verified in distrbution. Additional activities required in other logistics areas
[Eadie et al., 2011]	NO	-	Adaptable	Additional activities required to adapt to the service industry
[Mazur and Stachowiak, 2014]	NO	-	Adaptable	Additional activities required to adapt to the service industry
[Cao and Jiang 2013]	NO	Manufacturing	Adaptable	Tests required. Additional activities required to adapt to the service industry
[Janse et al., 2010]	YES	Electronic equipment manufacturing	Adaptable	Additional activities required to adapt to the service industry
[Battista & Schiraldi, 2013], [Battista et al., 2012]	YES	Fashion industry	Adaptable	
[Jellouli and Abdelkadhi, 2013]	NO	-	No data	

Source: own work

With reference to the RQ4, it was claimed that 40% of maturity models were theoretical, as they had not been verified. Some of the presented solutions were verified, but there were identified additional activities required for their practical use [Benmoussa et al., 2015; Bemelmans et al. 2013; Cao and Jiang 2013]. Despite the fact that there were found maturity models for service enterprises, they were dedicated to representatives of a particular sector, and in addition, they did not undertake logistics in a broad but narrow sense [Tontini et al. 2016; van Lith et al. 2015; Bemelmans et al. 2013]. It is unlikely that presented models would be adapted to the services, even if it was assumed as possible for almost all models (excluding the last one). However, it is possible to adapt presented maturity models to the service selector, but it is not a non-invasive solution in the author's opinion.

In summary, it was found that in the context of ongoing research on the logistics maturity of enterprises in the services sector, there has not been identified a comprehensive solution, which has resulted in the identification of a research gap in this research area.

CONCLUSIVE REMARKS

To sum up, companies should assess their state of logistics maturity in order to improve activities conducted within logistics. With logistics assessment, the company has more control over its logistics processes and the achievement of its goals. However, there may be perceived solutions for logistics assessment but the focus on the chosen logistics function does not consider all functions, so it is not valuable, in the author's opinion.

Considering the above, the logistics maturity of the service enterprises should be assessed, since the intangible service requires material logistic support, without which it cannot be performed. Achieved results of conducted research in this area will contribute to broadening the knowledge about the logistics maturity in the service sector. Consequently, this will close the research gap in this area. The expected research results will contribute to the systematization of the state of knowledge on logistics processes implementation in the service sector, thus affecting the state of theoretical knowledge in the field of economics, management, and logistics. In terms of civilization development, the research results will contribute to the improvement of logistics processes in service enterprises, which will positively affect the competitiveness of these enterprises. For practitioners, the results of such studies will be a starting point for further in-depth research in the field of logistics maturity in service enterprises.

The major conclusion of the research is that there is a research gap related to the logistics maturity model for service industry, so there is a need to develop a logistics maturity model, considering the achievements of previously defined maturity models available in the literature in order to define the best solution.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This paper refers to the research financed by the Polish National Science Centre, project: Research on logistics maturity in service enterprises, grant no. 2016/21/D/HS4/02116.

REFERENCES

Battista C., Fumi A., Schiraldi M., 2012. The logistic maturity model: guidelines for logistic processes continuous improvement. POMS 23rd Annual Conference, Chicago, Illinois, USA.

Battista C., Schiraldi M. M., 2013. The logistic maturity model: Application to a fashion company. International Journal of Engineering Business Management, 5 (10): 1-11. http://doi.org/10.5772/56838

Bemelmans J., Voordijk H., Vos B., 2013. Designing a tool for an effective assessment of purchasing maturity in construction. Benchmarking: An International Journal, 20 (3): 342-361. http://doi.org/10.1108/14635771311318126

Benmoussa R., Abdelkabir C., Abd A., Hassou M., 2015. Capability/maturity based model for logistics processes assessment: Application to distribution processes. International Journal of Productivity and Performance Management, 64 (1): 28-51. http://doi.org/10.1108/IJPPM-08-2012-0084

Cao W., Jiang, P., 2013. Modelling on service capability maturity and resource configuration for public warehouse product service systems. International Journal of Production Research, 51(6): 1898-1921. http://doi.org/10.1080/00207543.2012.720391

Christopher M., 2016. Logistics & supply chain management. Pearson UK.

Denyer D., Tranfield D., 2009. Producing a systematic review. In D.A. Buchanan, A. Bryman (Eds.), The Sage handbook of Organizational Research Methods, 671-689. Thousand Oaks, CA, USA: Sage Publications Ltd.

Eadie R., Perera S., Heaney G., 2011. Key process area mapping in the production of an e-capability maturity model for UK construction organisations. Journal of Financial Management of Property and Construction, 16(3); 197-210. http://doi.org/10.1108/13664381111179198

Herbsleb J., Zubrow D., Goldenson D., Hayes W., Paulk M., 1997. Software quality and the capability maturity model, Communications of the ACM, 40(6): 30-40.

Janse B., Schuur P., de Brito M. P., 2010. A reverse logistics diagnostic tool: the case of the consumer electronics industry. The International Journal of Advanced Manufacturing Technology, 47(5-8): 495-513. http://doi.org/10.1007/s00170-009-2333-z

Jellouli O., Abdelkadhi M., 2013. Test Logistics Maturity of the Industrial Zone in the Region of Gabes. International Journal of Supply Chain Management, 2(4): 71-75.

Kitchenham B., 2004. Procedures for performing systematic reviews. Keele, UK, Keele University 33: 1-26.

Lacerda T. C., von Wangenheim C. G., 2018. Systematic literature review of usability capability/maturity models. Computer Standards & Interfaces, 55: 95-105. http://doi.org//10.1016/j.csi.2017.06.001

Mazur A., Stachowiak A., 2014. The framework of methodology for identification of organizational maturity with assessment of excellence level of logistics systems. In: I. Abrud (Ed.), The Management between profit and social responsibility, Proceedings of the 4th Review of Management and Economic Engineering International Management Conference: 18-20.

Tontini G., de Carvalho L. C., Schlindwein N. F. D. C., Tomarevski V., 2016. Maturity model of procurement and supply management in small and medium-size enterprises: A benchmarking of hospitals and metal-mechanic companies. International Journal of Quality and Service Sciences, 8(3): 315-333 http://doi.org/10.1108/IJQSS-04-2016-0036

Van Lith J., Voordijk H., Matos Castano J., Vos B., 2015. Assessing maturity development of purchasing management in construction. Benchmarking: An International Journal, 22(6): 1033-1057. http://doi.org/10.1108/BIJ-07-2014-0071

Veldman J., Klingenberg W., 2009. Applicability of the capability maturity model for engineer-to-order firms. International Journal of Technology Management, 48(2): 219-239. http://doi.org/10.1504/IJTM.2009.024917

MODEL DOJRZAŁOŚCI LOGISTYCZNEJ PRZEDSIĘBIORSTW USŁUGOWYCH: STAN OBECNY I KIERUNKI DALSZYCH BADAŃ

STRESZCZENIE. **Wstęp:** Współcześnie logistyka uznawana jest za kluczowy czynnik sukcesu, co skutkuje istotnością zagadnienia dojrzałości logistycznej. Współcześnie, w literaturze wciąż brak jest systematycznego przeglądu literatury, podsumowującego stan wiedzy w zakresie dojrzałości logistycznej. Biorąc powyższe pod uwagę, za główny cel artykuły przyjęto wypełnić zidentyfikowaną lukę poprzez weryfikowanie aktualnego stanu wiedzy w zakresie rozwoju dojrzałości logistycznej przedsiębiorstw usługowych, wykorzystując przygotowaną procedurę do analizy literatury.
Metody: W pracy wykorzystano metodę analizy literatury celem weryfikacji aktualnego poziomu wiedzy na temat modelu dojrzałości logistycznej przedsiębiorstw usługowych, wykorzystując w tym celu opracowaną procedurę przeglądu literatury.
Wyniki: Opracowano procedurę dokonywania przeglądu literatury, która została wykorzystana do analizy oraz klasyfikacji zidentyfikowanych w literaturze opracowań podejmujących tematykę dojrzałości logistycznej celem identyfikacji dojrzałości logistycznej, istniejących modeli, ich struktury oraz obszarów dokonywania oceny. W rezultacie ukazano lukę badawczą dotyczącą modeli dojrzałości logistycznej przedsiębiorstw usługowych.
Wnioski: Oczekiwane wyniki badań przyczynią się do usystematyzowania wiedzy na temat realizacji procesów logistycznych w sektorze usług, co będzie oddziaływało na poziom wiedzy teoretycznej na temat ekonomii, zarządzania i logistyki. Rezultaty przeprowadzonych badań mogą zostać wykorzystane jako podstawa do opracowania podstaw modelu dojrzałości logistycznej, lecz również jako przewodnik w prowadzeniu badań nad aktualnym stanem literatury w danym zakresie.

Słowa kluczowe: dojrzałość logistyczna, przegląd literatury, aktualny stan wiedzy, sektor usług

Monika Kosacka-Olejnik ORCID ID: https://orcid.org/0000-0001-6950-2728
Faculty of Engineering Management
Poznan University of Technology
Strzelecka 11, Poznan, **Poland**
e-mail: monika.kosacka@put.poznan.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (2), 271-278

http://doi.org/10.17270/J.LOG.2020.390

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

METAL NANOPARTICLES IN NANOSENSORS FOR FOOD QUALITY ASSURANCE

Renata Dobrucka

Poznan University of Economics and Business, Poznań, **Poland**

ABSTRACT. **Background:** Nanotechnology is applied in the food industry to ensure food safety, and it is used both in the processing of food and detection of contaminants. The assurance of quality and safety of food has become an important issue for authorities and food supply chain actors. In order to protect consumers from contamination, adulteration and spoilage, it is absolutely necessary to conduct analyses of food, as it is exposed to numerous chemical substances, which may be harmful to human beings and the environment.

Methods: This work presents an overview of the literature concerning nanosensors with metal nanoparticles, which are used to detect the presence of chemical contaminants, pathogens and toxins, as well as to monitor food quality status. Such solutions will undoubtedly contribute to maintaining the safety and quality of food.

Results and conclusion: At present, food supply chains are becoming more complex, environmental constraints are becoming stricter, and consumers are changing the way in which they select and consume food, and all those factors inspire modern societies to be more concerned about the harmful substances that could be present in food products. Application of nanoparticles in the food production industry are farreaching and more research in this space is warranted. As developments in the research and development of nanotechnologies continue, so will the opportunities for the food industry to benefit from nanoscience.

Key words: nanotechnlogy, nanosensor, safety food.

INTRODUCTION

At present, food industry is the largest one in the world and it is still undergoing dynamic development. Food safety is reflected by the ability to cater for the food needs of people and access food that is necessary to ensure a healthy living. Food safety is one of the major global concerns that human beings have to confront and are continuously fighting for. According to the World Health Organization [WHO, 2015], safe food should be nontoxic and innocuous. Due to the global increase in food trade, both developed and developing countries have become concerned about food safety, as this issue may lead to numerous consequences that extend beyond life and health. Foodborne diseases also affect economy, trade and other industries, and they may require considerable outlays. Such outbreaks may cause medical and non-medical costs, productivity losses, as well as require additional expenditure of funds by the affected manufacturers, the relevant agencies, as well as public health and food safety authorities [Thomas et al., 2015]. In order to ensure the highest quality of food, the worldwide food industry extensively adopts food safety standards, such as BRC, FSSC 22000, IFS and HACCP [Aung, Chang, 2014, Chassy et al., 2004].

The presence of unwanted substances in food products may pose a threat to consumer health. One of the basic ways to ensure safe food quality is to constantly monitor food products for the presence of harmful

Citation: *Dobrucka R., 2020. Metal nanoparticles in nanosensors for food quality assurance. LogForum 16 (2), 271-278, http://doi.org/10.17270/J.LOG.2020.390*

Received: 26.09.2019, Accepted: 07.01.2020, on-line: 30.03.2020.

substances and pathogenic parasites, bacteria, viruses and prions. With the constant improvement of food testing methods and control programs, the threat to consumers is becoming significantly weaker. The control tests of chemical residues in food not only protect consumer health but also help to comply with the requirements of international food trade. Although traditional methods for identifying chemical residues in food are relatively sensitive and specific for the detection of microorganisms and tested analytes, most of these tests are laborious and time-consuming [Gracias and McKillip, 2004, Zhao et al., 2014], which makes them incompatible for point-of care testing.

According to King [2018], nanotechnology has emerged as a technological advancement to develop and transform the agrifood sector, with the potential to increase global food production, in addition to the nutritional value, quality and safety of food. Detection methods that employ nanotechnology have some advantages that can make them more beneficial than traditional laboratory methods. The use of nanoparticles combined with electrochemical or optical detection methods leads to the development of fast, sensitive and cost-effective procedures that allow for miniaturization and automation for point-of-care testing. Within the last ten years, we have witnessed some promising developments in modern nanotechnology and its application. Thanks to their unique characteristics, nanoparticles can be used in order to develop highly sensitive strategies for detecting contaminants [Krishna et al., 2018].

NANOSENSORS TO DETECT THE PRESENCE OF CHEMICAL CONTAMINANTS

Metal nanoparticles are applied in the production of nanosensors for detecting the presence of chemical compounds or pesticides. One example of the use of metal nanoparticles is the development of nanosensors for detecting melamine. Melamine is an aromatic compound that belongs to the amine group. It is a derivative of triazine and a trimer of cyanamide. It is used to produce melamine resins, which are applied in the manufacturing of household items, decorative laminates, glues, paints and lacquers. Due to the high nitrogen content [66% of mass], it was used to obtain a falsely high protein content in the analyses of animal feed and food products. Since the mass poisoning of children in China due to the presence of melamine in powdered milk, there have been introduced strict controls of melamine content in food. Wu et al. [2015] proposed a nanosensor for detecting the presence of melamine on the basis of energetic transitions related to the fluorescence between gold nanoparticles.

A similar sensor was created by Kumar et al. [2014]. It contained gold nanoparticles stabilized with sodium citrate. The presence of melamine in the tested samples led to the aggregation of gold nanoparticles and, in turn, a visible change in color. Another group of scientists [Ai et al., 2009] proposed a nanosensor in which gold nanoparticles reacted with a derivative of cyanuric acid. That derivative selectively bonded with melamine by means of hydrogen bonds. After bonding with melamine, the aggregated gold nanoparticles changed their color from red to blue.

Metal nanoparticles undoubtedly make it easier to examine detergent residues in food products, whose presence is inadvisable due to the high food safety standards. Kumar et al. [2016] used gold nanoparticles to develop a m in milk for children. The sensor works in such a way that gold nanoparticles are stabilized due to electrostatic repulsion among negatively charged citrate ions on the surface, preventing them from aggregation. The addition of inducer to gold nanoparticles neutralizes the surface charge and causes aggregation, which is reflected in color change of the solution from red to purple. It was observed that the aggregation of nanoparticles was impeded in the presence of anionic detergents and HCl, so the solution remained red.

For example, Zheng et al. [2018] used graphene-Au nanoparticles to develop the sensor of 4-nonylphenol in milk and its packaging materials. The studies carried out by the scientists showed that 4-nonylphenol was found in many food products, including vegetables, fruit, grains and drinks, and its main source was probably the packaging material. Therefore, it was very important to develop an effective and fast method for identifying 4-nonylphenol in the product and its packaging. Authors created the electrochemical sensor by depositing poly[p-aminothiophenol] film on an electrode modified with graphene-Au nanoparticles. The developed sensor was characterized by higher sensitivity and selectivity.

Another sensor has been developed by Shim et al. [2018]. The authors employed dendritic platinum nanoparticles to create a sensor designed for bisphenol A [BPA] detection, which may be used to assess the quality of packaged food and BPA migration from the packaging.

NANOSENSORS TO DETECT THE PRESENCE OF PATHOGENS AND TOXINS

The achievements in nanotechnology also offer technological solutions that make it possible to detect pathogens and toxins in food. Usually, they are based on the optical or electronic characteristics of nanomaterials [Valdes et al. 2009, Leonard et al. 2003]. Kalele et al. [2006] conjugated rabbit immunoglobulins G [IgG] with silver nanoparticles in order to quickly and selectively detect E. coli in the range of 5-109 by monitoring the shifts of the SPR band in the presence of E. coli cells. Wang et al. [2015] prepared an electrochemical immunosensor for E. coli 0157:H7 detection without any pretreatment. Proposed sensor was consisted of magnetic separation using antibody-functionalized MNPs and electrochemical reporters using lead sulfide nanoparticles linked to polyclonal antibody-functionalized Au nanoparticles. Dungchai et al. [2008] used gold nanoparticles to develop an effective immunological method for identifying S. typhimurium.

Moreover, nanosensors have been developed for the detection of a number of foodborne pathogens relevant to the poultry industry. Nanosensors have been designed to detect and quantify many types of analytes relevant to the meat industry, including gasses, vapors and ions, small organic molecules, biomolecules, and a range of foodborne pathogens [King et al.2018]. Liu et al. [2015] described the application of nanosensors for the detection of biogenic amines (i.e. putrescine, cadaverine) in the monitoring of spoilage in raw chicken meat.

Joo research group [2012] developed an easy and sensitive method for detecting pathogenic bacteria in milk. Salmonella bacteria present in milk were captured by antibodies coupled with magnetic nanoparticles and separated from analyte samples by means of an external magnetic field. The complexes of nanoparticles and Salmonella were dispergated in the buffer solution and then immobilized with the use of TiO_2 nanoparticles, which absorbed UV light. As the intensity of light absorption was inversely proportional to the concentration of Salmonella, the test was highly sensitive to low concentrations of the bacteria. The discovered detection limit of the bacteria in milk was 100 cfu ml^{-1}. Yuan et al. [2014] developed a visible detection method for Salmonella Typhimurium based on AuNPs labeling and silver enhancement signal amplification.

Staphylococcus enterotoxins are a family of proteins produced by some strains of S. ureus. Those toxins are characterized by resistance to heat, resistance to enzymatic proteolysis as well as mitogenic properties. In order to detect staphylococcus enterotoxins in food, Yang et al. [2009] developed an immunological nanosensor with gold nanoparticles based on enhanced chemiluminescence [ECL]. Chudobova research group [2015] developed a 3D-printed chip for detection of methicillin-resistant Staphylococcus aureus by measuring the color change, caused by the non-crosslinking aggregation phenomenon of DNA-functionalized AuNPs when mecA gene reacted with the AuNP probes.

NANOSENSORS FOR MONITORING FOOD QUALITY STATUS

Nanomaterials are also applied to monitor the freshness of food. The literature presents numerous examples of fish, fruit or meat freshness sensors. Chen at el. [2017] developed a visual sensor for monitoring the freshness of fish. The authors based the structure of the indicator on the presence of hypoxanthine, the end product of purine metabolism that is produced in the course of decay of animal meat. In their method, hypoxanthine reacted with dissolved oxygen in order to produce H_2O_2 in the presence of xanthine oxidase. Gold nanoparticles detected by H_2O_2 in the presence of Fe^{2+} caused a visible change in the indicator's color. Different concentrations of hypoxanthine caused the sensor to change its color.

Albelda et al. [2017] designed a sensor of meat freshness. The authors used a graphene–TiO_2 composite, which formed a beneficial microenvironment for the oxidation of xanthine oxidase. To develop a freshness sensor, the group of Zhang et al. [2008] used a SnO_2¬–ZnO nanocomposite. The sensor was highly sensitive and it quickly reacted to trimethylamines present in the tested samples. As xanthines are the product of purine decomposition, the sensor may be used to predict the shelf life of meat and fish.

Another sensor was developed by Devi et al. [2012]. Their xanthine sensor was based on chitosan modified with ZnO nanoparticles on a multi-layer system of carbon nanotubes in a polyaniline matrix, on which xanthine oxidase was bonded by means of a covalent bond. The lower xanthine detection limit indicated by the sensor was 0.1 mM. In 2013, the same research group proposed a biosensor with xanthine oxidase immobilized with the use of silver nanoparticles. The authors proved that the presence of silver nanoparticles increased the stability of xanthine oxidase activity during storage at room temperature for about 60 days [Devi et al., 2013].

Zheng et al. [2010] used silver and gold nanoparticles to develop a vanillin sensor. The presence of nanoparticles increased the sensitivity of the sensor by five times. Another solution was proposed by Dridi et al. [2015] – they created a stable biosensor with gold nanoparticles for direct conductometric detection of ochratoxin A [OTA], i.e. mycotoxin, in olive oil samples. In the food industry, an electronic nose and tongue are used to assess and classify raw materials and finished products. They help to assess the sensory properties of food, its durability, and changes that occur throughout storage. They are also used to monitor the respective stages of production, as well as to identify food preservation processes. Ghasemi Varnam-khastia et al. [2011] presented the possibility of using an electronic nose and tongue in the brewing industry in order to assess the quality of beer, especially during fermentation. An electronic nose was used to identify the contamination of grains with fungi, and to detect the presence of Ganoderma boninense on oil palm trunks [Abdullah et al., 2011]. Zhang et al. [2006] used an electronic nose to characterize 17 commercial vinegars. The nose contained nine sensors with ZnO nanoparticles doped with MnO_2, TiO_2, V_2O_5, Bi_2O_3, W and Ag, as well as fly ashes.

CONCLUSIONS

From the consumer's point of view, food safety is the most important feature of quality. The current legal conditions impose strict requirements on food manufacturers and all other entities in the food chain, thanks to which consumers can feel safe on the food product market. One of the greatest threats to food is contamination. Society's health and correct development depend on access to food that is not contaminated. Early and accurate detection of contamination is prerequisite for preventing, controlling and mitigating the impact of potential outbreaks. This work has presented nanosensors for detecting the presence of: a] chemical contamination, b] pathogens and toxins, and c] monitoring food quality status. The use of nanosensors will undoubtedly help to maintain food quality.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

Research on synthesis financed from grant for young researchers in 2016 of the Ministry of Science and Higher Education.

REFERENCES

Abdullah A.H., Adom A.H., Ahmad M.N., Saad M.A., Tan E.S., Fikri N.A., Zakaria A. 2011. Electronic nose system for Ganoderma detection. Sensor Letters, 9[1], 353-358. http://doi.org/10.1166/sl.2011.1479

Ai K., Liu Y., Lu L., 2009. Hydrogen-bonding recognition-induced color change of gold nanoparticles for visual detection of melamine in raw milk and infant formula. Journal of the American Chemical Society, 131[27], 9496-9497. http://doi.org/10.1021/ja9037017

Albelda J.A., Uzunoglu A., Santos G.N.C., Stanciu L.A., 2017. Graphene-titanium dioxide nanocomposite based hypoxanthine sensor for assessment of meat freshness. Biosensors and Bioelectronics, 89, 518-524. http://doi.org/10.1016/j.bios.2016.03.041

Aung M.M., Chang Y.S., 2014. Temperature management for the quality assurance of a perishable food supply chain. Food Control, 40, 198-207. http://doi.org/10.1016/j.foodcont.2013.11.016

Bi J., 2019. Electrodeposited silver nanoflowers as sensitive surface-enhanced Raman scattering sensing substrates. Materials Letters, 236, 398-402. http://doi.org/10.1016/j.matlet.2018.10.138

Chassy B., Hlywka J.J., Kleter G.A., Kok E.J., Kuiper H.A., McGloughlin M., 2004. Nutritional and safety assessments of foods and feeds nutritionally improved through biotechnology: an executive summary. Comprehensive reviews in food science and food safety, 3[2], 38-104.

Chen Z., Lin Y., Ma X., Guo L., Qiu B., Chen G., Lin Z., 2017. Multicolor biosensor for fish freshness assessment with the naked eye. Sensors and Actuators B: Chemical, 252, 201-208. http://doi.org/10.1016/j.snb.2017.06.007

Chudobova D., Cihalova K., Skalickova S., Zitka J., Rodrigo M.A., Milosavljevic V., Hynek D., Kopel P., Vesely R., Adam V., Kizek R., 2015. Electrophoresis [36], 457-466. http://doi.org/10.1002/elps.201400321

Devi R., Yadav S., Pundir C.S., 2012. Amperometric determination of xanthine in fish meat by zinc oxide nanoparticle/chitosan/multiwalled carbon nanotube/polyaniline composite film bound xanthine oxidase. Analyst, 137 [3], 754 -759. http://doi.org/10.1039/C1AN15838D

Devi R., Batra B., Lata S., Yadav S., Pundir C. S., 2013. A method for determination of xanthine in meat by amperometric biosensor based on silver nanoparticles /cysteine modified Au electrode. Process Biochemistry, 48 [2], 242-249. http://doi.org/10.1016/j.procbio.2012.12.009

Dridi F., Marrakchi M., Gargouri M., Garcia-Cruz A., Dzyadevych S., Vocanson F., Lagarde F., 2015. Thermolysin entrapped in a gold nanoparticles/polymer composite for direct and sensitive conductometric biosensing of ochratoxin A in olive oil. Sensors and Actuators B: Chemical, 221, 480-490. http://doi.org/10.1016/j.snb.2015.06.120

Dwiecki K., Nogala-Kalucka M., Polewski K., 2014. Application of quantum dots for the determination of ingredients and food contaminants. Food Science Technology Quality, 21[3].

Dungchai W., Siangproh W., Chaicumpa W., Tongtawe P., Chailapakul O., 2008. Salmonella typhi determination using voltammetric amplification of nanoparticles: a highly sensitive strategy for metalloimmunoassay based on a copper-enhanced gold label. Talanta, 77[2], 727-732. http://doi.org/10.1016/j.talanta.2008.07.014

Galian R.E., de la Guardia M., 2009. The use of quantum dots in organic chemistry. TrAC Trends in Analytical Chemistry, 28[3], 279-291. http://doi.org/10.1016/j.trac.2008.12.001

Gao M.X., Liu C.F., Wu Z.L., Zeng Q.L., Yang X.X., Wu W.B., Huang C.Z., 2013. A surfactant-assisted redox hydrothermal route to prepare highly photoluminescent carbon quantum dots with aggregation-induced emission enhancement properties. Chemical Communications, 49[73], 8015-8017. http://doi.org/10.1039/C3CC44624G

Ghasemi-Varnamkhasti M., Mohtasebi S.S., Rodriguez-Mendez M.L., Siadat M., Ahmadi H., Razavi S.H., 2011. Electronic and bioelectronic tongues, two promising analytical tools for the quality evaluation of non alcoholic beer. Trends in Food Science & Technology, 22[5], 245-248. http://doi.org/10.1016/j.tifs.2011.01.003

Gracias K.S., McKillip J.L., 2004. A review of conventional detection and enumeration methods for pathogenic bacteria in food. Canadian journal of microbiology, 50[11], 883-890. http://doi.org/10.1139/w04-080

Joo J., Yim C., Kwon D., Lee J., Shin H.H., Cha H.J., Jeon S., 2012. A facile and sensitive detection of pathogenic bacteria using magnetic nanoparticles and optical nanocrystal probes. Analyst, 137[16], 3609-3612. http://doi.org/10.1039/C2AN35369E

Kalele S.A., Kundu A.A., Gosavi S.W., Deobagkar D.N., Deobagkar D.D., Kulkarni S.K., 2006. Rapid detection of Escherichia coli by using antibody- conjugated silver nanoshells. Small, 2[3], 335-338. http://doi.org/10.1002/smll.200500286

Kelsall R.W., Hamley I.W., Geoghegan M., 2009. Nanotechnology. PWN, Warszawa 2009, 5.

King T., Osmond-McLeod M.J., Duffy L.L., 2018. Nanotechnology in the food sector and potential applications for the poultry industry. Trends in Food Science & Technology, 72, 62-73. http://doi.org/10.1016/j.tifs.2017.11.015

Kumar P., Kumar P., Manhas S., Navani N.K., 2016. A simple method for detection of anionic detergents in milk using unmodified gold nanoparticles. Sensors and Actuators B: Chemical, 233, 157-161. http://doi.org/10.1016/j.snb.2016.04.066

Kumar N., Seth R., Kumar H., 2014. Colorimetric detection of melamine in milk by citrate-stabilized gold nanoparticles. Analytical biochemistry, 456, 43-49. http://doi.org/10.1016/j.ab.2014.04.002

Krishna V.D., Wu K., Su D., Cheeran M.C., Wang J.P., Perez A., 2018. Nanotechnology: Review of concepts and potential application of sensing platforms in food safety. Food microbiology, 75, 47-54. http://doi.org/10.1016/j.fm.2018.01.025

Kumar M., Jeong H., Lee D., 2018. UV photodetector with ZnO nanoflowers as an active layer and a network of Ag nanowires as transparent electrodes. Superlattices and Microstructures. http://doi.org/10.1016/j.spmi.2018.12.004

Leonard P., Hearty S., Brennan J., Dunne L., Quinn J., Chakraborty T., O'Kennedy R., 2003. Advances in biosensors for detection of pathogens in food and water. Enzyme and Microbial Technology, 32[1], 3-13. http://doi.org/10.1016/S0141-0229(02)00232-6

Liu S.F., Petty A.R., Sazama G.T., Swager T. M., 2015. Single-Walled carbon nanotube/ metalloporphyrin composites for the chemiresistive detection of amines and meat spoilage. Angewandte Chemie International Edition, 54 [22], 6554–6557. http://doi.org/10.1002/anie.201501434

Rzeszutek J., Matysiak M., Czajka M., Sawicki K., Rachubik P., Kruszewski M., Kapka–Skrzypczak, L. [2014]. Application of nanoparticles and nanomaterials in medicine. Hygeia Public Health, 49[3], 449-457.

Shim K., Kim J., Shahabuddin M., Yamauchi Y., Hossain M.S.A., Kim J.H., 2018. Efficient wide range electrochemical bisphenol-A sensor by self-supported dendritic platinum nanoparticles on screen-printed carbon electrode. Sensors and Actuators B: Chemical, 255, 2800-2808. http://doi.org/10.1016/j.snb.2017.09.096

Suwanboon S., Chukamnerd S., Anglong U., 2007. Morphological control and optical properties of nanocrystalline ZnO powder from precipitation method. Songklanakarin Journal of Science & Technology, 29[6].

Thomas M.K., Vriezen R., Farber J.M., Currie A., Schlech W., Fazil A., 2015. Economic cost of a Listeria monocytogenes outbreak in Canada, 2008. Foodborne Pathogens and Disease, 12[12], 966e971. http://doi.org/10.1089/fpd.2015.1965.

Zhang W.H., Zhang W.D., 2008. Fabrication of SnO2–ZnO nanocomposite sensor for selective sensing of trimethylamine and the freshness of fishes. Sensors and Actuators B: Chemical, 134[2], 403-408. http://doi.org/10.1016/j.snb.2008.05.015

Zhang Q., Zhang S., Xie C., Zeng D., Fan C., Li D., Bai Z., 2006. Characterization of Chinese vinegars by electronic nose. Sensors and Actuators B: Chemical, 119[2], 538-546. http://doi.org/10.1016/S0925-4005(98)00160-9

Zhao X., et al., 2014. Advances in rapid detection methods for foodborne pathogens. J. Microbiol. Biotechnol. 24 [3], 297e312. http://doi.org/10.4014/jmb.1310.10013

Zhang H., Ming H., Lian S., Huang H., Li H., Zhang L., Lee S.T., 2011. Fe_2O_3/carbon quantum dots complex photocatalysts and their enhanced photocatalytic activity under visible light. Dalton Transactions, 40[41], 10822-10825. http://doi.org/10.1039/C1DT11147G

Zheng D., Hu C., Gan T., Dang X., Hu S., 2010. Preparation and application of a novel vanillin sensor based on biosynthesis of Au–Ag alloy nanoparticles. Sensors and Actuators B: Chemical, 148[1], 247-252.

Zheng L., Zhang C., Ma J., Hong S., She Y., EI-Aty A.A., Wang J., 2018. Fabrication of a highly sensitive electrochemical sensor based on electropolymerized molecularly imprinted polymer hybrid nanocomposites for the determination of 4-nonylphenol in packaged milk samples. Analytical biochemistry, 559, 44-50.

Yang M., Kostov Y., Bruck H.A., Rasooly A., 2009. Gold nanoparticle-based enhanced chemiluminescence immunosensor for detection of Staphylococcal Enterotoxin B [SEB] in food. International journal of food microbiology, 133[3], 265-271. http://doi.org/10.1016/j.ijfoodmicro.2009.05.029

Valdés M.G., González A.C.V., Calzón J.A.G., Díaz-García M.E., 2009. Analytical nanotechnology for food analysis. Microchimica Acta, 166[1-2], 1-19. http://doi.org/10.1007/s00604-009-0165-z

Wang Y., Fewins P.A., Alocilja E.C., 2015. IEEE Sensor. J. [15] 2015, 4692-4699.

WHO, 2015. WHO estimates of the global burden of foodborne diseases: Foodborne disease burden epidemiology reference group 2007-2015.

Wu Q., Long Q., Li H., Zhang Y., Yao S., 2015. An upconversion fluorescence resonance energy transfer nanosensor for one step detection of melamine in raw milk. Talanta, 136, 47-53. http://doi.org/10.1016/j.talanta.2015.01.005

Yuan J., Tao Z., Yu Y., Ma X., Xia Y., Wang L., Wang Z., Food Control [37]. 2014. 188-192. http://doi.org/10.1016/j.foodcont.2013.09.046

NANOCZĄSTKI METALI W NANOSENSORACH ZAPEWNIAJĄCYCH JAKOŚĆ ŻYWNOŚCI

STRESZCZENIE. Wstęp: Nanotechnologia jest stosowana w przemyśle spożywczym w celu zapewnienia bezpieczeństwa żywności i jest wykorzystywana zarówno w przetwórstwie żywności, jak i wykrywaniu zanieczyszczeń. Zapewnienie jakości i bezpieczeństwa żywności jest ważną kwestią w łańcuchu dostaw żywności. Aby chronić konsumentów przed skażeniem, zafałszowaniem i psuciem, absolutnie konieczne jest przeprowadzenie oceny jakości żywności, ze względu na narażenie na substancje, które mogą być szkodliwe dla ludzi i środowiska.

Metody: W pracy przedstawiono przegląd literatury dotyczącej nanosensorów zawierających nanocząstki metali, które służą do wykrywania obecności zanieczyszczeń chemicznych, patogenów i toksyn, a także do monitorowania stanu jakości żywności. Takie rozwiązania niewątpliwie przyczynią się do utrzymania bezpieczeństwa i jakości żywności.

Wyniki i podsumowanie: Obecnie łańcuchy dostaw żywności stają się coraz bardziej złożone, ograniczenia środowiskowe stają się coraz surowsze, a konsumenci zmieniają sposób, w jaki wybierają i spożywają żywność. Wszystkie te czynniki powodują zainteresowanie i coraz większą dbałość o jakość i bezpieczeństwo żywności. Zastosowanie nanocząstek w przemyśle spożywczym daje szerokie perspektywy, w związku z tym uzasadnione są dalsze badania w tym obszarze. Wraz z rozwojem badań i rozwoju nanotechnologii będą również rosnąć możliwości, jakie przemysł spożywczy może czerpać z nanonauki.

Słowa kluczowe: nanotechnologia, nanosensor, bezpieczeństwo żywności

Renata Dobrucka ORCID ID: https://orcid.org/0000-0003-1486-9412
Department of Non-Food Products Quality and Packaging Development
Institute of Quality Science
Poznan University of Economics and Business
al. Niepodległości 10, 61-875 Poznan, **Poland**
e-mail: renata.dobrucka@ue.poznan.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (2), 279-286

http://doi.org/10.17270/J.LOG.2020.391

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

BIODEGRADABLE PACKAGING BASED ON PLA WITH ANTIMICROBIAL PROPERTIES

Natalia Czaja-Jagielska, Anna Praiss, Michał Walenciak, Dajana Zmyślona, Natalia Sankowska

Poznan School of Logistics, Poznań, **Poland**

ABSTRACT. **Background:** Packaging is an inseparable element of most consumer products. In addition to its primary passive protective and logistic function, it is also an excellent tool for the innovation development. One of the types of packaging innovations in the food and cosmetic industry are antimicrobial packaging. They are an example of packaging that actively protects packed products and eliminates harmful preservatives. Protection of goods against microbial spoilage extends shelf life and at the same time facilitates storage processes.

Methods: This paper aims to obtain biodegradable films based on PLA with antimicrobial properties. Four different natural antimicrobial agents were used: clove essential oil, peppermint essential oil, and two commercial powders containing nisin (Nisaplin and Novagard). The mechanical, barrier and optical properties were tested.

Results: The implementation of antimicrobial agents changed the properties of the tested bio-packaging in different rate depending on the agent. The new blends showed antimicrobial activity, however the addition of antimicrobials weakened the mechanical properties and changed the colour.

Conclusions: The biodegradable packaging materials can be used as a polymer matrix of different antimicrobial agents. They can inhibit the growth of bacteria in food or cosmetics and regarding their future use the influence on mechanical properties should be considered. Moreover, the biodegradability of biopolymers containing antimicrobial agents has barely been investigated.

Key words: antimicrobial packaging, biodegradable packaging, mechanical properties, barrier properties, innovation.

A part of this study was presented as oral presentation at the „8th International Logistics Scientific Conference WSL FORUM 2019" in Poznan (Poland), 18th-19th of November 2019.

INTRODUCTION

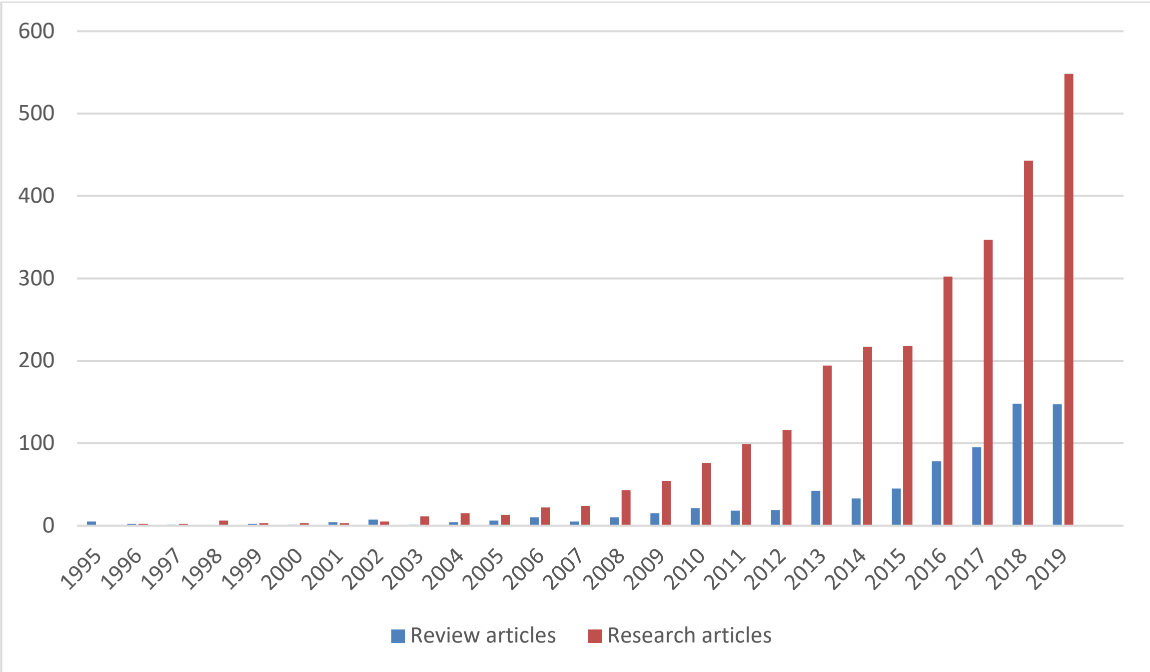
Packaging is a very important factor in the food industry. The mail goal of packaging is to preserve the quality and safety of products during transport and storage. Protection of the packaged product should include protection against the damaging effects of mechanical and climatic exposures, quantitative losses, changes or loss of product performance as a result of reactions taking place in the product. The reason for the short shelf life of many products is their microbial infection during entire logistics system. Therefore active packaging has been very common in the last years as a new approach to food security. According to Fig. 1 there has been visible growth of interest in research into combining bio- and functional packaging in the recent 10 years. They are very important for supply chain professionals in the food, pharmaceutical and other industries due to limited longevity and specific environmental requirements, waste reduction and increased efficiency.

The most often used biopolymers are starch [ZhaO et al. 2019; Fonseca et al. 2019; Ali et

Citation: *Czaja-Jagielska N., Praiss A., Walenciak M., Zmyślona D., Sankowska N., 2020. Biodegradable packaging based on PLA with antimicrobial properties. LogForum 16 (2), 278-286,* *http://doi.org/10.17270/J.LOG.2020.391*

Received: 26.09.2019, Accepted: 06.02.2020, on-line: 30.03.2020.

al. 2019], PLA [Qin et al 2019; Heydari-Majd 2019], PVAL [Lan et al. 2019; Liu et al. 2017], chitosan [Zheng et al. 2019; Wang, et al. 2019] and zein-proteins [Boyacı et al 2019, Kashiri et al. 2019].



Source: Science Direct

Fig. 1. Number of publications concerning antimicrobial biodegradable packaging

Antimicrobial agents can be either incorporated into packaging material or covered as active coating. There are numerous types of active substances which can be used in the active packaging system: synthetic (e.g. organic acids, metals, antibiotics) or natural (e.g. natural extracts, essential oils, enzymes, bacteriocins) [Korzeniowski et al 2011; Malhotra et el. 2015].

Plant-derived essential oils (EOs) are generally accepted as great potential to be used for extending the shelf life of different foods [Talebi et all 2018]. The most cited are: rosemary, eucalyptus, oregano, thyme, cinnamon, clove and citrus fruit [Lee et al 2015, Agrimonti et al. 2019]

The effectiveness of these composites depends on product and goods combination of bio-matrix and the antimicrobial agent. Yahyaoui et al [2016] proved that the incorporation of essential oils from rosemary, myrtle and thyme in the PLA matrix can improve the mechanical properties and does not affect the colour change of the films significantly.

Therefore the aim of the study was to obtain PLA films with natural antimicrobial agents (nisin and essential oils) and investigate the effects on the optical, mechanical and antimicrobial properties of these blends. The studies are an attempt to confirm that the use of biomaterials with antimicrobial agents has a positive effect on extending the shelf life of food products by limiting contamination.

MATERIALS AND METHODS

Materials

The PLA (plylactic acid) was an Ingeo™ Biopolymer 4043D obtained from Natureworks LLC. The polymer was in the form of pellets that can be converted into film.

Antimicrobial agents used in the study were: clove essential from Etja Company, peppermint essential from PPHU KEJ

Company, Nisaplin and NovaGARD CB1-35 from Danisco Company.

The following strains of bacteria were used in this study: *Clostridium perfringens, Staphylococcus Aureus, Pseudomonas aeruginosa, Yersinia enterocolitica, Salmonella enteritidis, Bacillus subtilis, Listeria innocua, Eschericha coli, Staphylococcus paratyphi* and *Enteroccocus fecalis.*

Descriptions of the samples are presented in Table 1.

Table 1. Description of samples tested

Code	Description
PLA	Pure PLA film
PLA_N	PLA with 2% Nisaplin
PLA_NG	PLA with 2% NovaGard
PLA_C	PLA with 2% clove essential
PLA_PM	PLA with 2% peppermint essential

Film formation

Films of PLA (20-40 mm) were prepared by solvent cast technique. Pure PLA films were obtained by solving 16g PLA pellets in 400 ml chloroform under magnetic stirring for 6h in the temperature of 23°C. After the films were casted, they were dried overnight (24h) at room conditions. The antimicrobial films were prepared by solving 16g of PLA pellets in chloroform under magnetic stirring for 6h with addition of 2% of antimicrobial agent.

Mechanical properties

Thickness

The thickness of the films was measured at several locations randomly around the film using a micrometre SYLVAC with 0.001mm accuracy.

Tensile strength

The mechanical resistance of films was performed on a Zwick Roell Z020 strength testing machine according to the PN-EN ISO 527-3 standard. Tensile strength [MPa] and elongation at break [%] were evaluated. At least five samples were tested for each film and the average value was reported.

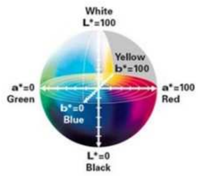
Puncture testing

The test consists in determining the puncture force [N] and elongation at puncture [mm] on the

Zwick Roell Z020 instrument in accordance with PN-EN 14477.

Optical properties

The colour measurement was made with the Focus on Color envisense NH 310. The L*a*b model was used to describe the colour of the samples tested. The L* parameter specifies the brightness (L * value = 100 means perfectly white, while 0 value – perfectly black), while a * and b * are trichromatic coordinates that specify the tone and colour saturation (Fig 2.).



Source: www.perten.com

Fig. 2. CIE Lab colour space

Antimicrobial activity

The antimicrobial effectiveness of the composite films was tested against 10 bacteria mentioned above. Suspensions of microbes were prepared, then seeded onto Petri dishes by the flooding method, consisting in applying 1ml of inoculum to the dish and pouring Agar medium.

On the solid agar the test films (dimensions of 10x10mm) were applied and incubated at 37°C. After incubation, antimicrobial activity was measured by observation of zones inhibiting the growth of microorganisms around the film samples.

RESULTS

Mechanical properties of the samples tested are shown in Table 2, 3 and 4. They are, especially tensile strength and elongation at break, very crucial parameters in exploiting different bio-based films for packaging purposes. The addition of antimicrobial agents enlarges the thickness of the PLA films (Table 2).

Table 2. Thickness

	Thickness [mm]
PLA	0.211±0.021
PLA_N	0.420±0.076
PLA_NG	0.490±0.072
PLA_C	0.290±0.033
PLA_PM	0.405±0.032

Source: own work

Table 3 represents tensile strength and elongation at break for pure PLA films and modified with antimicrobial agents. According to these data the incorporation of essential oil into PLA matrix resulted in a significant decrease in the tensile strength and elongation at break.

he same was observed by other authors [Qin et all 2017].

Table 3. Tensile strength and elongation at break

	Tensile strength [MPa]	Elongation at break [%]
PLA	16.00±1.23	267±24
	16.94±2.57	162±42
PLA_N	8.07±1.65	18±5,0
	19.6±0.89	20±8.0
PLA_NG	6.19±0.92	3.8±0.4
	6.63±1.12	3.6±0.5
PLA_C	10.09±0.37	156±24
	7.69±1.36	140±26
PLA_PM	4.86±0.34	2.6±0.3
	5.64±0.35	2.1±0.4

Source: own work

The resistance for puncture was determined for the films tested. Pure PLA film did not break through, which means that it had high strength and flexibility. The addition of antimicrobials weakened the puncture strength. The film with Nisaplin and clove essential oil showed the highest strength, while the lowest was observed for PLA with peppermint essential oil.

Table 4. Puncture test

	Force [N]	Elongation at puncture [mm]
PLA	*	*
PLA_N	38.3±3.25	13.2±1.12
PLA_NG	23.0±2.27	13.1±0.98
PLA_C	40.5±0.22	14.3±2.23
PLA_PM	7.25±0.44	2.85±0.35

*The sample was not damaged till elongation reached the maximum for the instrument (300 mm)

Source: own work

Table 5. Optical parameters of samples tested

	L*	a*	b*
PLA	31.6±0.01	0.18±0.02	-0.4±0.02
PLA_N	48.4±0.51	0.94±0.01	6.1±0.02
PLA_NG	45.9±0.05	0.09±0.02	7.24±0.01
PLA_C	42.6±0.03	-1.2±0,02	0.17±0.05
PLA_PM	58.0±0.01	-1.22±0.01	-1.3±0.02

Source: own work

The PLA sample had the lowest brightness. A positive value of the a* parameter indicates that the sample is in the yellow space, and a negative value of the b* parameter indicates that the sample is in the blue space. There is visible change in colour after the addition of antimicrobial additives. They are a little brighter and have different colours. PLA film with peppermint essential oil showed the highest brightness. t In the first quarter of the colour space diagram (Fig 2.) the colour of the sample with nisin (PLA_N) was between red and yellow. The addition of essential oils turned the colour into green-yellow space (PLA_C) and dark blue and blue (PLA_PM). NovaGARD powder located the sample in the first quarter between the red and yellow colour (PLA_NG).

The results of the antimicrobial study are presented in Table 6. It shows that pure PLA film has no antimicrobial activity. The strongest antimicrobial effect was observed for the film with Nisaplin powder. Its antimicrobial activity was against all the bacteria tested - the largest against *Pseudomonas aeruginosa, Bacillus subtilis* (Fig. 4) and *Clostridium perfringers* (Fig. 3) and the smallest against Listeria innocua. Clove oil incorporated in PLA film was effective in three cases: against *Bacillus subtilis* (Fig 4), E coli (Fig. 5) and Pseudomonas aureginosa. For the other bacteria, clove oil showed the bacteriostatic effect, except *Clostridium perfringens* that was resistant to this film.

Table 6. Clear zones (in mm) after antimicrobial testing

	PLA	PLA_N	PLA_C	PLA_NG	PLA_PM
Clostridium perfringens	0	20	0	12	10.5
Staphylococcus aureus	0	18	11	10.5	0
Pseudomonas aeruginosa	0	22	12	0	0
Yersinia enterocolitica	0	12	10.5	10.5	0
Salmonella enteritidis	0	13	10.5	10.5	0
Bacillus subtilis	0	21	17	10.5	10.5
Listeria innocua	0	12	10.1	0	0
Eschericha coli	0	16	14	11	0
Staphylococcus paratyphi	0	16	10.5	14	10.5
Enteroccocus faecalis	0	16	10	12	10.5

Source: own work

The addition of Novagard powder showed no significant antibacterial activity. Only growth of four bacteria (*Clostridium perfringens, Eschericha coli, Staphylococcus paratyphi, Enteroccocus faecalis*) was slightly inhibited and for the other 4 (*Staphylococcus aureus, Yersinia enterocolitica, Salmonella enteritidis, Bacillus subtilis*) there was the bacteriostatic effect. There was no effect for Pseudomonas aeruginosa and Listeria innocula. The film with peppermint oil had the worst results. The bacteriostatic effect was observed in the case of four bacteria: *Clostridium perfringens, Bacillus subtilis, Staphylococcus paratyphi* and *Enteroccocus faecalis*.

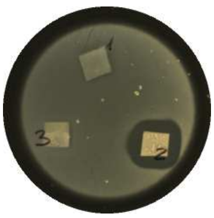


Fig. 3. Antimicrobial properties of PLA (1), PLA_N (2) and PLA_C (3) against Clostridium perfringers

Fig. 4. Antimicrobial properties of PLA (1), PLA_N (2) and PLA_C (3) against Bacillus subtilis

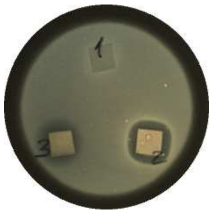


Fig. 5. Antimicrobial properties of PLA (1), PLA_N (2) and PLA_C (3) against E. Coli

CONCLUSIONS

This investigation showed the possibility of obtaining PLA films with natural antimicrobial substances such as bacteriocins and essential oils. Based on this research and the literature view, we can conclude that the incorporation of natural antimicrobial substances into PLA film positively influences its antimicrobial properties, however there are some differences in their activity. While pure PLA film does not show any antimicrobial activity, the highest limitation of the growth of microorganisms was for nisin. It can help maintain the high quality of products and ensure safety of consumers. The antimicrobial protection of films tested can extend food storage and protect against the adverse effects of microorganisms throughout the entire logistics chain.

Nevertheless in this study these additives weakened the mechanical properties (tensile strength, elongation at break and puncture strength) of PLA blends. It was also observed that the addition of active ingredients changed the colour of the films, which is not always preferable.

Summarizing, the use of antimicrobial additives applied is an excellent proposition for producers looking for new ecological solutions. Moreover, it is advisable to use biodegradable materials, including PLA pellets as matrix for new active packaging. It is an innovative and excellent offer for producers who are searching for innovative ideas and who care about ecology.

For future investigations it is very important to check the biodegradability and compostability of these novel packaging systems..

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

Statutory fund of Poznan School of Logistics.

REFERENCES

Agrimonti C., White J.C., Tonetti S., Marmiroli N., 2019. Antimicrobial activity of cellulosic pads amended with emulsions of essential oils of oregano, thyme and cinnamon against microorganisms in minced beef meat, International Journal of Food Microbiology, 305, 108246, http://doi.org/10.1016/j.ijfoodmicro.2019.108246.

Ali A., Chen Y., Liu H., Yu L., Baloch Z., Khalid S., Zhu J., Chen L. 2019. Starch-based antimicrobial films functionalized by pomegranate peel, International Journal of Biological Macromolecules, 129, 1120-1126, http://doi.org/10.1016/j.ijbiomac.2018.09.068.

Aswathy J., Heera K.V., Sumi T.S., Meritta J., Shiji M., Praveen G., Indu C. Nair, Radhakrishnan E.K., 2019. Starch-PVA composite films with zinc-oxide nanoparticles and phytochemicals as intelligent pH sensing wraps for food packaging application, International Journal of Biological Macromolecules, 136, 395-403, http://doi.org/10.1016/j.ijbiomac.2019.06.018.

Boyacı D., Iorio G., Sozbilen G. S., Alkan D., Trabattoni S., Pucillo F., Farris S., Yemenicioğlu A., 2019. Development of flexible antimicrobial zein coatings with essential oils for the inhibition of critical pathogens on the surface of whole fruits: Test of coatings on inoculated melons, Food Packaging and Shelf Life, 20, 100316, http://doi.org/10.1016/j.fpsl.2019.100316.

Heydari-Majd M., Ghanbarzadeh B., Shahidi-Noghabi M., Najafi M.A., Hosseini M. 2019. A new active nanocomposite film based on PLA/ZnO nanoparticle/essential oils for the preservation of refrigerated Otolithes ruber fillets, Food Packaging and Shelf Life, 19, 94-103 http://doi.org/10.1016/j.fpsl.2018.12.002.

Fonseca L., dos Santos Cruxen C.E., Bruni G.P., Fiorentini A.M., da Rosa Zavareze E., Lim L., Dias A. 2019. Development of antimicrobial and antioxidant electrospun soluble potato starch nanofibers loaded with carvacrol, International Journal of Biological Macromolecules, 139, 1182-1190, http://doi.org/10.1016/j.ijbiomac.2019.08.096.

Kashiri M., López-Carballo G., Hernández-Muñoz P., Gavara R., 2019. Antimicrobial packaging based on a LAE containing zein coating to control foodborne pathogens in chicken soup, International Journal of Food Microbiology, 306, 108272, http://doi.org/10.1016/j.ijfoodmicro.2019.108272.

Lee, H., Kim, K., Choi, K.-H., Yoon, Y., 2015. Quantitative microbial risk assessment for Staphylococcus aureus in natural and processed cheese in Korea. J. Dairy Sci. 98, 5931–5945. http://doi.org/10.3168/jds.2015-9611.

Lan W., Zhang R., Ahmed S., Qin W., Liu Y., 2019. Effects of various antimicrobial polyvinyl alcohol/tea polyphenol composite films on the shelf life of packaged strawberries, LWT, 113, 2019, 108297, http://doi.org/10.1016/j.lwt.2019.108297.

Liu B., Xu H., Zhao H., Liu W., Zhao L., Li Y. 2017. Preparation and characterization of intelligent starch/PVA films for simultaneous colorimetric indication and antimicrobial activity for food packaging applications, Carbohydrate Polymers, 157, 842-849, http://doi.org/10.1016/j.carbpol.2016.10.067.

Malhotra B, Keshwani A and Kharkwal H., 2015. Antimicrobial food packaging: potential and pitfalls. Front. Microbiol. 6:611. http://doi.org/10.3389/fmicb.2015.00611

Qin Y., Li W., Liu D., Yuan M., Li L. 2017. Development of active packaging film made from poly (lactic acid) incorporated essential oil, Progress in Organic Coatings 103, 76–82, http://doi.org/10.1016/j.porgcoat.2016.10.017

Talebi F., Misaghi A., Khanjari A., Kamkar A., Gandomi H., Rezaeigolestani M. 2018. Incorporation of spice essential oils into poly-lactic acid film matrix with the aim of extending microbiological and sensorial shelf life of ground beef, LWT, 96, 482-490, http://doi.org/10.1016/j.lwt.2018.05.067.

Wang K., Lim P.N., Tong S.Y., Thian E.S. 2019. Development of grapefruit seed extract-loaded poly(ε-caprolactone)/chitosan films for antimicrobial food packaging, Food Packaging and Shelf Life, 22, 2019,100396, http://doi.org/10.1016/j.fpsl.2019.100396.

Yahyaoui M., Gordobil O., Díaz R. H., Abderrabba M., Labidi J., 2016. Development of novel antimicrobial films based on poly(lactic acid) and essential oils, Reactive and Functional Polymers, 109, 1-8, http://doi.org/10.1016/j.reactfunctpolym.2016.09.001.

Zhao Y., Teixeira J.S., Saldaña M. D.A., Gänzle M. G., 2019. Antimicrobial activity of bioactive starch packaging films against Listeria monocytogenes and reconstituted meat microbiota on ham, International Journal of Food Microbiology, 305, 108253, http://doi.org/10.1016/j.ijfoodmicro.2019.108253.

Zheng K., Xiao S., Li W., Wang W., Chen H., Yang F., Qin C. 2019. Chitosan-acorn starch-eugenol edible film: Physico-chemical, barrier, antimicrobial, antioxidant and structural properties, International Journal of Biological Macromolecules, 135, 344-352, http://doi.org/10.1016/j.ijbiomac.2019.05.151.

BIODEGRADOWALNE OPAKOWANIA NA BAZIE PLA O WŁAŚCIWOŚCIACH PRZECIWDROBNOUSTROJOWYCH

STRESZCZENIE. **Wstęp:** Opakowanie jest nieodłącznym elementem większości produktów dostępnych na rynku. Oprócz pierwotnej, pasywnej funkcji ochronnej i logistycznej jest także doskonałym narzędziem do rozwoju innowacji. W poszczególnych ogniwach łańcucha dostaw rola opakowań w sprawnym przemieszczaniu towarów od producenta do odbioru odgrywa duże znaczenie. Odpowiednio zaprojektowane i wykonane opakowania nie tylko w istotny sposób mogą wpłynąć na obniżenie kosztów, ale także zapewnić jakość i bezpieczeństwo całego łańcucha. Z punktu widzenia ekologicznego coraz częściej wykorzystuje się opakowania na bazie surowców odnawialnych, np. na bazie PLA. Podstawowym zadaniem opakowań jest zabezpieczenie produktu przed niekorzystnymi zmianami jakie są następstwem oddziaływań czynników zarówno egzo – jak i endogennych na zapakowany w nie produkt podczas transportu i przechowywania. Jednym z rodzajów innowacji opakowaniowych są opakowania przeciwdrobnoustrojowe - jako sposób aktywnej ochrony zapakowanych produktów. Ochrona towarów przed psuciem mikrobiologicznym wydłuża okres przydatności do spożycia, a jednocześnie ułatwia procesy przechowywania.

Metody: Celem badania jest uzyskanie biodegradowalnych folii na bazie PLA o właściwościach przeciwdrobnoustrojowych. Zastosowano cztery różne naturalne środki przeciwdrobnoustrojowe: olejek goździkowy, olejek miętowy i dwa proszki zawierające nizynę (Nisaplin i Novagard). Przetestowano właściwości mechaniczne, barierowe, antymikrobiologiczne i optyczne.

Wyniki: Dodatek środków przeciwdrobnoustrojowych zmienił właściwości badanych prób w różnym stopniu. Badane folie wykazały aktywność przeciwdrobnoustrojową, jednak dodanie środków przeciwdrobnoustrojowych osłabiło właściwości mechaniczne i zmieniło ich kolor.
Wnioski: Przytoczone badania potwierdziły, że PLA można stosować jako matrycę polimerową dla różnych środków przeciwdrobnoustrojowych. Mogą hamować rozwój bakterii w żywności lub kosmetykach, a przy ich przyszłym zastosowaniu należy wziąć pod uwagę wpływ na właściwości mechaniczne. Testowane folie mogą korzystnie oddziaływać na zapakowane produkty w całym systemie logistycznym, wydłużając ich termin przydatności do spożycia, a jednocześnie ich biodegradowalność sprawia, że są opakowaniami przyjaznymi środowisku.

Słowa kluczowe: opakowania przeciwdrobnoustrojowe, opakowanie aktywne, opakowanie biodegradowalne, właściwości mechaniczne, właściwości barierowe

Natalia Czaja-Jagielska ORCID ID: https://orcid.org/0000-0001-7472-1319
Poznan School of Logistics
Estkowskiego 6, 61-755 Poznań, **Poland**
e-mail: natalia.czaja-jagielska@wsl.com.pl

Anna Praiss ORCID ID: https://orcid.org/0000-0003-2642-5165
Poznan School of Logistics
Estkowskiego 6, 61-755 Poznań, **Poland**

Michał Walenciak ORCID ID: https://orcid.org/0000-0003-1016-3359
Poznan School of Logistics
Estkowskiego 6, 61-755 Poznań, **Poland**

Dajana Zmyślona
Poznan School of Logistics
Estkowskiego 6, 61-755 Poznań, **Poland**

Natalia Sankowska
Poznan School of Logistics
Estkowskiego 6, 61-755 Poznań, **Poland**

LogForum

> Scientific Journal of Logistics <

2020, 16 (2), 287-298

http://doi.org/10.17270/J.LOG.2020.383

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

RELATIONSHIP OF ADVERTISING APPEALS, CORPORATE REPUTATION AND BRAND ADVOCACY: THE MEDIATION ROLE OF BRAND LOYALTY

Asif Mahmood[1], Syed Zeeshan Haider[2]

1) Namal Institute, Mianwali, **Pakistan**, 2) National University of Computer and Emerging Sciences Chiniot-Faisalabad, Punjab, **Pakistan**

ABSTRACT. **Background:** Retention of customers to maintain long term profitable relationship is indispensable for the organizations operating in Fast Moving Consumer Goods (FMCGs) sector. Due to lucrative nature of market, proximity of new entrants is very high in emerging FMCGs markets. In order to retain customers for longer time and make them loyal with the brand, companies are spending heavily on advertising campaigns. Informative and normative advertising appeals are two widely used appeals in FMCGs advertisements. This research aims at finding the degree of relationship of informative and normative ad appeals with brand loyalty in FMCGs context. Efforts have been put to understand the relationship of three very important variables; corporate reputation, brand loyalty and brand advocacy in FMCGs sector.

Methods: Data were collected using questionnaire with the sample size of 400 from four different cities of Pakistan. Regression analysis was conducted to find the relationships between variables. Firstly, all were measured independently with each other, and then mediating effect of brand loyalty on the relationship between corporate reputation and brand advocacy was measured.

Results: The results revealed that informative advertising appeal has created more impact on brand loyalty than normative advertising appeal in FMCGs sector. On the other hand, findings also suggest that corporate reputation and brand loyalty are important but not the major contributor towards the brand advocacy in FMCGs sector.

Conclusions: The research has great significance for marketing professionals and practitioners as it would guide them about strategic direction for the use of appropriate appeals in advertising campaigns.

Key words: advertising appeals, corporate reputation, brand advocacy, brand loyalty, FMCGs sector.

INTRODUCTION

In current era, market for retail products is growing rapidly particularly in Asia pacific region. Fast Moving Consumer Goods markets are the prime concern for national as well as multinational manufacturing organizations [Bill, Feurer, Klarmann, 2020]. In South Asian countries, Pakistan is a developing economy with approximate population of 200 million. Adequately developed infra-structure, sufficient availability of modern technologies and overwhelming demand make it a very lucrative market for the consumer goods. There are many multinational companies such as Unilever, Proctor&Gamble, Colgate Palmolive and local companies catering to the consumer needs of this market. Some companies are offering large product mix including different product lines in different product categories.

Fast Moving Consumer Goods markets contain products which are produced and used on massive scale. Companies make them available in the markets on large accounts. FMCGs products are quickly consumable products and consumers put in fewer amounts of pre-purchase efforts. Further they tend to

Citation: Mahmood A., Haider S.Z., 2020. Relationship of advertising appeals, corporate reputation and brand advocacy: the mediation role of brand loyalty. LogForum 16 (2), 287-298, http://doi.org/10.17270/J.LOG.2020.383

Received: 17.09.2019, Accepted: 23.01.2020, on-line: 30.03.2020.

easily substitute these products if a specific brand is not available in the market. Per unit profit margins are usually low because of large number of items sold. So tactical planning plays very vital role in this market to maintain sustainable long run profitability [Aribarg, Schwartz, 2020]. Those products which are adequately available in the marketplace and are commonly used by the general public in geographical vicinity are called public goods and those products which are not extensively distributed in the market and brand names are not recognized among general public are called private good.

Customer relationship management (CRM) has its huge academic and practitioner value but still the discussion about its domain and meanings continues. CRM has deep relationship with marketing and some management disciplines. Whereby it is a very important strategic resource for the business. CRM concept should be focused resiliently; a better relationship with customer gives more brand loyal customer and increasing corporate reputation. When customers become the central points in companies, need for the long-term customer relationship evolves. Companies understand that they must take care of customers and it becomes a standard thought that while attracting new customers companies should pay more attention to retain old customers. In FMCGs industry of Pakistan, consumers are selective in their choices and one finds low number brand loyal customers due to availability of various alternative brands in same category. This behavior has invited brand managers to emphasize more on brand loyalty and customer retention programs [Gulbrandsen, Plesner, Raviola, 2019].

Increased competition in emerging Fast Moving Consumer Goods (FMCGs) market has made brand loyalty a very vital subject for brand managers across the world [Filatotchev et al. 2020]. Due to the individual differences in purchase behaviors and large scale advertising campaigns brand switching is very common practice in consumer goods market [Vlachy et al., 2020]. Therefore, companies operating in FMCGs industry are more concerned about making customers loyal to the brands. Managers feel difficulty in constructing long-term brand value for organizations and their brands have high pressures to gain short-term profits. Losing a customer in consumer goods market is not a one-time loss. Company is losing total revenue stream of all the purchases made by that customer over the entire life span. In hyper competition making your customer loyal with the brand offered by the company is always a challenge for marketers [Armstrong, Kotler, 2011].

Since the last decade, arrival of social media and awareness about advertising and its benefit to persuade consumers to influence their purchase intentions has radically changed the product promotion activities. Now companies are more focused towards 360-degree advertising campaigns which includes mixture of above the line (ATL) and below the line (BTL) activities. As per the nature of market, consumers usually substitute the products without much consideration and availability of many substitute brands is also contributing to lesser brand loyalty [Aribarg, Schwartz, 2020]. In order to remain intact and maintain longer relationships with existing customers companies have to introduced strong customer retention programs which will lead to gaining customer loyalty. Enhanced brand loyalty will help companies to remain profitable and sustain competitive advantage in cut-throat competition [Saeed et al., 2013]. From the above discussion it can be concluded that brand loyalty is very important for the companies working in FMCGs industry.

The accumulated impression formed by the stakeholders of a company which is generally resulting from the long-term two-way interactions between the company and customers is known as corporate reputation [Narteh, Braimah, 2019]. General customers develop corporate reputation from overall assessment of business as well as social activities performed by a particular company in the market environment. It also includes the behavior of company towards customers in terms of how they respond to the problems faced in the marketplace. By fulfilling the commitments with customers, companies construct good reputation amongst them [Keh, Xie, 2009].

After evaluating a particular product, customer forms a positive or negative opinion about the same which he/she shares in his/her social circle. If the experience is positive after repetitive exposure to same brand customer starts spreading positive word of mouth and starts defending that brand in his social appearances [Wong, Sheng, 2008]. By developing knowledge partnership and aiming to build stronger customer relationships companies ensure that customers start spreading positive word of mouth and defending brand in the marketplace. In growing markets, importance of word of mouth brand advocacy is increasing on regular bases. Firms are putting quantifiable efforts to enhance quantity and quality of WOM brand advocacy. This phenomenon is laying the bases for a strong need to analyze firm's efforts to improve and increase WOM advocacy for different brands. In FMCG context, consumer's psychological behavior and social concerns which impact on purchase intentions should be analyzed [Zeithaml, et. al., 2020]. In another study, [Jeong, Kim, 2019] emphasized to work on exploring the contribution of social and community factors to brand advocacy.

Thus, in the contemporary era large FMCG companies working in the country are bound to ascertain the relationship between advertising appeals, corporate reputation and brand loyalty. Further brand loyalty has to be grasped fully by analyzing its mediating role between corporate reputation and brand advocacy in FMCGs industry. The study will act as a litmus test for the contribution of corporate reputation building activities towards brand loyalty and brand advocacy in FMCGs industry.

LITERATURE REVIEW

Informative advertising appeals

When consumer is more interactive and his involvement is high during buying process, requirement for information about product attributes and core products benefits will be high. In such situation using informative/ rational advertising appeal is more appropriate. In context of digital advertising informative advertising has more significant impact on consumer behavior so companies should design strategically more convergent informative advertising to be used for digital signage [Argyres, Bercovitz, Zanarone, 2019]. The role of advertisement is very important in selling the products as it conveys accurate and informative message related to product. There are number of customers who only use advertisements as a source of information for buying products. Consumer information about the product may increase or decrease the profit through increased/decreased sales volume. In advertising information may be on product quality, manufacture Company or price [Anderson, Renault, 2009]. The price advertisement cost is related to the cost of the product and the sales volume. Consumers usually gather price information before purchasing to save shopping trip cost. When companies control advertising costs it will help them to remain competitive in price. Advertisements containing appropriate information are more liked by consumers while those with inadequate/irrelevant do not present clear messages. So the main role of disseminating information is to give details about a product. Consumer's awareness about product features is very important and it makes advertisement a very vital subject for organizations. Many advertisements do not contain clear message about product qualities, prices and other details. In oligopolistic markets it is mandatory for the advertisers to convey the proper information in the advertisement.

Normative advertising appeals

In normative advertising appeals, consumer is persuaded by transforming a message that creates peer pressure to influence the purchase decision. The influences of colleagues, close friends and family are normative factors. Marketer tries to communicate the usage of particular product as norm of the society in which the consumer is living. As consumer purchase decision is influenced by the people or a group of people in consumer's habitant environment, some researchers are discussing that normative influence is different when the compliance to the group norm is not compulsory [Matzler, Pichler, Hemetsberger, Applications 2007, Zhao, Lee 2019]. Reference groups have great impact on consumer opinions and belief. Reference groups are divided into two types: Normative reference groups (have impact on consumer's norms and attitude) and Comparative reference groups (in which consumers compare themselves with celebrities). While purchasing identical product consumer purchase pattern are influenced by the association with a group and that particular group has a great influence in selection of brand. During routine purchases many consumers give good weightage to the fact that they should buy those products which tends to inspire others in their respective social environment. A company attracts more customers to build relationship to work on social norms of that region. Social norms, such as cultural values are more important for a brand to build a strong relationship with consumers. Those consumers which are extroverts and are enjoying more societal affiliations are more inclined towards purchasing the product consumed by the particular social group with whom they are associated.

Brand Loyalty

Brand loyalty refers to specific behavior of customer in which the customer keeps buying company product or services for an extended period of time and generally shows positive attitude and behavior towards that specific brand he or she is using. Brand awareness is the first step towards the whole procedure which should have been ended with loyal customer base as desired by marketers around the globe. Brand awareness is divided into two components, one is brand recognition and other is brand recall. When people find some brand from their memory of sensory inputs it is called brand recall and when they are stimulated by some external force or activity it is defined as brand recognition. Loyalty not only tells us about the customer behavior, but it reveals the conduct of company as well. Companies make products to facilitate the customers and if customers are purchasing their products repeatedly, it shows that they are loyal with the company but it also show that the company is continuously surpassing their expectations [Rietveld, van Dolen, Mazloom, Worring, 2020]. Researchers in past have measured relationship of brand loyalty with different variables. Corporate image, trust and satisfaction have noteworthy effect on brand loyalty [Islam, 2008]. Providing better services in hyper competition markets helps a great deal in satisfying customers which ultimately results in greater brand loyalty. Customer satisfaction is deeply related to brand loyalty. Satisfaction state arrives when a brand meets the expectations of customer and then this state influences the next purchase behavior by encouraging customer to go for the repeat purchases with the same brand. Along with satisfaction trust also has strong bonding with brand loyalty; if customers have trust in the company they will be more loyal to the brands offered by that company [Gulbrandsen, Plesner, Raviola, 2019]. Trust has achieved substantial standing in maintaining brand loyalty for companies. Trust is a precondition to brand loyalty and with rapid growth in population in developing countries increased focus on customer satisfaction is becoming a must to retain customers and to stimulate them for repeat purchases [Jia, Management, 2020]. A company's financial conditions can be evaluated by its customer's equity. High customer equity prevents the brand switching and increase brand loyalty.

Corporate Reputation

Having favorable reputation is the objective of every firm. Managers of the firm influence other shareholders by signaling the social deeds of the firm. The reputation of the firm is constructed based on its internal structure and its social norms. Shareholders measure the organization's reputation by gathering important information through media and other monitors. Insignificant and weak relation is shown between switching and corporate reputation, but strong relation founded between customer satisfaction and corporate reputation. Many companies do not know how to create a corporate reputation, while others do not know how to use it. In these two unwanted situations, copying the behavior of other companies is not a recommended technique. Buyer's expectations are controlled by corporate reputation and market offerings. Buyers' response is affected by his viewpoint of seller's reputation. Collectively customer expectations, company's offerings and reputation affect the buying intentions. Corporate social responsibility (CSR) has a great impact on stakeholder equity. CSR also has a great contribution in the improvement of managerial and marketing disciplines and which results in better corporate reputation. The good reputation of the company can be measured through its financial performance. Better repute can only be generated if the financial statement is presenting a healthy picture. An organization has many types of social images which are formed by consumers, social analysts, critiques, arbiters and the interested investors. Expressions and impressions collectively make a scattered image and create problems. An organization should control its complexity, perspective and diverse image to control the scattered image problem [Price, Gioia, Corley 2008]. Corporate philanthropy is a very important asset of any business. Company should focus strategy of philanthropy instead of increasing financial activities. For a good repute in corporate philanthropy strategy helps a great deal. This strategy facilitates to achieve economic goal and the ultimate result will be amplification of goodwill. The corporate branding (reputation building) takes part in perspectives of different stake holders in an organization. The functional satisfaction is not only a key to success; cultural affection in brand is also an important factor. Thus, all these concepts are accumulated in corporate branding concepts. Corporate social responsibility activities have positive effect on consumer attitude, and it helps a great deal to develop favorable corporate reputation across the marketing environment. In not-for-profit organizations (NPOs) socially responsible attitude stimulate vendor donation attitudes.

Corporate Reputation & Brand Loyalty

Corporate relations are the major part of an organization. These relationships are formed as a result of trust and fulfillment of commitments over a course of time. If an organization is loyal to its customers, then in the long run customers will also pay back by remaining loyal to that organization. It will result in the formation of a trust relationship. Corporate reputation is identified to gain new customer. Reputation's effect on customer relationship is not fully inspected. There is a strong connection between reputational perception of a firm and expectations fulfillment of customer. Customer shows loyalty to those firms which have better pre-economic performance and reputation. A company should invest in human resource for good reputation, to make the firm a better place to work. It will bring innovation which is further linked to the customer satisfaction and retention. Socially responsible behavior has great worth for any organization. It can be measured at different levels of corporate gestures. The good CSR will result in better brand image and will help in improved corporate relations. CSR activities benefits an organization by increasing its sales revenue and brand loyalty and by decreasing brand turnover. All consumer expectations are determined by firm's reputation and services given by firm. Empirical study revealed that customer response is favorable if the attitude and vendor's reputation is according to customer expectation. Corporate image has a substantial but indirect effect on customer loyalty, as customer loyalty is determined by both confirmation of hopes and company image. Corporate image and reputation contributes towards increased brand loyalty [Bartikowski et al., 2011].

Brand Advocacy

Brand advocates are extremely loyal to the brand; their relationship is far more than just deriving functional benefits from brand. They act as a militant for brand and their commitment is to the extent of generating positive word of mouth (WOM), fully experiencing the brand and becoming biggest allies of the brand. WOM has three aspects "opinion seeking" "opinion giving" and "opinion passing". Opinion seekers are the persons who tend to take advice and opinions from others and then take any major decision. The people who are opinion givers are often the opinion leaders and have a great influence on the attitudes of their followers or group. Opinion passing is an important behavior of electronic-WOM that regulates the information flow towards the different consumers in a social group [Chu, Kim, 2011].The power of word of mouth is really affective. Many companies seek positive word of mouth to gain competitive advantage. Positive WOM does not generate automatically, one company has to perform up to the total satisfaction of consumer to generate positive word of mouth [Mazzarol, Sweeney, Soutar 2007]. Companies focus on retaining existing customer because they are not only a permanent source of income but they also influence new ones. Loyal customers are considered alternative of advertising because their positive word of mouth (WOM) can nourish company's image. So, there is a big existence of existing customer on company's performance. When consumers become dissatisfied then generation of word of mouth is obvious in most of the cases. One of the important and interesting aspect is that dissatisfied customers are more engaged in spreading negative word of mouth, but satisfied consumers are less engaged into word of mouth. The difference between both satisfied and dissatisfied is inflated. Companies are offering reward to ensure repeat purchases but through this in the long run, consumers become reward worm. Through referral reward company cannot build the actual image of the brand and if the reward is removed there are chances of decrease in the sale of the product. Stronger brands do not necessarily use referral reward rather they focus more on customer relationship marketing and improved product and services to generate positive word of mouth.

After the support of existing literature following hypotheses have been developed for current study as shown in Figure 1:

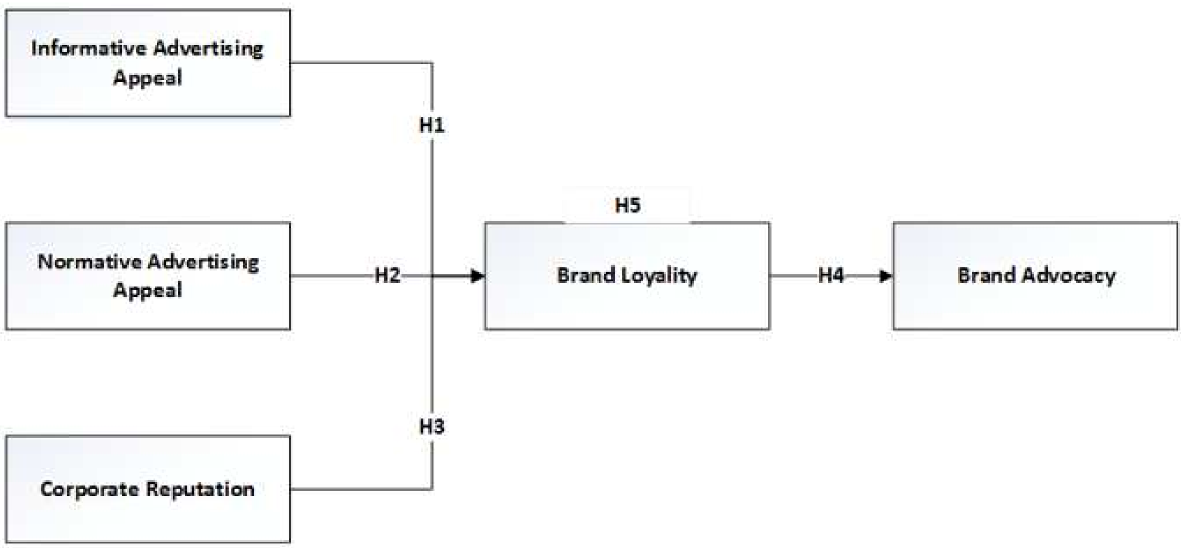
H1: Informative advertising appeal has significant relationship with brand loyalty.

H2: Normative advertising appeal has significant relationship with brand loyalty.

H3: Corporate reputation has significant relationship with brand loyalty.

H4: Brand Loyalty has significant relationship with brand advocacy

H5: Brand loyalty will mediate between corporate reputation and brand advocacy.



Source: own work

Fig. 1. Research Framework

RESEARCH METHODOLOGY

Sampling

Population for current study is customers of fast-moving consumer goods (FMCG). Resources and time constraints limits the sample to FMCG customers from four major cities which include Lahore, Faisalabad, Islamabad and Multan. Non-probability sampling technique along with convenience sampling method is used. Rationale behind using convenient sampling is that it is the most efficient and economical method [Sekaran, Bougie, 2013]. Questionnaires were distributed to 450 respondents of Faisalabad, Lahore, Multan and Islamabad. Out them 50 questionnaires were faulty and responses of 400 questionnaires were recorded to SPSS for analysis, having response rate of 88.8 %. The demographical characteristics of these respondents are shown in the Table 1.

Table 1. Demographical characteristics of respondents

Characteristics	Frequency	Percentage
Gender		
Male	254	63.5
Female	146	36.5
Total	**400**	**100.0**
Age (in years)		
15-25	181	45.3
26-35	106	26.5
36-45	77	19.3
45 +	36	9.00
Total	**400**	**100.0**
Occupation		
Services	86	21.5
Business	74	18.5
Students	187	46.8
Others	53	13.3
Total	**400**	**100.0**
City		
Lahore	90	22.5
Faisalabad	229	57.3
Islamabad	42	10.5
Multan	39	9.8
Total	**400**	**100.0**

Research instrument

Structured questionnaire is used as research instrument for obtaining responses. Questionnaire is derived from existing studies on the relevant variables. The items and dimensions are then rationalized according to the current study and context. The questionnaire is divided into five parts in which each variable is measured on same scale. Five-point Likert scale has been used to measure the answers of respondents in which 1=strongly disagree is minimum and 5=strongly agreed is been the maximum range of responses. The Table 2 below explains about variables included in research which are extracted from secondary data. Different number of measures and result of reliability test is also described.

Table 2. Reliability analysis of all measurement scales

Variable	Source	Number of Items	Reported Reliability
Normative appeal	[Phau & Teah, 2009]	8	0.836
Informative appeal	[Korgaonkar, Silverblatt, & O'Leary, 2001]	5	0.627
Corporate Reputation	[Ponzi, Fombrun, & Gardberg, 2011]	4	0.729
Brand Loyalty	[Moolla & Bisschoff, 2012]	10	0.752
Brand Advocacy	[Matzler, & Hemetsberger, 2007]	5	0.809

Date collection method

The data were collected in non-contrived settings of natural environment by gathering self-administered questionnaires. The individuals with different demographic characteristics, who are consumers of FMCGs, were considered as unit of analysis. The respondents were briefed on research purpose before having their responses.

Data analysis & Results

Responses from questionnaire were entered in excel sheet and SPSS 20.0 is used for data analysis and hypothesis testing. Following analysis is performed.

Correlation analysis

Correlations are calculated to assess the nature of relationship among variables of study. A we can see from Table 3 below that informative advertising appeal has strong positive correlation with dependent variable brand loyalty as $r = 0.510$, $p < 0.01$. Whereas normative advertising appeal has weak relationship with brand loyalty as $r = 0.386$, $p = 0.01$. Corporate reputation has moderate positive correlation with brand loyalty as $r = 0.467$, $p = 0.01$. In the last, brand loyalty has high positive correlation with brand advocacy as $r = 0.571$, $p = 0.01$.

Table 3. Correlation analysis of study variables

		Informative	Normative	Creuptation	Loyalty	Badvocacy
Informative	Pearson Correlation	1	.027	.401(**)	.510(**)	.159(**)
	Sig. (2-tailed)		.592	.000	.000	.001
	N	400	400	400	400	400
Normative	Pearson Correlation	.027	1	.064	.386(**)	.329(**)
	Sig. (2-tailed)	.592		.201	.000	.000
	N	400	400	400	400	400
Creuptation	Pearson Correlation	.401(**)	.064	1	.467(**)	.210(**)
	Sig. (2-tailed)	.000	.201		.000	.000
	N	400	400	400	400	400
Loyalty	Pearson Correlation	.280(**)	.386(**)	.257(**)	1	.571(**)
	Sig. (2-tailed)	.000	.000	.000		.000
	N	400	400	400	400	400
Badvocacy	Pearson Correlation	.159(**)	.329(**)	.210(**)	.571(**)	1
	Sig. (2-tailed)	.001	.000	.000	.000	
	N	400	400	400	400	400

** Correlation is significant at the 0.01 level (2-tailed)

Regression Analysis

Simple regression analysis has been applied to measure relationship of informative appeal, normative appeal, corporate reputation, Brand loyalty and Brand advocacy. H1 is formulated to evaluate the impact of independent variable Informative advertising on dependent variables brand loyalty. Table 4 is showing that 48 % variation in brand loyalty is caused by informative advertising appeal (R2 = 0.48, p = 0.000).

Table 4. Regression analysis of informative advertising and brand loyalty

Model	**B**	**SE**	**B**	**T**	**F**	**R^2**	**p**
Constant	20.769	2.043		10.164	33.959	0.48	.000
Informative	0.586	0.101	0.280	5.827			

Table 5. Regression analysis of normative advertising and brand loyalty

Model	**B**	**SE**	**B**	**T**	**F**	**R^2**	**p**
Constant	24.096	1.047		23.021	69.498	0.369	.000
Normative	0.341	0.041	0.386	8.337			

Table 6. Regression analysis of corporate reputation and brand loyalty

Model	**B**	**SE**	**B**	**T**	**F**	**R^2**	**p**
Constant	23.459	1.742		13.465	28.047	0.416	.000
C. reputation	0.561	0.106	0.257	5.296			

Table 7. Regression analysis of brand loyalty and brand advocacy

Model	**B**	**SE**	**B**	**T**	**F**	**R^2**	**p**
Constant	2.623	1.025		2.559	192.576	0.324	.000
Loyalty	0.431	0.031	0.571	13.877			

While testing hypothesis H2 for normative advertising appeal as predictor variable and brand loyalty as criterion variable, it is revealed that 37 % variation in dependent variable is predicted by independent variable normative advertising appeal (R2 = 0.369, p = 0.000).

In Hypothesis H3 regression analysis has been calculated by taking corporate reputation as independent variable and brand loyalty as dependent variable. It is concluded that corporate reputation contributes 41 % variation in brand loyalty ($R2 = 0.416$, $p = 0.000$).

As per H4, brand loyalty has been considered as predictor variable and brand advocacy as criterion variable. Regression analysis revealed that brand loyalty has 32% contribution in the prediction of brand advocacy ($R2 = 0.324$, $p = 0.000$).

H5 states the mediation effect of Loyalty on the relationship between Informative appeal & brand advocacy. Mediation analysis has been performed through Multiple regression analysis followed by Sobel test where following values from Table 8 has been inserted as:

a = raw (unstandardized) regression coefficient for the association between IV and mediator.

s_a = standard error of a.

b = raw coefficient for the association between the mediator and the DV (when the IV is also a predictor of the DV).

s_b = standard error of b.

Results of the mediation analysis of suggests that the brand loyalty not mediates the relationship between corporate reputation and brand advocacy as P > o.o5 for the Sobel test as depicted in Table 9. the Hypothesis H5 is not supported.

Table 8. Regression analysis of brand loyalty and brand advocacy

Model	B	SE	B	T	F	R^2	p
Constant	1.233	1.345		.917	97.927	0.327	
Corporate reputation	.112	.070	.068	1.592			.112
Loyality	.418	.032	.554	13.030			.000

Table 9. Sobel test

	Input	Test-statistic	S.E	P-value
A	.561	4.905	.04780	>0.05
B	.418			
S_a	.106			
S_b	.032			

CONCLUSION AND RECOMMENDATIONS

The statistical results are showing that the customers who are influenced by informative advertising appeals i.e. price, quality, and convenience are showing more loyalty towards the specific brands of FMCGs. The customers who are purchasing a particular brand by the influence of normative advertising appeals i.e. family, friends or peer pressure are found less loyal in FMCGs sector. So, companies working in FMCGs sector should pay more attention towards the informative appeals if the objective of advertising is to ensure repetitive purchase by the consumers and to remain profitable for the longer period. Corporate reputation has moderate relationship with brand loyalty which shows that it is an important but not the major determinant of brand loyalty in FMCGs sector. Further study is required to assess the contribution of other factors such as price, product availability and quality conformance towards the brand loyalty in FMCGs sector.

While analyzing the mediation role of brand loyalty between corporate reputation and brand advocacy it is revealed that there is no mediation in this relationship. Specifically, in studied sector, corporate reputation has moderate relationship with brand loyalty and brand loyalty has weak relationship with brand advocacy. By introducing brand loyalty as mediator, the betas or nonstandardized coefficients remains unchanged, so this means there is no mediation effect in this relationship. So, we can conclude by the results of mediation that in FMCGs sector, corporate reputation has less contribution towards the brand loyalty and there is less proximity that loyal customers will also act as brand advocates. So strategically companies should think a step ahead to convert brand loyal customers to brand advocates.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The authors received no funding for conducting of this research.

REFERENCES

Armstrong G., Kotler Ph., 2011. Principles of Marketing by Gary Armstrong and Philip Kotler (2011, Hardcover). Retrieved June 28, 2014, from http://www.ebay.com/ctg/Principles-Marketing-Gary-Armstrong-and-Philip-Kotler-2011-Hardcover-/1699446

Anderson S.P., Renault R., 2009. Comparative advertising: disclosing horizontal match information. The RAND Journal of Economics, 40(3), 558–581. http://doi.org/10.1111/j.1756-2171.2009.00077.x1

Argyres N., Bercovitz J., Zanarone G.J.S.M.J., 2019. The role of relationship scope in sustaining relational contracts in interfirm networks, Strategic Management Journal, 41(2), 222-245.

Aribarg A., Schwartz E.M., 2020. Native Advertising in Online News: Trade-Offs Among Clicks, Brand Recognition, and Website Trustworthiness. Journal of Marketing Research, 57(1), 20–34. http://doi.org/10.1177/0022243719879711

Bartikowski B., Walsh G., Beatty S.E., 2011. Culture and age as moderators in the corporate reputation and loyalty relationship. Journal of Business Research, 64(9), 966–972. http://doi.org/10.1016/j.jbusres.2010.11.019

Bill F., Feurer S., Klarmann M., 2020. Salesperson social media use in business-to-business relationships: An empirical test of an integrative framework linking antecedents and consequences. J. of the Acad. Mark. Sci. http://doi.org/10.1007/s11747-019-00708-z

Chu S.-C., Kim Y., 2011. Determinants of consumer engagement in electronic word-of-mouth (eWOM) in social networking sites. International Journal of Advertising, 30(1), 47-75. http://doi.org/10.2501/IJA-30-1-047-075

Filatotchev I., Wei L.Q., Sarala R.M., Dick P., Prescott J.E.J.J.o.M.S., 2020. Connecting Eastern and Western Perspectives on Management: Translation of Practices Across Organizations, Institution and Geographies, Journal of Management Studies, 57(1), 1-24.

Graf-Vlachy L., Oliver A.G., Banfield R., König A., Bundy J., 2020. Media Coverage of Firms: Background, Integration, and Directions for Future Research, Journal of Management, 46(1), 36–69. http://doi.org/10.1177/0149206319864155.

Gulbrandsen I.T., Plesner U., Raviola E.J.I.J.o.M.R., 2019. New media and strategy research: towards a relational agency approach, International, Journal of Management Reviews, 22(1), 33-52.

Islam M.S., 2008. The Analysis of Customer Loyalty in Bangladeshi Mobile Phone Operator Industry. Presented at: Independent University, Bangladesh. 83 Suhrawardy Avenue, Dhaka-1212, Bangladesh, 1-16.

Jeong Y.-C., Kim T.-Y.J.A.o.M.J., 2019. Between legitimacy and efficiency: An institutional theory of corporate giving, Academy of Management, 62(5), 1583-1608.

Jia X.J.C.S.R., Management E., 2020. Corporate social responsibility activities and firm performance: The moderating role of strategic emphasis and industry competition, Corporate Social Responsibility and Environmental Management, 27(1), 65-73.

Keh H.T., Xie Y., 2009. Corporate reputation and customer behavioral intentions: The roles of trust, identification and commitment. Industrial Marketing Management, 38(7), 732–742. http://doi.org/10.1016/j.indmarman.2008.02.005

Korgaonkar P., Silverblatt R., O'Leary B., 2001. Web advertising and Hispanics. Journal of Consumer Marketing, 18(2), 134–152.

Matzler K., Pichler E.A., Hemetsberger A.J.M.T., Applications, 2007. Who is spreading the word? The positive influence of extraversion on consumer passion and brand evangelism, 18(1), 25-32.

Mazzarol T., Sweeney J.C., Soutar G.N., 2007. Conceptualizing word-of-mouth activity, triggers and conditions: an exploratory study. European Journal of Marketing, 41(11/12), 1475–1494. http://doi.org/10.1108/03090560710821260

Moolla A.I., Bisschoff C.A., 2012. Validating a model to measure the brand loyalty of fast-moving consumer goods. Journal of Social Sciences, 31(2), 101–115.

Narteh B., Braimah M., 2019. Corporate reputation and retail bank selection: the moderating role of brand image, International Journal of Retail & Distribution Management, Vol. ahead-of-print No. ahead-of-print. http://doi.org/10.1108/IJRDM-08-2017-0164

Phau I., Teah M., 2009. Devil wears (counterfeit) Prada: a study of antecedents and outcomes of attitudes towards counterfeits of luxury brands. Journal of Consumer Marketing, 26(1), 15–27. http://doi.org/10.1108/07363760910927019

Rietveld R., van Dolen W., Mazloom M., Worring M.J.J.o.I.M., 2020. What You Feel, Is What You Like Influence of Message Appeals on Customer Engagement on Instagram, Journal of Interactive Marketing, 49, 20-53.

Ponzi L.J., Fombrun C.J., Gardberg N.A., 2011. RepTrakTM Pulse: Conceptualizing and Validating a Short-Form Measure of Corporate Reputation. Corporate Reputation Review, 14(1), 15–35. http://doi.org/10.1057/crr.2011.5

Price K.N., Gioia D.A., Corley K.G., 2008. Reconciling Scattered Images: Managing Disparate Organizational Expressions and Impressions. Journal of Management Inquiry, 17 (3), 173-185, http://doi.org/10.1177/1056492608314991

Saeed R., Tufail S., Lodhi R.N., Ahmad M., Arshad H.M., Saeed R., 2013. Antecedents of Cigarette Brand Loyalty in Pakistan. Journal of Basic and Applied Scientific Research, 3(5), 969–975.

Sekaran U., Bougie R., 2013. Wiley: Research Methods for Business: A Skill-Building Approach, 6th Edition - Uma Sekaran, Roger Bougie. Retrieved July 1, 2015, from http://eu.wiley.com/WileyCDA/WileyTitle/productCd-111994225X.html

Wong R., Sheng S.Y., 2008. A System Dynamics Approach to the Study of Word-of-Mouth and Its Effect in an Online Environment, Technol. Innov. Manage. Rev, 42-48. Retrieved from http://www.ebrf.fi/_file/44151/EBRF11_Paper_v02.pdf

Zeithaml V.A., Jaworski B.J., Kohli A.K., Tuli K.R., Ulaga W., Zaltman G., 2020. A Theories-in-Use Approach to Building Marketing Theory. Journal of Marketing, 84(1), 32–51. http://doi.org/10.1177/0022242919888477

Zhao W., Lee, Y.-J.J.J.o.P.M., 2019. The Moderating Effects of Status-Consumption Motive and Age in the Relationship between CSR Advertising Appeal Type and Purchase Intentions. Journal of Promotion Management.

ZALEŻNOŚCI POMIĘDZY MARKETINGIEM, REPUTACJĄ FIRMY I POLITYKĄ MARKI: ROLA MEDIACYJNA LOJALNOŚCI MARKI

STRESZCZENIE. **Wstęp:** Utrzymanie klientów w relacjach długoterminowych, umożliwiających osiąganie stabilnych zysków jest kluczowym zagadnieniem w branży szybko rotujących dóbr zbywalnych (FMCG). Ze względu na stosunkową łatwość uzyskiwania zysków na tym rynku, można zaobserwować dużą ilość nowych podmiotów wkraczających na wschodzące rynki FMCG. W celu zatrzymania istniejących klientów na dłuższy okres czasu i przywiązanie ich do danej marki, firmy przeznaczają znaczne kwoty na kampanie reklamowe. W obrębie działań marketingowych na rynku FMCG można zaobserwować dwa kierunki: informujący oraz normatywny.
Celem pracy jest określenie stopnia powiązania pomiędzy podejściem normatywnym i informującym a lojalnością marki w kontekście rynku FMCG. Główny nacisk położono na zrozumienie zależności pomiędzy trzema ważnymi zmiennymi: reputacją firmy, lojalnością marki oraz polityką marki w obrębie rynku FMCG.
Metody: Dane zostały zebrany przy użyciu ankiety o liczbie prób 400, pochodzących z czterech różnych miast w Pakistanie. Zależności pomiędzy zmiennymi były badane przy użyciu analizy regresji. Na początku określono niezależność każdej ze zmiennych w stosunku do pozostałych, następnie zmierzono efekt mediacyjny lojalności marki na relacje pomiędzy reputacją firmy a polityką marki.
Wyniki: Uzyskane wyniki wskazały na większy wpływ informacyjnego podejścia działań marketingowych na lojalność marki aniżeli podejście normatywne dla sektora FMCG. Z drugiej strony, wyniki sugerują, że reputacja firmy oraz lojalność marki mają ważne, ale nie główny wpływ na politykę marki dla produktów FMCG.
Wnioski: Praca ma istotne znaczenia dla specjalistów marketingu oraz praktyków, będąc wskazówką odnośnie strategicznych kierunków prawidłowego prowadzenia kampanii marketingowych.

Słowa kluczowe: metody ogłoszeniowe, reputacja firmy, polityka marki, lojalność wobec marki, branża FMCG

Asif Mahmood ORCID ID: https://orcid.org/0000-0003-1416-0390
Department of Business Studies, Namal Institute,
30 KM Talagang Road,
Mianwali, Pakistan, **Pakistan**
e-mail: mahmood.engieer@gmail.com

Syed Zeeshan Haider
National University of Computer and Emerging Sciences Chiniot-Faisalabad
Punjab, **Pakistan**

LogForum

> Scientific Journal of Logistics <

2020, 16 (2), 299-310

http://doi.org/10.17270/J.LOG.2020.385

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

SHOPFLOOR MANAGEMENT (SFM) AS A TOOL FOR IMPROVING CONTROL OF PRODUCTION AND VISUALIZATION OF RESULTS

Maciej Ciszewski, Magdalena K. Wyrwicka

Poznan University of Technology, Poznań, **Poland**

ABSTRACT. **Background:** Due to the small number of scientific publications covering the area of implementation of Lean Management in small and medium companies, this paper presents the observation and analysis of obtained results, which could be the basis for the implementation of Shopfloor Management (SFM) as a tool for improving both the operational production control as well as the visualization of results in small and medium companies (SME).

Methods: The researches consist of the comparative analysis based on the scientific literature and the observation of effects of implementation of SFM method in selected company from the SME sector.

Results: The advantages of the implementation of SFM method were found in such areas as: simplification of organisational solutions, use of visual management and shaping the desirable competencies of leaders.

Conclusions: The presented results show that coordinated and constantly implemented Lean elements in the company from the SME sector, which previously did not use any tools of this concept, can give a significant increase of turnover, prompt eliminations of shortages as well as the change of the attitude of all employees to continuous improvement. The positive effects of Lean implementation, based on SFM method, were confirmed empirically.

Key words: effects of Lean implementation, production management, Lean Production, Shopfloor Management.

INTRODUCTION

Dynamically developing enterprises are currently facing several problems related to the coordination of the flow of goods and information in production departments. To keep up with the dynamically changing market environment, it is necessary to pay special attention to the effective management of the production process. There should be an area to reduce operation times, eliminate losses, increase efficiency and improve the quality of products. Opposing the expectations of directors and production managers, management methods derived from the lean philosophy come out.

The paper shows how individual areas of the enterprise have changed after the introduction of one of the methods supporting effective operational management of a production workshop, which is derived from the concept of Lean Management. Consistent use of Shopfloor Management techniques helps to make quick decisions, identify deviations in production results and effectively solve problems related to workshop management that appear in the production system. Present research [Alkhoraif, Rashid, McLaughlin 2019] demonstrates the lack of information and knowledge concerned with the implementation of Lean Production in SMEs, in comparison with implementation among LEs. This research aims to bridge this gap through both academic research writings referring to the implementation of lean tools and showing effects of implementation in Polish steel company described by several indicators. The aim of this study is to present

Citation: *Ciszewski M., Wyrwicka M.K., 2020. Shopfloor management (SFM) as a tool for improving control of production and visualization of results. LogForum 16 (2), 299-310, http://doi.org/10.17270/J.LOG.2020.385*

Received: 24.09.2019, Accepted: 03.03.2020, on-line: 30.03.2020.

the effects of the implementation of the above-mentioned Lean Production method in the area of control of the production department in the medium metal industry company. The benefits of simplifying the organization, the use of visual management and implementing the desired competencies of masters and leaders are presented. The analysis and assessment of the phenomenon were carried out in two ways: based on literature studies and the basis of participatory authors observation.

THE ESSENCE OF THE LEAN CONCEPT

The concept of Lean Management comes down to limit and avoid broadly understood waste. The literature presents many benefits of implementing lean tools. The most frequently mentioned include: increasing competitive ability, increasing the productivity of the company, reducing costs and improving the quality of production, increasing work efficiency, paying more attention to the needs and wishes of customers, growing employee satisfaction, stronger employee motivation and identifying with success of the enterprise. The most commonly used tools in Lean Management as logistics strategy include Value Stream Mapping, JIT, Open Book Management and others applicable in Lean approach for supply chains [Hadaś, Stachowiak, Cyplik, 2014]. Today, Lean Management is no longer limited only to production but enters into other areas of business activity and the sphere of services. New areas of application of this concept are: Lean Office, Lean Logistics, Lean Product Development, Lean Supply Chain, Lean Customer Service, Lean Accounting, Lean Administration, and Lean Healthcare [Trenkner 2016]. A special feature of the lean philosophy is to point the direction of improvements based on defining what is added value and what is a waste [Jasińska, Żurek, Wyrwicka 2015].

The concept of Lean enables entrepreneurs to develop and improve their market position. Contemporarily, the implementation of Lean Manufacturing is methodically elaborated under the assumption that waste elimination, which can be divided into nine categories (overproduction, motion, waiting, transportation, inventory, defects, over-processing, not-utilized talent and unsafe or unergonomic working conditions), can be guaranteed by the application of a few organizational techniques in a defined sequence [Wyrwicka 2009]. Among them, the mainly implemented include:

- Workplace organization – 5S – sort, set in order, shine, standardize and sustain
- Visualization of work and its results
- Standardization
- Complex maintenance – TPM (Total Productive Maintenance) – based on all employee involvement to identification, monitoring and eliminating wastes resulting from: breakdowns, equipment setup and adjustment, idling and minor stoppages, spills and process upset conditions or not satisfactory quality
- Fast refitting – SMED (Single Minute Exchange of Dies) – all methods focusing on reducing changeover and setup (it should be no longer than 10 minutes)
- Implementing quality in processes
- Continuous improvement.

In the area of production, the Lean Management philosophy is carried out as Lean Production. One of the features of Lean Production is the striving for failure-free production, and cleanliness and order are the basis for healthy processes [Cyplik, Hadaś 2013]. The philosophy of Lean Production from traditionally understood production distinguishes the implementation of continuous flow and unit production or in small batches. Another feature is the desire to radically reduce inventory and to engage the entire staff in processes improvement. Lean Production is derived from the industrial practices of Japanese Toyota, whose international expansion and excellent economic results have led to the spread of this idea in the US and Europe [Aluchna, Płoszajski 2008]. The success of the implementation of Toyota Production System (TPS) results from the fact that it was introduced from the beginning of establishment of the enterprise and put into practice consistently. It is claimed [Cusumano 1994] that at Toyota in the late 1980s, the output per worker was two to three times higher than at US or European plants. A critical foundation is a TPS culture of continuous improvement which relies on attracting, developing, and engaging outstanding people, solving problems at all organization levels, making management accountable to employees, workers to be devoted to the company, family, and society, having HR department as the arbitrators of fair and using a top-down and bottom-up planning process to enable everyone to be involved in achieving goals [Liker, Hoseus 2008]. Whilst being considered the industry standard for systematic productivity improvement, the success of Lean in a large variety of industries is tainted by many failed implementations [Pearce, Pons, Neitzert 2019]. Failures in the putting into practice processes of lean philosophy and practices in production environments are largely due to the inadequacy of theories derived from the TPS or a lack of understanding thereof. The TPS is a system whose functioning depends on a correct interrelationship between all its elements, not a partial application of its tools. Before its implementation can begin, it is thus necessary to establish a holistic vision, in order to accurately understand TPS concepts and principles [Cruz, Figueiredo, Passos 2019].

At the core of the concept of lean attitude lies the development of employees and the continuous improvement of production processes. The main characteristics of Lean Production are, among others, standardization of work, Just in Time deliveries, embedding quality into the process, one-piece flow or pull system. When it comes to the level of the physical production of goods with the characteristics desired by customers, we are talking about the concept of Lean Manufacturing. The main element of Lean Manufacturing is the immediate identification of errors and their immediate elimination.

Lean Production supports the process of exclusion of waste and allows to synchronize production in value streams with the help of pull system and tact time. The pull system is closely related to the customer relationship, both internal and external, and consists in the fact that it is necessary to produce exactly as much as the customer needs, on the date he/she ordered. This allows overproduction to be avoided and stocks that would otherwise occupy space and lose their quality with the passage of time are not created [Pawłowski, Trzcieliński 2010].

In order for the implementation of lean philosophy in each of the above-mentioned areas to be effective, it is necessary to acquire management skills that are referred to as 'lean thinking'. Successful transformation towards Lean Manufacturing should concentrate on two areas in parallel. Next to building technical stability of processes, it is also necessary to develop an in-house culture at the following levels: production leaders (foremen, managers) and managerial staff. The idea is to create an organizational culture in which employees demonstrate initiative to solve problems and improve their work and in which everyone will co-operate in order to provide value to the client and contribute to the continuous improvement of processes. Lean Production will not be maintained in an organization without employees that are involved, trained and oriented on continuous improvement [Balle 2012]. The implementation of Lean Production may meet struggles with the individuals in enterprises, who have poor personal habits, feeling of personal insecurity and bad perception of other coworkers and on the other hand, it can be the resistance from the organization itself [Wyrwicka 2016]. Research prove that the factors that significantly determine the effective implementation of Lean Management principles are possession of a permanent and competent managerial and executive staff [Niewiadomski, Pawlak, Tsimayeu, 2018].

Managers should give the right example, and through appropriate management techniques, support the employees' behaviors focused on continuous improvement. In recent years and decades, the managerial staff has usually moved away from production and focused in increasingly specialized organizational divisions. Shopfloor Management reverses this trend and leads management again in the place of added value growth. The manager should take the roles of a committed teacher who has the ability to use 'common sense' judgment. The manager must be able to estimate what assistance the employee actually needs and authorize him if possible to solve problems independently. A characteristic feature of this concept is learning the problem-solving methodology. The Genba Walk principle is applied here, which involves the necessity of approaching the site where the downtime occurs. The employee, being unable to solve the problem, asks the foreman to attend the workspace. If the supervisor (manager, superior, etc.) is not able to remedy the situation, a call to a higher manager is made, escalating the issue higher and higher up the organizational chart if required.

The main pillars of Lean Manufacturing philosophy in accordance with the above definitions are the economical use of resources, the constant elimination of all kinds of waste and the process of continuous improvement. Waste, in the dictionary of lean specialists, referred to in Japanese as muda, means carrying out works that consume resources, without adding any value to them. The muda includes, among others maintaining excessive stocks, overproduction, waiting, defective products or services, excessive processing, unnecessary movements in the production process and unnecessary transport [Rother, Shook 2009].

In addition to classic waste, contemporary literature mentions the untapped potential of employees and work without indicators as an additional two wastes. On the above grounds, a production department management tool called Shopfloor Management was built. The basics related to the universal methodology of managing current themes in the company have been presented in a book of a Japanese author Kiyoshi Suzaki 'The New Shop Floor Management'. This method puts the spatial organization of the production hall in the center of interest. The organization of flows in the workshop is to be an installation for the harmonious production of goods. Production should take place in the most effective, flexible and undisturbed way.

CONDITIONS FOR THE IMPLEMENTATION OF THE ELEMENTS OF LEAN PRODUCTION IN STEEL RBB

STEEL RBB is a Polish company from the SME sector with 60 years of experience in the metal industry. The main business profile is the processing and distribution of steel products. The company has been certified by PN-EN ISO 9001: 2015 Quality Management System and Environmental Management System. Additional information about the history of the company and portfolio can be found on the website https://steel-rbb.pl/pl/ and digital public relations channels. The company is managed by a director who manages three production departments: Production Preparation (DPP - 26 production workers), Mechanical Department (DPK - 34 employees) and Welding Department (DPS - 108 employees). Each department has its own production hall and office rooms for the manager, foremen and planners. All halls, warehouses, main office building and social buildings are located in one area.

The rapid development of the company from 2015 to 2018 brought problems in operational management at the production department. They mainly concerned delays in the execution of orders according to the production plan and late identification of faults. The laser cutting department focused on achieving its own goals and high quality of external customer service, at the expense of internal projects carried out in the company. To improve the functioning of the company, it was decided to divide it into three organizational sections responsible for: production preparation (lasers and saws), mechanical machining and welding (together with sandblasting, painting and packaging) respectively. However, this had not improved the flow of details and information between departments. There was no factor facilitating the integration of these three functional areas.

Analysis of the production situation by a team appointed by the Managing Director, including three managers, three production foremen and a consulting company showed that one should turn to management methods derived from the philosophy of Lean Production. Reference visits to contractors and other companies with a corresponding profile that implemented Lean Manufacturing convinced the management that STEEL RBB should implement the SFM method.

Table 1 summarizes the main areas of activity that required improvement and the desired target effects that were expected to be achieved through the implementation of effective department management (coordination of the three production departments).

Table 1. Reasons for implementation SFM in STEEL RBB

Pre-implementation analysis		
Reported undesirable effects	**Symptoms**	**Objectives**
complaints about not meeting the deadline,	lowering the profitability of production	punctuality of shipments at the level of 95%
problems with coordination of the flow of details between departments,	accumulation or shortages in the storage areas, delays in processing orders,	improvement of production results after intervention and balanced flow of details through the production hall,
		early identification of faults
late identification of faults,	small number of internal complaints	getting dedicated access to information about a situation in the company and the ability to react within 24 hours,
unreliable production data in the ERP system,	wrong plans and production routes	ensuring effective communication about production results, arising problems or expected decisions,

Source: own work

Conditions collected in table 1 showed that operational management was burdened with many errors in the area of work and information flow. The lack of a coordinated method of controlling and a transparent system of presenting outcomes resulted in delaying the execution of orders and dispelling responsibility for the occurrence of deficiencies. Expectations for the implemented system have shown the benefits of employing the SFM method. An additional goal was to raise the competence of production foremen to learn about modern control techniques, and thus became the leaders in the implementation of the concept of continuous improvement.

It should be noted that the implementation of SFM tools was not an isolated project. At the same time, the 5S concept, as well as elements of the Kaizen method were implemented for office and production positions of the company. At STEEL RBB, it was called ‘a good idea’ and involved setting up a team that assessed, rewarded and led to the implementation of the best improvements proposed by the employees and submitted through so-called ‘good idea’ boxes. All these methods were introduced at the same time, and the aim was to support mutual improvement activities and gain synergy effects. Among other things, an SFM meeting discussed the level of incoming reports of ‘good ideas’, and during the review of the correctness of the SFM method, a 5S audit is also conducted at production sites.

MAIN OBJECTIVES AND COMPONENTS OF SFM METHOD

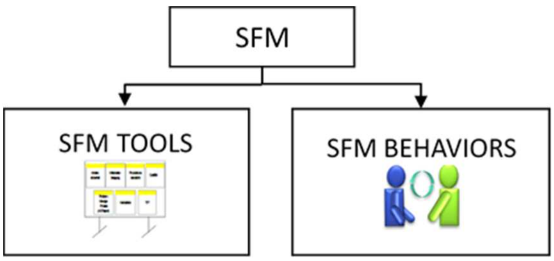
The main goal of Shopfloor Management is to work out the principles of verifying and presenting production results to merge the efforts and initiative of the production units with production supervision and together seek to eliminate errors and improve the efficiency of the process. According to the assumptions of the author of the method [Suzaki 2010], SFM should focus on real objects:

– Genba (real place) - SFM's preferred place is the production hall where the products are created,
– Genbutsu (real information) - true information on all problems encountered,

– Genjitsu (facts) - information should be based on objective and real facts, not on subjective judgment.

SFM task is to solve current problems by eliminating process errors, determining proper communication within the organization and through continuous improvement [Suzaki 2010]. SFM belongs to the methods of visual management. The most common form of SFM for production processes is the daily reporting of results from the previous day at the scoreboards. All problems that have arisen and caused the failure to keep the plan must be discussed. Then, it is necessary to implement corrective actions or escalation to a higher level if a complicated problem arises.

SFM is based on two pillars (Figure 1). The tools (technical elements of visual management with a system of procedures) and proper behaviors of leaders (employees focused on eliminating waste and errors) are needed.



Source: Suzaki 2010

Fig. 1. Elements of SFM

Table 2 contains the main components of individual SFM elements. The role of management is to determine what data and areas will be discussed at meetings, as well as to create a positive culture of information management and issues discussed during the SFM review.

Table 2. Elements of SFM

SFM Tools:
– production diary, – indicators (performance, absences, punctuality and shortages are presented in various graphical forms), – escalation criteria, – table of continuous improvement.
SFM Behaviors - the role and characteristics of the leader:
– leaders use the right questioning techniques, – do not blame employees, – summarize briefly, – form an objective picture of the situation, – actively listen to employees, give and receive feedback and recognize waste in processes

A production diary is a key tool determining the type, rank, and schedule of meetings within the SFM method. An exemplary excerpt of the agenda used in STEEL RBB is shown in Figure 2. It contains a meeting schedule and a list of people who should participate in them. There is also a list of employees who are invited for an optional review if necessary, e.g. technical director at a time when a failure is discovered. The general rule is to designate a replacement if one cannot participate. Table 3 contains a ranking description of the meetings. The link between the meetings is the escalation procedure, which determines what problems should be solved on the first level SFM and what should be left for consideration on the second level SFM.

SFM meetings prove highly efficient in transferring key information in the shortest possible time. The participants are required to be punctual and well-prepared for the discussion about deviations from the standard/pattern, as well as to comply with a moderator and giving feedback each time.

Table 3. SFM meetings hierarchy

SFM meetings	
0 degree	daily review of the department by the master of production, gathering information about downtime, breakdowns, failures or accidents
I degree	daily meetings in each department at the SFM table and discussing all tasks in accordance with the agenda
II degree	meeting of managers and directors of each department, once a week, setting tasks for 14 days, solving problems escalated from the first degree meeting

Time	**Thursday**	Who	**Friday**	Who	Level	Frequency
5:55-6:10 13:55-14:10 21:55-22:10	Shift inspection	Foreman/Worker	Shift inspection	Foreman/Worker	SFM - 0	Daily meetings (working Saturdays and Sundays too)
8:15-8:24	Shopfloor Meeting - laser cutting	Foreman, PP, DP, DL, MA, DT*, DJ*, DK*, DI*	Shopfloor Meeting - laser cutting	Foreman, PP, DP, DL, MA, DT*, DJ*, DK*, DI*	SFM - I	
8:24-:8:29	Walk and see	Foreman, PP, DP, DL, MA, DT*, DJ*, DK*, DI*	Walk and see	Foreman, PP, DP, DL, MA, DT*, DJ*, DK*, DI*		
8:30-8:39	Shopfloor Meeting - machining	Foreman, PK, DP, DL, DT*, DJ*, DK*, DI*	Shopfloor Meeting - machining	Foreman, PK, DP, DL, DT*, DJ*, DK*, DI*		
8:39-8:44	Walk and see	Foreman, PK, DP, DL, DT*, DJ*, DK*, DI*	Walk and see	Foreman, PK, DP, DL, DT*, DJ*, DK*, DI*		
8:45-8:54	Shopfloor Meeting - w elding	Foremen, PS, DP, DL, DT*, DJ*, DK*, DI*	Shopfloor Meeting - w elding	Foremen, PS, DP, DL, DT*, DJ*, DK*, DI*		
8:54-8:59	Walk and see	Foremen, PS, DP, DL, DT*, DJ*, DK*, DI*	Walk and see	Foremen, PS, DP, DL, DT*, DJ*, DK*, DI*		
9:00-9:30	Production meeting	DP, D, PP, PK, PS, DH, DZ, DK, DL			SFM - II	Weekly meetings
12:00-12:20	Weekly meeting w ith General Manager	D, DZ	Weekly meeting w ith General Manager	D, DK		
12:30-13:30			'Good idea' meeting	D, DJ, DT		

D - General Manager	DP - Planning Manager	DL - Logistics Specialist	DK - Designer
PP - Production Preparation Chief	MA - Warehouse Master	DT - Technical Manager	DI - IT Specialist
PK - Machining Department Chief	DJ - Quality Manager	DZ - Purchase Manager	
PS - Welding Department Chief	DH - Key Account Manager	* - presence on request	

Source: own work based on implementation in STEEL RBB

Fig. 2. Production diary – excerpt

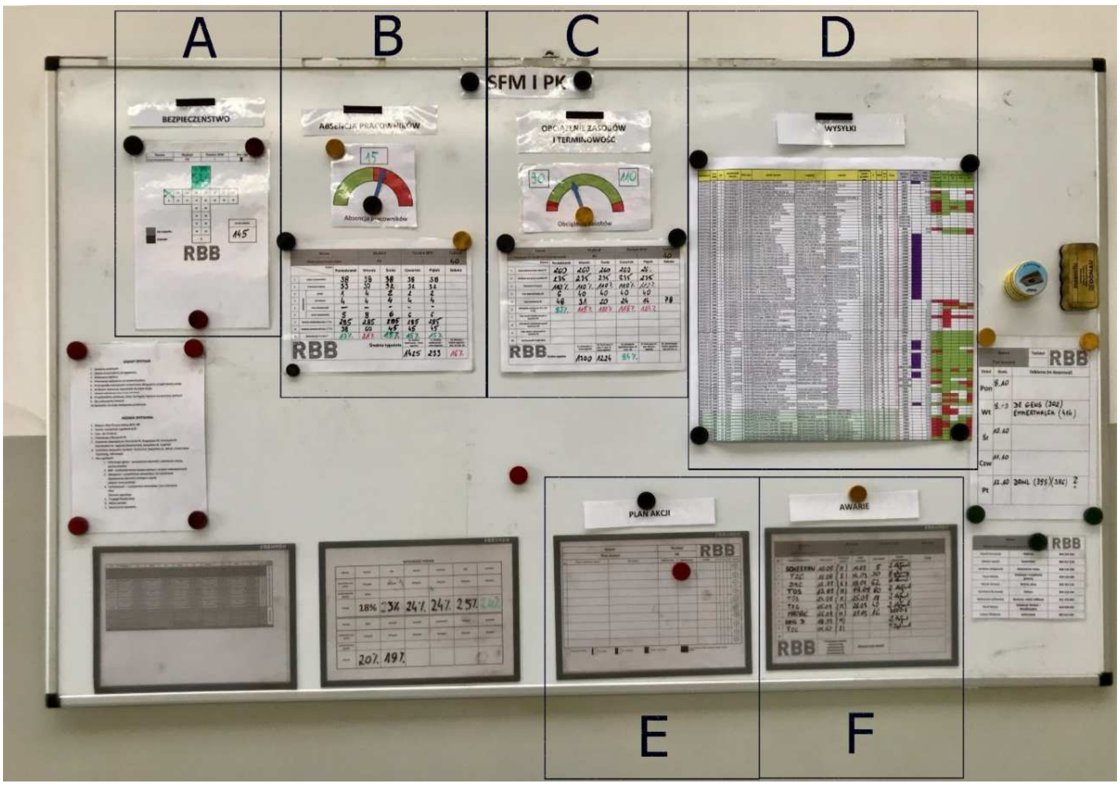
This distribution of meetings allows the moderator (master, leader, director) to efficiently discuss the results and hear reports from a group of 8-15 people in about 30 minutes. Each meeting is equally important and determines the possibility of holding a higher-level meeting. Summits form a coherent stream of information and decisions in both directions. The principles of cooperation are defined in the production diary.

An example of the first degree SFM board at the machining department at STEEL RBB is shown in Figure 3. According to the agenda posted on the board, the following areas and data are discussed:

- safety (safety cross - whether accidents or potentially dangerous events occurred) - area A,
- absence of employees (checking if the absenteeism rate is within the assumed range) - area B,
- resource usage and timeliness (ratio of the planned amount of hours to available resources) - area C,
- shipment (progress of individual orders and discussion of critical threats of deadlines - attention is focused on discussions about problems that have occurred in production and could potentially lead to failure to achieve the goal, the actions taken and their status) - area D,
- action plans (tasks to be completed in more than 24 hours, planned by the PDCA principle, progress checked daily) - area E,
- failures (an overview of the progress of repairs broken machines and devices) - area F.

The above-mentioned elements described in the table constitute a permanent agenda for each meeting and require each time to be discussed. The review of SFM ends with a discussion of problems that the master of production was unable to solve by himself during the inspection of the department and the collection of data. This is done in accordance with the 'Gemba Walk - go, see and react' principle. It involves direct assessment of the situation by the manager in the place where the problem occurred. Thanks to this, he gains an opinion about the situation and supports the team in solving the problem.

However, the system of tables and indicators alone will not optimize any area of the enterprise without changing the attitude of employees, their way of thinking and acting, and promoting active and continuous involvement in the improvement of the enterprise [Nowosielski 2015]. It is advisable to choose leaders who have a good reputation, decision-making power, information, expertise, and interpersonal relationships to ensure a smooth change [Yang, Yu 2010]. Manager's role in lean implementation is the main factor of success and emphasize the necessity of developing lean knowledge. Root-cause of lean success may be simply leadership knowledge and therefore specifically the attitude and commitment of leadership to learning. The enlarged understanding became the wisdom for successfully implementing change. The organizational challenges necessitated particular skillfulness in the application of organizational leadership as well as the lean techniques. This includes how to form the vision for change and present that to others, educating them and motivating them to take steps towards its goal [Pearce, Pons, Neitzert 2018]. Therefore, it is crucial to develop a pattern of desired behaviors, especially for foremen and production managers. As in the case of SFM tools (data, indicators, procedures), and in the case of shaping the proper SFM behaviors, the greatest responsibility lies with the managers. The company's management is obliged to personally become involved in the implementation of the lean idea. The master learns good practice from the manager and then passes it on to the employee. Desirable characteristics of direct production supervisors and leaders are included in table 2. Training of staff should be carried out according to the principle of continuous improvement.



Source: own study

Fig. 3. Appearance and components of the SFM table

It should be noted that the implementation of a system that redefines the structure and management of the production department causes a natural objection of part of the crew and does not always gain full management approval. Employees see additional control measures and unnecessary bureaucracy in SFM methods [Peters 2009]. On the other hand, managers perceive them solely as operational tools of visual operational control. The SFM method has a much wider range and long-term measurable effects that improve the functioning of the entire production department.

One year after the implementation of SFM in the company, it can be determined that the main expectations assumed have been met. The measurable effect is an increase in the company's turnover by 14% compared to the previous year. Higher timeliness of shipments for the main customer (up to 92%) contributed to the receipt of new orders for more advanced and profitable details (smaller share of welding and a larger of machining). Besides, lowering the rate of complaints regarding untimely deliveries, improving the efficiency of work and more than a dozen implemented projects submitted under the 'good idea' program. In the analyzed period, no investment projects were carried out, meaning that the increase in turnover was related to improving the organization of production and increasing the efficiency of the work of the staff. Positive changes occurred in the area of quality assurance. There was a decrease (by 3% compared to the previous year) of registered complaints from external customers. At the same time, the Quality Department monitored the continuous increase in internal claims. This shows that the effectiveness of error detection has been improved, and thus the costs of complaints are reduced. There has been a break in the growing trend of the share of defective products in relation to the volume of production. Since the implementation of the SFM method, the failure rate has decreased from 2.1% to 1.2%.

Taking into account the expectations specified before the introduction of the method, the remaining positive effects include:

- improving the flow of information, goods and obtaining easy transparent monitoring of results (incorrect or disturbing data are immediately identified),
- the possibility of reacting to any undesirable or contentious event by the next morning at the latest,
- increased operational efficiency due to management standardization,
- the ability to quickly make decisions and resolve disputes,
- limiting the occurrence of errors at work,
- stimulating the bottom-up initiative of employees under the 'good idea' program,
- positive impact on the company's income.

The success of implementation should be considered as a synergy effect of several components. At the same time, the 5S rules were implemented in all production departments and offices. Also, instruments and measures were prepared according to the Poka-Yoke tools to eliminate the possibility of making mistakes at the production sites. But all of them belong to Lean Production techniques and often play a supportive role.

However, the implementation was not without undesirable events. Especially in the initial period, there were many negative emotions among production workers. They perceived change as introducing strange-sounding practices that did not match the Polish reality of work. In the first contact they treated SFM as a form of controlling and verifying the work done and pointing mistakes. At this point, the management failed to prepare the right attitude of the organization. The manager's role in Lean is to be supportive and challenge the people they manage to develop this philosophy. It results from the fact that the constant transformation of the company is not possible without respect for people. It seems common in practice that the "respect for people" principle is misunderstood or neglected, which is often called an obstacle to Lean [Mrugalska, Ahram 2016]. The analysis of theoretical and empirical research on lean implementation allowed including negative staff attitudes, resistance to change, poor communication, lack of management support, and commitment to main inhibitors in lean implementation [Wyrwicka 2016].

Another problem for the implementation team was the initiation of the project from the Welding Department, which was the last one in the production chain and which was responsible for preparing shipments to the customer. The pre-implementation analysis showed that the department was the one most affected by incompatibility and timing issues. It turned out, however, that these were errors inherited from previous links in the production process. Only improvements in the area of production preparation (laser and cutting) became the flywheel of positive changes in the whole enterprise.

CONCLUSIONS

It should be noted that SFM as a component of the Lean Production philosophy is the basis for continuous improvement. The auditing system helps to control the correctness of SFM meetings and correct inconsistencies on an ongoing basis. The 'good idea' program introduced during the implementation of SFM (boxes for submission of improvement forms by the employees) stimulated the bottom-up initiative and creativity of the entire crew. In 2019, actions were initiated to change the analog boards to digital interactive displays that will present the results of the ERP system in real-time.

Like any empirical study, this research has limitations. By being based on a single case, it is not possible to generalize results, and the external validity is small. However, it was found relatively strong evidence that the Lean Production implementation had positive impacts on the operational performance of the company. It is noticeable that the level of integration of lean tools in SMEs is quite low [Alkhoraif, Rashid, McLaughlin 2019] and that even knowledge of it is poor also [Achanga, Shehab, Roy, Nelder 2006]. There are many reasons for this have been identified. Although there have been studies based on the general implementation of Lean Production the majority of the research has concentrated on large enterprises and has omitted SMEs. This discrepancy is significant and deserves rectification. Most of Lean research up until now has focused on the Western countries and have largely ignored developing countries such as Middle-East Europe and Asia. Suitable aspects of research based on this could include comparative case studies of SMEs implementing Lean Production in developed versus developing countries to determine the application of lean tools in SMEs in developing economies. [Alkhoraif, Rashid, McLaughlin 2019].

This paper contributes to showing how full, isolated implementation of one of the Lean Production methods allows to break long-term trends and improve the production process in SME company. The analysis of the results concerned turnover, deficiency indicator and implementation of continuous improvement. The additional advantage is identifying the importance of the leadership in the success of lean endeavors and showing how improving control of production and visualization of results is critical, and especially so in resource-constrained organizations, like SMEs. References to similar research results confirm the key role of shaping the right behaviors and attitude of managers to Lean Production. If leaders do not truly understand how to gain the benefits of Lean and an existing operational culture that opposed lean principles is not changed implementation cannot achieve total success. Another advantage of the article is its adaptive value. The described enterprise is one of several SME suppliers of components for the automotive industry and household appliances located in Poland. Most of these companies have evolved from small businesses created during the economic boom of the early 21st century, and many of them still do not use modern workshop control tools based on lean philosophy. Obtained information and conclusions may be valuable for them. For SMEs implementing Lean, on the positive side, they typically have a flat structure and simple systems, which promote flexibility to change and dissemination of knowledge. On the negative side, there are limited resources, including capital and staff capabilities. A typical SME may have only a few key employees and as their skills develop staff retention can be problematic.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

Poznan University of Technology 11/142/SBAD/100.

REFERENCES

Achanga P., Shehab E., Roy R., Nelder G., 2006. Critical success factors for lean implementation within SMEs, Journal of Manufacturing Technology Management; 17(4):460–71, http://doi.org/10.1108/17410380610662889

Alkhoraif A., Rashid H., McLaughlin P., 2019. Lean implementation in small and medium enterprises: Literature review, Operations Research Perspectives 6, 2019, 100089, http://doi.org/10.1016/j.orp.2018.100089.

Aluchna M., Płoszajski P. (red.), 2008. Zarządzanie japońskie: ciągłość i zmiana [Japanese management. Continuity and change], Warsaw School of Economics.

Balle M., Balle F. 2012. Company director as Lean Manager. A novel about enterprise transformation.

Cruz R., Figueiredo P., Passos F., Cruz Souza E., 2019. Operational impacts of lean manufacturing: the case of a consumer goods industrial company, GEPROS: Gestão da Produção, Operações e Sistemas, http://doi.org/10.15675/gepros.v14i4.2362.

Cusumano M. A., 1994. The limits of lean. Sloan Management Review 1994;35:27–32.

Cyplik P., Hadaś Ł., 2013. Theory of constrains and Lean Production: idea, tools, practice of application, Poznań University of Technology Publishing House.

Jasińska S., Żurek M., Wyrwicka M.K., 2015. Analiza efektywności wdrożenia Lean Manufacturing. Studium przypadku [Analysis of the effectiveness of Lean Manufacturing implementation. Case study], Economics and Management, 7, 1, http://doi.org/10.12846/j.em.2015.01.19.

Liker J, Hoseus M., 2008. M. Toyota culture: the heart and soul of the Toyota way. New York: McGraw-Hill.

Mrugalska B., Ahram T., 2016. Managing variations in process control: an overview of sources and degradation methods. In: Soares M, Falcao C, Ahram T, editors. Advances in Ergonomics Modeling, Usability and Special Populations. Advances in Intelligent Systems and Computing,486:377–387, http://doi.org/10.1007/978-3-319-41685-4_34

Niewiadomski P., Pawlak N, Tsimayeu A., 2018. Barriers to effective implementation of lean management principles - empirical exemplification in the industry of agricultural machinery, Logforum 14.4, 10. http://doi.org/10.17270/J.LOG.2018.308.

Nowosielski S., 2015. The concept of Lean Management in a small enterprise. Possibilities and restrictions of application [in:] J. Lichtarski, ed., The practical dimension of the achievements of management sciences. Science for economic and local government practice, [in Polish] Volume XVI, Notebook 3, SAN Publishing House.

Pawłowski E., Pawłowski K., Trzcieliński S., 2010. Metody i narzędzia. Lean Manufacturing. Materiały dydaktyczne. [Lean Manufacturing methods and tools]. Poznan University of Technology.

Pearce A., Pons D., Neitzert T., 2018. Implementing lean-Outcomes from SME case studies, Operations Research Perspectives 5 (2018) 94–104; http://doi.org/10.1016/j.orp.2018.02.002.

Pearce A., Pons D., Neitzert T., 2019. Operations Research Perspectives 6 (2019) 100114, http://doi.org/10.1016/j.orp.2019.100114.

Pekarčíková M., Trebuňa P., Kliment M., 2019. Digitalization effects on the usability of lean tools, Acta Logistica. 2019;6(1):9-13 http://doi.org/10.22306/al.v6i1.112.

Peters R., 2009. Shopfloor Management, Log_X Verlag, Ludwigsburg.

Rother M., Shook J., 2009. Learn to see, Lean Enterprise Institute Polska.

Suzaki K., 2010. New Shop Floor Management: Empowering People for Continuous Improvement, Free Press.

Trenkner M., 2016. The role and tasks of managers in implementing the concept of Lean Management - social aspects. Entrepreneurship and Management XVII, 4, I, SAN Publishing House.

Wielki J., Kozioł P., 2018. The analysis of opportunities to use the lean it concept in modern enterprise. Polish Journal of Management Studies 2018; 18 (2): 388-401, http://doi.org/10.17512/pjms.2018.18.2.31.

Wyrwicka M. K., ed., 2009. Marnotrawstwo. Przejawy i sposoby minimalizacji [Wastes. Symptoms and ways of elimination], Poznan: Publishing House of Poznan University of Technology.

Wyrwicka M. K., Mrugalska B., 2016. Mirages of Lean Manufacturing in Practice, Procedia Engineering 182 (2017) 780 – 785, http://doi.org/10.1016/j.proeng.2017.03.200

Yang P, Yu Y., 2010. The barriers to SMEs' implementation of lean production and countermeasures – based on SMEsin Wenzhou. International Journal of Innovation, Management and Technology; 1(2):220–225.

SHOPFLOOR MANAGEMENT (SFM) JAKO NARZĘDZIE USPRAWNIAJĄCE STEROWANIE PRODUKCJĄ I WIZUALIZACJĘ WYNIKÓW

STRESZCZENIE. **Wstęp:** Ze względu na stosunkowo małą liczbę prac naukowych dotyczących implementacji narzędzi szczupłego zarządzania w małych i średnich przedsiębiorstwach (MŚP) niniejszy artykuł prezentuje obserwacje i analizę otrzymanych wyników, które mogą stanowić podstawę do implementacji metody Shopfloor Management (SFM) jako narzędzia ułatwiającego zarówno operacyjną kontrolę produkcji, jak i wizualne zarządzanie wynikami w firmach z sektora MŚP.

Metody: Badania zostały przeprowadzone dwutorowo: w oparciu o analizę porównawczą, bazującą na studium literatury źródłowej i obserwacje efektów zastosowania metody SFM w wybranym przedsiębiorstwie z sektora MŚP.

Wyniki: Stwierdzono korzyści uzyskane w efekcie wdrożenia metody SFM w postaci uproszczenia rozwiązań organizacyjnych, zastosowania zarządzania wizualnego i kształtowania pożądanych kompetencji liderów.

Wnioski: Prezentowane badanie pokazuje, że skoordynowane i konsekwentne wdrażanie elementów Lean w przedsiębiorstwie należącym do kategorii MŚP, które wcześniej nie korzystało z żadnych narzędzi tej koncepcji, może dać wyraźną poprawę w zakresie wzrostu obrotów, wczesnego wykrywania i eliminacji braków, a także jako zmiana nastawienia całej załogi w kierunku ciągłego doskonalenia. Pozytywne skutki wdrożenia Lean, w oparciu o metodę SFM zostały potwierdzone empirycznie.

Słowa kluczowe: efekty wdrożenia Lean, zarządzanie produkcją, Lean Production, Shopfloor Management

Maciej Ciszewski ORCID ID: https://orcid.org/0000-0002-9963-6759
Poznan University of Technology
Faculty of Engineering Management
ul. Strzelecka 11, 60-965 Poznan, **Poland**
e-mail: maciej.j.ciszewski@doctorate.put.poznan.pl

Magdalena K. Wyrwicka ORCID ID: https://orcid.org/0000-0002-9513-7354
Poznan University of Technology
Faculty of Engineering Management
ul. Strzelecka 11, 60-965 Poznan, **Poland**
e-mail: magdalena.wyrwicka@put.poznan.pl

LogForum
> Scientific Journal of Logistics <
2020, 16 (2), 311-321
http://doi.org/10.17270/J.LOG.2020.411
http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

TRUCK PLATOONING IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT'S TARGETS DEFINED IN EUROPEAN UNION'S STRATEGIES

Mateusz Pająk[1], Piotr Cyplik[2]

1) Poznan School of Logistics, Poznań, **Poland,** 2) Poznań University of Technology, Poznan, **Poland**

ABSTRACT. **Background:** Consequence of growing consumer market is grow of transportation and logistics sector estimated in Europe at 42% by 2050. Therefore innovations in transportation have recently become one of key focus areas for enterprises' supply chains and for authorities. Challenge is not only how to meet market expectations but also how to achieve this in line with sustainable development's principles. The aim of the paper is to resolve the research problem regarding the magnitude of contribution of truck platooning to the sustainable development in the context of selected European Union's strategies.

Methods: Based on literature review, author attempted to add value by this publication by establishing the connection between truck platooning and sustainable development's targets defined in European Union's strategies.

Results: Author was able to identify strengths and weaknesses of truck platooning in the context of sustainable development criteria: economical in terms of generating efficiencies for transport industry thanks to fuel reduction, ecological in terms of contributing to lower CO_2 emission and social in terms of giving the possibility of transforming the job of a truck driver as well as increasing the safety on the roads.

Conclusions: Conducted research indicates that the thesis that truck platooning fits in with the European Union's strategies as one of the elements supporting sustainable development has been partially confirmed and partially denied. Truck platooning may support sustainable development's targets, however due to its limitations the magnitude of its contribution is not significant.

Key words: truck platooning, sustainable development.

INTRODUCTION

Growing consumer market and constant pressure to shorten the lead times of deliveries up to next-day or even same-day-deliveries is a challenge for transportation and logistics. Free delivery and free return offers lead to increase of transported volume. On one hand freight sector in Europe is estimated to grow by 42% by 2050. On the other hand European Commission targets to decrease carbon emission by 60% by 2050 [Boysen et al. 2018]. Road transport represents ¾ of all goods transported in Europe and is estimated to continue to grow. Result of that growth is increasing pollution, congestion on the roads, higher risk of road accidents. On top of that comes shortage of drivers, as well as high fuel costs which became 1/3 of operational cost of an average fleet operator [Krüger et al. 2018].

Correlation between development of economy and environment has been identified already in 1960s. The more economy develops, the more concerns about the negative impact of human activity on environment. That requires looking for new solutions which would not only help the business to be more efficient but which would also take care of environment. Increasing demand for transport shall not be in correlation with increasing CO_2 emission,

Citation: Pająk M., Cyplik P., 2020. Truck platooning in the context of sustainable development's targets defined in European Union's strategies. LogForum 16 (2), 311-321, http://doi.org/10.17270/J.LOG.2020.411
Received: 12.11.2019, Accepted: 05.03.2020, on-line: 30.03.2020.

congestion and number of accidents any more. The opportunity lays with increasing transport efficiency. Challenge is however not only how to meet high market expectations but also how to do this in line with sustainable development's principles. That is why transportation is one of the areas where diverse innovations take place. One of such innovations is truck platooning.

Truck platooning fits in with the European Union's strategies as one of the elements supporting sustainable development. The aim of the paper is to resolve the research problem regarding the magnitude of contribution of truck platooning to the sustainable development in the context of selected European Union's strategies.

THE ROLE OF SUSTAINABLE DEVELOPMENT

The origin of sustainability comes from Brundtland's report "Our Common Future" from 1987. In its point 30th it was said that sustainable development is a process of changes which take into consideration not only present but also future needs. Sustainable development means that needs of the present shall be met by growth of economy but without compromising the ability of future generations to meet their needs too [Chin et al. 2015]. As noticed by Pichlak [2017], the definition was not very detailed and left room for interpretation. Despite that, it was acknowledged by United Nations in 1992, set the direction and widespread in literature since.

Sustainable development shall not be understood as pure eco-development as eco-development focuses only on ecologic. After [Kumar 2017], [Chin et al. 2015] there are three main criteria of sustainable development: economical, ecological (also called environmental) and social. Purol [2014] defines those areas as follow:

1. Economical criteria are about research and development supporting economic growth.
2. Ecological criteria are renewable resources coming from natural ecosystem and pollution prevention.
3. Social criteria are improvement of living conditions.

Advantage of sustainability is not only positive impact on those areas but also the fact of being a driver of innovative thinking leading to improving efficiency, cost and risk reduction as well as identification of new products and services [Purol 2014]. In the area of transportation there have been several innovations aiming to make transport more sustainable, one of which is Truck Platooning.

TECHNOLOGY OF TRUCK PLATOONING

Platooning or platoons has its origin in military and means a unit composed of 2 or more trucks that travel in a reduced distance between them, connected using wireless Vehicle-to-Vehicle (V2V) communication. Platooning is also called electronic drawbar and means automatic following of one or more conventional vehicles at reduced distance in a shape of a convoy. Driver of the first (leading) vehicle controls direction and the speed of the vehicles behind him (following vehicles) [Wang et al. 2019].

First platooning attempts were based on adaptive cruise control systems (ACC). Leading vehicle was suppose to maintain the constant speed and the following vehicles were suppose to maintain same distance behind the vehicle in front of them. It turned out very quickly not to be an efficient way of generating fuel savings due to changing road topography. In order to avoid excessive acceleration while uphill climbing and sharp breaking on the downhill descents, more sophisticated systems are used now which enable the following vehicles to vary the speed and to keep a range of required distance at the same time [Torabi et al. 2018]. Those systems are data exchange based solutions which enable communication between the vehicles as well as between the platoon and the back office coordinating the movements of the platoon [Bergenhem et al. 2013].

In a platooning the driver of the lead vehicle is fully engaged in the driving tasks, gives the direction to the platooned vehicles, accelerates, breaks, changes the lanes. The others vehicles follow him automatically, keeping short distance which occurs without a need for their drivers for doing those maneuvers themselves. That means that trucks following the leading truck do require drivers too but the technology enables them to be partially engaged also in other activities besides driving. Today's technology, however, is not advanced the way that human driver could be replaced by the software in any possible traffic situation. The software is not capable of all maneuvers which may be needed on the road. For this reason, conditions of the permits for platooning tests on selected motorways not only require a driver to be present in each of the following trucks but to even have constantly hands on the steering wheel in order to take over control over the vehicle whenever required and alerted by the system. Requirement for the driver in each vehicle is a reason for platooning to be classified as level 3 automation in scale of automation standardized by Society of Automotive Engineers (SAE), US-based global standards developing organization for automotive industry. Level 3 means conditional automation which still requires presence of a human driver but allows the system to perform all aspects of driving such as lane change, turning or using signals. Human driver is on stand-by mode to intervene whenever required [Wang et al., 2019].

MAIN EUROPEAN UNION'S STRATEGIES TARGETING SUSTAINABLE DEVELOPMENT

Sustainable development is vital target for European Union and is reflected in its strategies since the Sustainable Development Strategies from 2001. The direction Europe has taken is to invest in innovations in order to create sustainable economy based on efficient usage of resources [Wysokinska 2018]. The catalogue of targets aligned on United Nations level has been incorporated into European strategies. At first, in year 2000, European Union committed to achieve Millennium Development Goals (MDGs) by 2015. Afterwards, in year 2015, United Nations General Assembly set a catalogue of 17 Sustainable Development Goals to be achieved by 2030 which became basis for European Union's development programs too. Out of 17 Sustainable Development Goals, the following ones are in particular relevant for the Truck Platooning according to the author of this paper:

- Goal 3: Good health and well-being
- Goal 8: Decent work and economic growth
- Goal 9: Industry innovation and infrastructure
- Goal 13: Climate action

Europe 2020 is the current strategy valid till 2020. The years 2021-2027 will be covered by follow up program called Horizon Europe. In both of them focus is on and large portion of budget is dedicated for achieving targets of sustainable development. Ultimately European Union has set a target for 2050 called Climate-neutral Europe.

In Europe 2020, established by European Commission in 2010 as a follow up of Lisbon Strategy 2000-2010, and dedicated to "smart, sustainable, inclusive growth", European Union set main goals as follow: smart growth (based on knowledge and innovation), sustainable growth (more resource efficient economy) and inclusive growth. The targets are to increase employment rate, invest more in research and development and to meet so called 20/20/20 climate targets. Those climate targets mean to reduce greenhouse emission by 20% (in comparison to 1990 level), increase share of renewable energy sources by 20% and increase energy efficiency by 20%. This program itself, likewise Lisbon strategy, was a vision of European Commission of where Europe should put its priorities in order to adopt to economical and environmental changes faced at the beginning of new century, in particular in the time of global economic slowdown started in 2018.

Horizon Europe is a European Commission's document from April 2019 and is meant to cover years 2021-2027. Budget is believed to be increased again in comparison to the previous strategies and is estimated to be defined at 94 billions of Euros, 35% of which is meant to be spent for tacking climate change. The other focus areas are supporting achieving sustainable development goals and growth of European Union. Already in its opening sentence, proposal of Horizon Europe draws attention to research and innovation on the economical, ecological and social areas which are the principles of sustainable development. One of its five core missions is called "climate-neutral and smart cities" which covers such areas like CO_2 reduction and mobility solutions – both fully in line with core functions of platooning. At the end of 2019, document is still in the draft version and continues to follow its alignment process.

In November 2018 European Commission issued a long-term vision document called "A clean planet for all". It foresees achieving zero greenhouse emissions in Europe by 2050. It follows the direction taken by targets set for 2030. That document of European Commission treats about clean, safe and connected mobility. It underlines usage of low and zero emission vehicles, more efficient batteries, and autonomous driving which would not only lead to cleaner environment but it would also enable noise and road accident reduction. This is believed to improve the quality of life of European citizens.

TRUCK PLATOONING AS AN ELEMENT SUPPORTING SUSTAINABLE DEVELOPMENT IN EUROPEAN UNION'S STRATEGIES

Author of this paper has examined sustainable development targets in the context of truck platooning to determine interdependencies between them. The result is that truck platooning may support sustainable development in the following areas:

1. Economical
   - Fuel saving
   - Labor cost reduction
2. Ecological
   - CO_2 reduction
3. Social
   - Change of truck driver job
   - Congestion reduction on the roads
   - Increase of safety level on the roads

Below Table 1 provides an overview on selected European strategies in the context of sustainable development where truck platooning may be a supportive element.

Table 1. Overview on selected European strategies in the context of sustainable development where truck platooning may be a supportive element

Sustainable development's aspects		**European Union's strategies**			**Worldwide context**
		Europe 2020 (2010-2020)	Horizon Europe (2021-2027)	Climate-neutral Europe 2050	Sustainable Development Goals (SDGs) of United Nations
Economical	Fuel saving	Resource efficient economy	Pilar 1: Excellent Science	No usage of fossil fuel	Goal 9: Industry innovation and infrastructure
	Labor costs reduction	fostering a high-employment economy delivering social and territorial cohesion.	Pilar 3: Innovative Europe	People well being	Goal 8: Decent work and economic growth
Ecological	CO_2 reduction	"Resource efficient Europe" to help decouple economic growth from the use of resources, low carbon economy, use of renewable energy sources, energy efficiency	Pilar 2: Climate, Energy and Mobility	Zero emission mobility	Goal 13: Climate action
Social	Change of truck driver job	"An Agenda for new skills and jobs" Europe 2020	Pilar 3: Innovative Europe	People well being	Goal 8: Decent work and economic growth
	Less congestion on the roads	"Resource efficient Europe" to modernise transport sector	Pilar 2: Health	Connected mobility	Goal 3: Good health and well-being
	More safety on the roads	Intelligent traffic management	*Pilar 2: Health*	*Safe mobility*	*Goal 3: Good health and well-being*

Economical aspect

Fuel reduction

Trucks in a platoon have proven to achieve fuel saving thanks to lower air resistance which is also called slipstream driving while moving in shorter distance between each other [Wang et al. 2019]. Lower full consumption was identified not only in the following but also in the leading vehicle. Depending on the tests, fuel saving varies from 4 to 15% per vehicle [Słowik et al. 2018]. Higher efficiency could be achieved thanks to implementation of local controllers to facilitate formation process of multi brand platoons means platoons built out of the vehicles of different fleet operators. Such platoons are more likely to happen than single brand platoons, however costs of local operators have to be considered in the overall calculation [Larson et al. 2013].

Real saving potential from driving in a platoon depends, however, on several factors such as position of the vehicle in the platoon, inter-vehicle distance and time needed for platoon forming process [Boysen et al. 2018]. Also the speed of the vehicles in platoons influences the real fuel savings. The lower speed, caused for example by traffic congestion, the lower aerodynamic drag benefit and therefore lower fuel reduction [Larson et al. 2015]. Not always platoons are formed at the moment when all 2 or 3 vehicles are loaded and share the whole path from the start to the same consignee. The idea of platooning is also to enable the ad-hoc joining and leaving the platoons whenever required. In such cases drivers are required to wait until platoon can be formed and they must be willing to cooperate. This is a factor which shall be considered when estimating cost reduction of platooning transportation as the benefits thanks to fuel reduction can be offset by the waiting time to form a platoon [Muratori et al. 2017]. Truck platooning's limitations related to its forming process are also related to the costs of early or late deliveries. Current market expectations to deliver the goods next day or even same day lead to considerably less possibilities of increasing waiting time in order to form a platoon. [Boysen et al. 2018] prove also in their analysis that potential fuel saving due to driving in a platoon does not justify the investment in the technology. It can be therefore concluded that theoretical fuel saving are much lower in reality due to the fact that optimal truck platooning conditions are rare to happen on European roads.

Labor costs reduction

Truck platooning foresees that system would maneuver the vehicle. Truck driver could be engaged in other activities. That could potentially help in achieving labor costs reduction when the driver takes care of certain administrative tasks such as route planning. The potential labor cost reduction is, however, only theoretical since the system does require the driver to be able to take over control of the vehicle whenever required. Truck driver has to consciously and constantly observe the road. This is because platooning is an conditional automation which still requires presence of a human driver. That leads to the conclusion that labor cost reduction is only illusory as the driver has to be in the position to immediately start controlling the vehicle when other maneuvers are required [Wang et al 2019]. In the calculation of labor cost reduction also potential requirement for back office to support platooning should be considered. To take advantage from the data exchange between the trucks in platoon and to help in coupling tucks to built a heterogeneous platoons, coordination from back office may be required to support navigation [Bergenhem 2013]. For this reason author of this paper sees potential for labor cost reduction not with platoons but when driverless driving would be popularized on the roads.

Ecological aspect

CO_2 reduction

Transportation causes degradation of ecosystems due to CO_2 emission and due to extension of the transport infrastructure [Berg et al. 2016]. To degradation of the ecosystems counts in particular deforestation, biodiversity loss, higher air pollution [Laurance et al. 2009]. Truck Platooning is one of the recent technologies which aim to reduce the diesel consumption by the heavy-duty vehicles and by that to reduce the CO_2 emissions. Truck platooning is, however, neither self driving nor electric driving. It does reduce CO_2 emission but only in certain conditions. Benefits of reduced CO_2 emissions thanks to truck platooning can be achieved only on motorway where trucks go at higher speed to stimulate the effect of slipstream driving. Truck platooning does not solve the problem of pollutions on off-motorway roads or in cities or metropolises with congestions caused by vehicles. Truck platooning, even if does support sustainable development targets, does it only to a small extent [Caparros-Midwood et al. 2017]. As noted by [Simionescu et al. 2017], European Commission Directive 2012/0288 expected the member countries to use at least 10% of the energy in transportation from renewable energy by 2020. Renewable energy is a core characteristic of platooning neither. For all those reasons, author of this paper concludes that truck platooning cannot be called sustainable transport. Sustainable transport would be self driving and non emission driving which does not emit greenhouse gas.

Social aspect

Different role of a truck driver

Truck platooning foresees that drivers in following vehicles in a platoon do not have to be engaged in the steering of them but can do other activities such as route planning, phone calls or theoretically also taking the rest time required by the law. That not only could increase productivity but also create different profile of a driver. Facing shortage of the traditional truck drivers on the European market over last years, that could be encouragement to this job. Doing other activities while platooning can be more attractive work environment than conventional truck driving. Platooning can replace the driver in some of his activities but not in all. The other risk or limitation is drivers' behavior and reaction time to take over control over the vehicle whenever needed. Thus, on one hand truck platooning is believed to release the driver from some driving activities but on the other hand driving in a platoon requires from the driver not only driving skills but also multi tasking skills, quick reaction time, monitoring traffic situation while doing other tasks at the wheel. For this reason author of this paper does not see high potential for the development of the driver job because of platooning. More potential seems to be with developing other jobs and functions needed for instance for traffic control support functions while full automation (driverless vehicles) will be achieved and popularized on the market.

Congestion reduction on the roads

Thanks to much shorter distance between the trucks in the platoons, they reduce the space which is needed on motorway for the same number of unplatooned trucks. Three trucks on a motorway occupy 150 meters if unplatooned while 80 meters if in a platoon. Therefore platoons are believed to reduce the congestion on the roads. Simulations estimate almost double road capacity increase [Shladover et al. 2012]. Time spent in traffic could be used in more productive pursuits. Higher congestion leads to more accidents and injuries [Berg et al. 2016]. However, trucks grouped in a platoon sharing the same path to the destination would need to decouple at the exits of motorways. Cumulating of them on the local roads or cities may cause additional congestion and traffic. Against congestion's reduction speaks also platooning forming process. When drivers of several trucks will aim to build an ad-hoc platoon and travel part of their path together, some of them will need to reduce the speed in order to wait for the partners. Several heavy-duty vehicles at lower speed on the motorway may hinder the traffic on the right rightmost lane. For those reasons author of the paper puts in question potential positive impact of reducing congestion on the roads thanks to platooning.

Increase of safety level on the roads

Truck platooning is believed to enhance safety on the roads. Connection between the trucks enables much faster reaction time in case of emergency breaking. While human reaction time is estimated to be 1.4 seconds, trucks following the lead truck in platoons start breaking already within 0.1 seconds. Breaking distance of a truck with human driver is longer due to perception and reaction time of the driver before even the breaking activity starts. Perception and reaction time is the reason why trucks driven by human drivers have to mind the distance of typically 50 meters at minimum when not in a platoon. Platooned trucks are more safe in terms of the breaking, even if the distance between them is much shorter (typically between 7 and 12 meters). There has not been however enough tests to know what would be the reactions of drivers of passenger cars towards platooned heavy-duty vehicles and if those drivers would not cause danger when forcing platooned trucks to decouple. Another element to be considered is also the reaction time of the drivers in case of unexpected traffic situation when they will be asked by the system to take control of the vehicle and to maneuver the truck manually. Drivers in platooned vehicle engaged in other activities such as phone calls or resting time may not react quick enough and cause additional danger on the road. For those reasons author of this paper believes that all in all there is no real added value of platooning in terms of the safety on the roads. Nevertheless, full driving automation could increase the safety on the roads.

CONCLUSIONS

Truck platooning is one of the ideas and innovations on how to increase transportation potential and achieve it in line with sustainable development principles [Boysen et al. 2018]. As demonstrated earlier in this paper, truck platooning is only limited contributor to the sustainable development's targets. This is because its potential benefits can be generated only in specific circumstances which are rare to happen in real business situation in Europe. Theoretically possible savings thanks to fuel consumption reduction when driving in a slipstream are limited to minimum in real traffic circumstances in European conditions with highly congested roads. This is due to platoon forming time, rare possibility for several trucks to share same path at the same time, occasionally long time driving at high enough speed to enable slipstream effect, incompatibilities of software or lack of needed software in case of multi brand platooning, market pressure on shortening the lead times, cost of investments, lack of permissions for platooned driving in European countries. All this puts in question justification of investments in the platoon technology for the fleet operators on European market. For those reason economical target of sustainable development is questionable. If fuel consumption reduction is not proven to happen in real traffic situation or only at as small scale, then also significant CO_2 emission reduction is unlikely to happen. That means that also ecological target of sustainable development may not be achieved either. Also limited level of driving automation in case of platooning does not give the real benefit of replacing human driver by a software being capable of sophisticated traffic maneuvers. If the release of the driver from driving task is not the face for level 3 automation which is platooning, then this jeopardizes the social aspect of sustainable development. For all those reasons, truck platooning is not a technology which would revolutionize the transport industry or have great impact on sustainability in Europe.

Strength of the work is that it treats about truck platooning not only from the perspective of its potential benefits but also that it also puts them into perspective of several different limitations considering economical, ecological and social aspect of this technology.

Limitation of the work is that it treats about the technology which is not commercially available in Europe and therefore there is no real data available except for those from few, isolated tests. What is more, in Europe neither European Union law nor local law of member countries allow platooning. Truck platooning is a technology and innovation in transportation industry which is known for years but which does not have real use cases in Europe so far.

In this paper author concentrated on truck platooning considering European economy, infrastructure and legislation. Author accepts the possibility that impact of truck platooning on sustainable development's targets may be different in other markets such as Australia or United States.

The thesis that truck platooning fits in with the European Union's strategies as one of the elements supporting sustainable development has been partially confirmed and partially denied. Truck platooning may support sustainable development's targets, however due to its limitations the magnitude of its contribution is not significant, which is demonstrated in the below Table 2.

Table 2. Opportunities and strengths as well as threats and weaknesses of truck platooning in the context of sustainable development

Sustainable development's aspects		**Truck platooning response**	
		Opportunities & Strengths	**Threats & Weaknesses**
Economical	Fuel saving	Lower diesel consumption due to aerodynamic drag	No zero or low emission technology Depends on inter-vehicle distance, speed and vehicle's position in the platoon Depends on platoon formation process
	Labor costs reduction	Driving automation may reduce labor costs	Platooning is not a driverless driving Still driver in each vehicle needed
Ecological	CO_2 reduction	Reduced greenhouse gas emissions	Still usage of fossil fuel
Social	Change of a truck driver job	Drivers to do other activities such as route planning , work on the phone computer while driving – new set of skills required	Legislation requires drivers in each vehicle. Platooning is not driverless driving Driver to be ready to take over control of vehicle whenever needed
	Congestion reduction on the roads	Shorter distance between trucks means less space on the road occupied	Additional congestion due to platoon forming process (waiting for the partners to join the platoon)
	Increase of safety level on the roads	Shorter breaking reaction time	Human-dependent breaking process in the leading vehicle Non standard traffic situations not covered by platooning

Source: own creation

Author of this paper believes that more potential in terms of achieving sustainable development targets would be when using renewable fuel in the trucks or different sources of power such as electricity, not necessary based on currently widely spread lithium-ion batteries. Author's position is that more effort should be devoted in replacing fossil fuel by more environmentally friendly technology rather than looking for isolated, almost artificial use cases where fossil fuel consumption could be only slightly reduced like in case of truck platooning. Once full truck driving automation has been achieved and popularized in the transport industry, efficient transportation it would contribute to the sustainable development's targets to significantly higher extent.

FUTURE RESEARCH

Those conclusions directly lead to future research needs. Truck platooning seems to be only step on the way to the world of driverless vehicles powered by efficient and ecologically friendly source of power. For this reason technology, legislation and people awareness shall be developed in this direction. Truck platooning due to its all limitations shall not be seen as ultimate solution for the transport industry and for achieving sustainable development targets. One-digit fuel savings to be generated only on a part of the vehicle's path and this upon a waiting time in order to built a platoon out of trucks powered by fossil fuel cannot look as an attractive solution. There have been already tests of other promising solutions on the market such as driverless vehicles and zero or even negative emission transportation (so called Carbon Dioxide Removal or Bioenergy with Carbon Capture and Storage technologies). Future research may investigate magnitude of impact of those technologies on sustainable development.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This paper has been the result of the study conducted within the projects pursued at the Poznan University of Technology, Faculty of Engineering Management [project number: 11/140/SBAD/4168] and Poznan School of Logistics [project number KSL 2/17].

REFERENCES

Berg C.N., Deichmann U., Liu Y., Selod H., 2017. Transport Policies and Development, The Journal of Development Studies, 53:4, 465-480, http://doi.org/10.1080/00220388.2016.1199857

Bhoopalam A-K., Agatz N., Zuidwijk R., 2018. Planning of truck platoons: a literature review and directions for future research, Rotterdam School of Management, Erasmus University, Department of Technology and Operations Management, Rotterdam, Netherlands, http://doi.org/10.1016/j.trb.2017.10.016Get

Boysen N., Briskorn D., Schwerdfeger S., 2018. The identical-path truck platooning problem, Transportation Research Part B 109. http://doi.org/10.1016/j.trb.2018.01.006

Brennan L., Owende P, Biofuels from microalgae - a review of technologies for production, processing and extractions of biofuels and co-products, "Renewable and Sustainable Energy Reviews" 2010, 14, 2, 557-577, http://doi.org/10.1016/j.rser.2009.10.009

Caparros-Midwood D., Barr S., Dawson R., 2017. Spatial optimization of future urban development with regards to climate risk and sustainability objectives, Risk Analysis 37, 11, Newcastle University, http://doi.org/10.1111/risa.12777

Chin, T. A., Tat, H. H. and Sulaiman, Z., 2015. Green supply chain management, environmental collaboration and sustainability performance. International Journal of Operations and Production Management, 26, 695-699, http://doi.org/10.1016/j.procir.2014.07.035

Huang Q. , Benmimoun A. , Robinson T., 2010. "Challenges of Platooning on Public Motorways", 17th World Congress on Intelligent Transport Systems, October 25-29, 2010, [online] Available: https://pdfs.semanticscholar.org/c5af/e2bfbf86062e00149504fd185c94b8a6d74a.pdf

Krüger N., Teuteberg F., 2018. Truck platooning: Towards Future Business Models, University of Osnabrück, Multikonferenz Wirtschaftsinformatik, Lüneburg. Germany.

Kumar K-M., Rahman A-A., Jayaraman K., Rahim S-A., 2017. Conceptualization of a research model for sustainable logistic practices and logistics transport performance, Jurnal Pengurusan 51, University Sains Malaysia.

Larson J., Kammer Ch., Liang K-Y., Johansson K-H., 2013. Coordinated Route Optimization for Heavy-duty vehicle platoons, Proceedings of the 16th International IEEE Annual Conference on Intelligent Transportation Systems (ITSC 2013), http://doi.org/10.1109/ITSC.2013.6728395.

Larsson E., Sennton G., Larson J., 2015. The vehicle platooning problem: computational complexity and heuristics, Argonne National Laboratory, Lemont, Illinois, Mathematics and Computer Science Division, http://doi.org/10.1016/j.trc.2015.08.019.

Laurance W., Goosem M., Laurance S., 2009. Impacts on roads and linear clearings on tropical forests, Trends in Ecology & Evolution, http://doi.org/10.1016/j.tree.2009.06.009

Muratori M., Holden J., Lammert M., Duran A., Young S., Gonder J., 2017. Potential for platooning in U.S. highway freight transport, National Renewable Energy Laboratory, Colorado.

Pichlak M., 2017. W kierunku gospodarki o obiegu zamknietym – przeglad koncepcji wdrazania zielonej gospodarki [Towards a circular economy – a review of the concept of implementing of a green economy], http://doi.org/10.12775/AUNC_ECON.2017.001

Purol M., Matuszak-Flejszman, A., 2014. Kryteria zrownowazonego rozwoju jako element zintegrowanego system system zarzadzania w przemysle spozywczym [Criteria of sustainable development as an element of the integrated management system in the food industry], Research papers of Wroclaw University of Economics, 377.

Simionescu M., Albu L-L., Raileanu Szeles M., Bilan Y., 2017. The impact of biofuels utilization in transport on the sustainable development in the European Union, Technological and economic development of economy, 23(4), http://doi.org/10.3846/20294913.2017.1323318

Shladover S., Su D., Lu X-Y., 2012. Impacts of cooperative adaptive cruise control on freeway traffic flow, Transportation Research Record Journal, University of California, Berkeley, http://doi.org/10.3141/2324-08

Słowik P., Sharpe B., 2018. Automation in the long haul: Challenges and opportunities of autonomous heavy-duty trucking in the United States, The International Council on Clean Transportation.

Strategies of European Union: a) Horizon 2020 work programme 2018-2020 - Strategic Programme Overarching Document, https://ec.europa.eu/programmes/horizon2020/sites/horizon2020/files/stratprog_overarching_version_for_publication.pdf

b) EUROPE 2020, A European strategy for smart, sustainable and inclusive growth, https://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf

c) A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773

Torabi S., Wahde M., 2018. Fuel-efficiency driving strategies for heavy-duty vehicles: a platooning approach based on speed profile optimization, Department of Mechanics and Maritime Sciences, Chalmers University of Technology, Göteborg, http://doi.org/10.1155/2018/4290763

Wang M., van Maarseveen S., Happee R., Tool O., van Arem B., 2019. Benefits and Risks of Truck Platooning on Freeway Operations Near Entrance Ramp. Transportation Research Record, 2673, 8, 588-602, http://doi.org/10.1177/0361198119842821

Wysokinska Z., 2018. Implementing the main circular economy principles within the concept of sustainable development in the global and European economy, with particular emphasis on central and eastern Europe – the case of Poland and region of Lodz, 2018, Comparative Economic Research, 21, 3, University of Lodz, Poland

PLATOONING POJAZDÓW CIĘŻAROWYCH W KONTEKŚCIE CELÓW ZRÓWNOWAŻONEGO ROZWOJU ZDEFINIOWANYCH W STRATEGIACH UNII EUROPEJSKIEJ

STRESZCZENIE. **Wstęp:** Konsekwencją rosnącego rynku konsumenckiego jest wzrost sektora transportu i logistyki szacowany w Europie na 42% do roku 2050. Dlatego też innowacje w transporcie stały się jednym z kluczowych obszarów dla łańcuchów dostaw. Wyzwaniem jest nie tylko sprostanie oczekiwaniom rynku, ale także osiągnięcie tego zgodnie z zasadami zrównoważonego rozwoju. Celem artykułu jest odpowiedź na pytanie o wielkość wpływu platooningu pojazdów ciężarowych na cele zrównoważonego rozwoju sformułowane w wybranych strategiach Unii Europejskiej.

Metody: Na podstawie przeglądu literatury, autor wniósł wkład tą publikacją, ustanawiając związek między rozwiązaniem platooningu pojazdów ciężarowych a celami zrównoważonego rozwoju określonymi w strategiach Unii Europejskiej.
Wyniki: Autor zidentyfikował mocne i słabe strony platooningu pojazdów ciężarowych w kontekście celów zrównoważonego rozwoju: cel ekonomiczny osiągany poprzez redukcję zużycia paliwa, cel ekologiczny osiągany dzięki przyczynianiu się do niższej emisji CO2 oraz cel społeczny osiągany poprzez zwiększenia bezpieczeństwa na drogach.
Wnioski: Przeprowadzona analiza częściowo potwierdza a częściowo odrzuca tezę o platooningu pojazdów ciężarowych jako jednego z elementów wspierających zrównoważony rozwój zgodnie z założeniami strategii Unii Europejskiej. Platooning pojazdów ciężarowych może wspierać cele zrównoważonego rozwoju. Na obecnym etapie, jednakże, skala wpływu tego rozwiązania na cele zrównoważonego rozwoju nie jest znacząca. Jest tak ponieważ pojazdy ciężarowe w platooningu stosują nadal paliwa konwencjonalne a stan legislacji w krajach Unii Europejskiej nie pozwala jeszcze na pełną komercjalizację tego rozwiązania i generowanie wspomnianych korzyści dla rynku transportowego oraz zrównoważonego rozwoju.

Słowa kluczowe: platooning, zrównoważony rozwój

Mateusz Pajak
Poznan School of Logistics
Estkowskiego 6, 61-755 Poznań, **Poland**
e-mail: mateusz.pajak@wsl.com.pl

Piotr Cyplik ORCID ID: https://orcid.org/0000-0002-5775-6760
Poznań University of Technology,Strzelecka 11, 60-965 Poznań, **Poland**
e-mail: piotr.cyplik@put.poznan.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (3), 333-345

http://doi.org/10.17270/J.LOG.2020.409

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

THE ALGORITHM OF DEVELOPING PRIORITIES IN THE SUPPLY CHAIN

Bożena Zwolińska[1], Agnieszka A. Tubis[2]

1) AGH University of Science and Technology, Krakow, **Poland**, 2) Wroclaw University of Science and Technology, Wroclaw, **Poland**

ABSTRACT. **Background:** The presented research problem concerns the operational (executive) level and does not include tactical or strategic solutions. The described algorithm concerns the determination of the priority number of objects that are the equipment of any considered production system. The algorithm takes into account the states of work in the external and internal areas of the evaluated system. The analysed characteristics mainly include: values of work levels in the supply chain (to and from the enterprise) and values of system work levels within the company in the area of continuity of the processed material flow and failure levels of technological equipment. The algorithm of the object priority evaluation takes into account the existing synergy of a single element of the system with the whole system.

Methods: The presented method of assessing priorities enables determination of critical elements of a complex system. The evaluation is carried out in a three-dimensional system. It takes into account machine failure, the operation of processes in the area of the analysed manufacturing system but also the levels of operation of supply systems (supply chains). The presented method of determining priorities requires adapting the assessment methodology to the individual characteristics of the test object. For this reason, the analysis includes, among others: the type of the system, its structural and functional complexity, complexity of interoperability and the size of material flow streams and their frequency.

Results: The developed algorithm was verified on a selected example of a production system. Due to the complexity of the presented algorithm, the article presents results for a system that is characterized by a relatively high level of process flexibility and has a large number of technological processes. The article presents the values of indicators that were calculated for individual modules

Conclusions: The presented algorithm is a general approach to the evaluation of the elementary objects of the system, while taking into account the existing synergy between the other elements of the entire system. In the next stages of the research, the authors will develop algorithms for various production systems (convergent and divergent), for different manufacturing specifications (objective and technological) and for different levels of process flexibility values.

Key words: priorities of objects, supply chain.

A part of this study was presented as oral presentation at the „8th International Logistics Scientific Conference WSL FORUM 2019" in Poznan (Poland), 18th-19th of November 2019.

INTRODUCTION

The effectiveness of any complex system depends on many factors. The most frequently indicated here are: efficiency and reliability of components, the level of quality of tasks implementation defined for the whole system and its individual links, the degree of connections between components, the level of complexity of relationships occurring within the system and between the system and the environment. The levels of system operation parameters occur in their close correlation and create the global effectiveness of the entire system or each isolated link. Each improvement in the level of the assessed indicator being perceived as the system

Citation: Zwolińska B., Tubis A.A., 2020. The algorithm of developing priorities in the supply chain. LogForum 16 (3), 333-345, http://doi.org/10.17270/J.LOG.2020.409

Received: 12.11.2019, Accepted: 01.04.2020, on-line: 30.06.2020.

improvement, determines the changes in the operating parameters of interdependent links/components (not necessarily positive). Therefore, thoughtful and fully effective implementation of improvement solutions should take into account a holistic approach in the existing relationships.

The use of multi-faceted criteria for assessing complex technical systems is a NP-hard task. Formulating algorithms that define levels of effective work, which take into account the synergy of the system with its individual elements is a time-consuming process and requires knowledge of existing intra-system relationships. The degree of difficulty and time consumption of the algorithms prepared for complex systems increases exponentially with the number of components considered. For this reason, the first analyses and tests are formulated for simplified systems. However, the obtained results are determined for isolated systems.

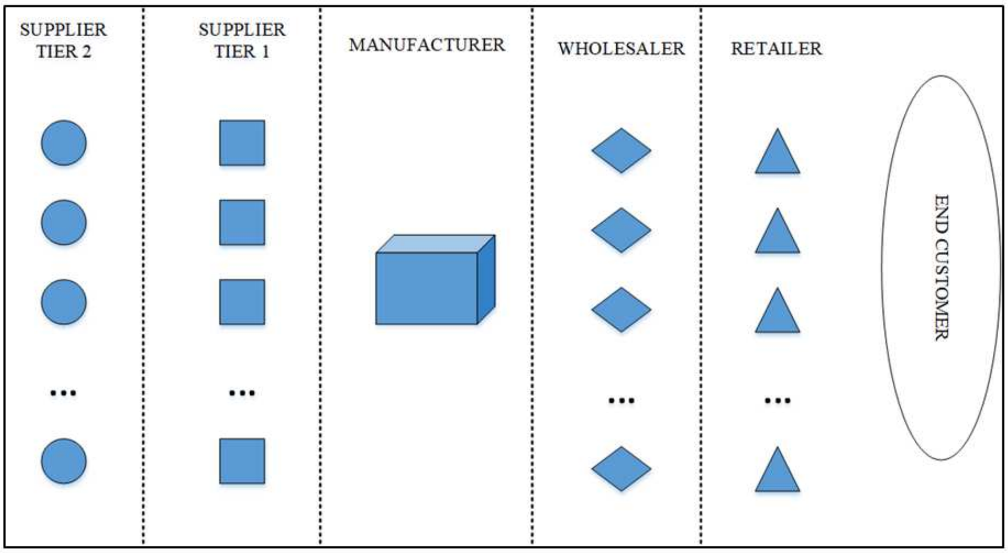
The article presents the algorithm for determining the priority value level for the components of any logistics system. The developed algorithm comprehensively considers the system at the operational level, including the time and spatial horizon. The priority values determined according to the model for the analysed objects are multi-criteria. They take into account the location of the evaluated element in relation to the bottleneck (theory of constraints) and in relation to the client.

The main goal of the article is to formulate an algorithm for creating priority values – PV for any object of a complex logistics system. The developed algorithm PV takes into account existing intra-system correlations and individual operating parameters of the analysed module. The article presents examples of calculations for a separate supply chain, which consists of seven links that participate in the flow of processed material. The example aims to show, how to determine the value of PV.

PRIORITY VALUE IN SUPPLY CHAIN PROCESSES

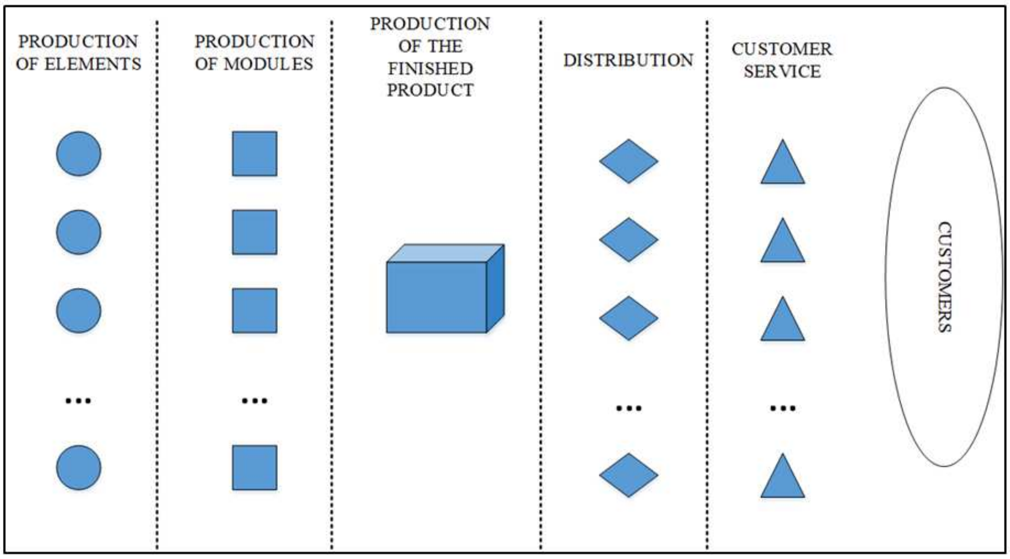
Various approaches to the supply chain can be found in the literature [Attran 2007, Burgess 2006, Carter 2008, Cooper 1997, Ciesielski 2019]. In the model approach, the supply chain is presented as a system of individual relationships between the links representing the subsequent stages of the processed product that is delivered to the market. However, the SCM definitions in many papers seem to indicate a move away from the chain analogy to a network analogy in many papers. Hertz [Hertz 2001] also discusses Supply Chain Networks as "the network that supplies a specific product or product group following the chain from raw material to the final consumer". Lambert et al. [Lambert et al. 2005] write that "Given that a supply chain is a network of companies, or independent business units, from original supplier to end-customers, management of this network is a broad and challenging task". Thus supply networks comprise of both "upstream" network of suppliers and "downstream" network of distributors and customers. Similarly to supply chains, networks encompass several dimensions of physical, payment and information flows and also other dimensions such as social, technological, legal and administrative ones. Therefore, the subject of the analysis is the network system, which can of course be limited to one manufacturer or one product (Figure 1).

The supply chain presented in the figure 1 is compatible with the concept of subjective approach to participants in the chain. The links of the presented system are enterprises participating in subsequent stages of production and delivery of the finished product to the market. In this approach, attention is paid to the relationships connecting individual enterprises that form links in the supply chain. However, for the needs of the investigated concept, a process approach to the analyzed supply chains is more justified. Process orientation in supply chain management has been the subject of many scientific and business discussions for several years. Examples of research in this area are articles [Mauoumis et al. 2019, Kotzab and Otto 2004, Lambert et al. 2005]. In this approach, the researchers' attention is focused not on enterprises integrating their activities, but on the process integration of subsequent stages of production and delivery of the finished product to the consumer/user. The model layout of the supply chain defined in this way is shown in Figure 2.



Source: own study

Fig. 1. Supply chain in a subjective approach

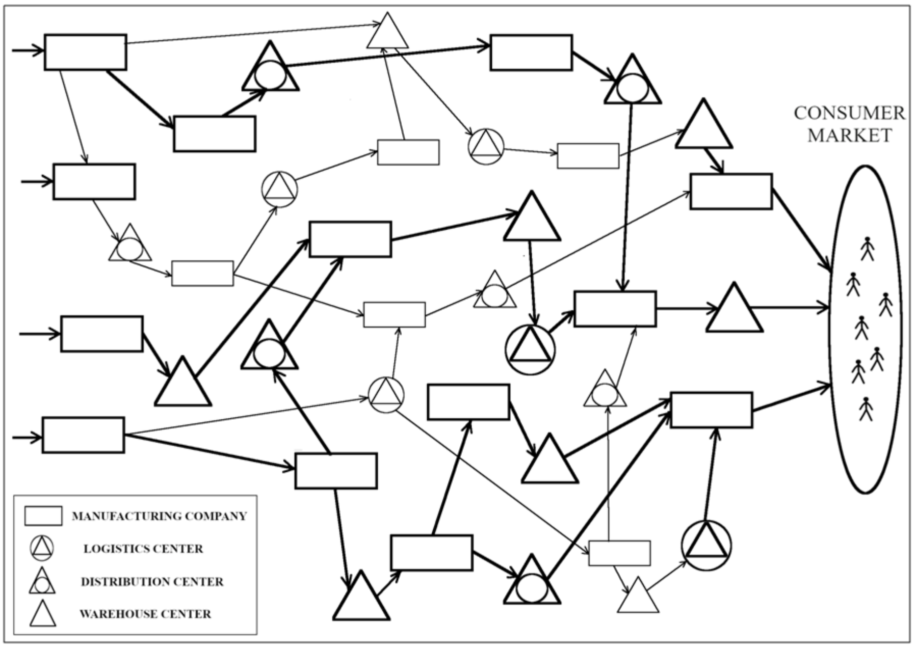


Source: own study

Fig. 2. Supply chain in a process approach

The individual stages of the production and distribution of the finished product are of course carried out by specific companies. However, the lack of an indication of specific companies allows researchers to focus their attention on processes. This allows to increase the flexibility of the entire supply chain and it is in accordance with current trends in supply chain management. This approach also limits existing waste in the traditional supply chain. It is therefore consistent with the concept of LSCM, which is currently being developed in published research [Compos et al. 2016, Huo et al. 2019]. At the same time, it is in accordance with the assumptions of the concept of priority value. In this concept, the prepared analyses are focused on the process of performing tasks, and not on the units that are responsible for this process.

The article uses the theory of complex systems [Klir 1976, Mesarovic 1964] to formalize a universal algorithm for developing priority values for any set of different supply chains. In the first stage, the system components were classified into sets of separate subsystems. Then, assessment parameters for separate elementary objects were formulated. These parameters have been divided into three categories: use of available resources, share of maximum storage or processing times and the risk level indicator, which results from not delivering the product to the customer in accordance with the 7R principle (right product, right place, right quantity, right condition, right time, right customer, right price). In recent years, the last category regarding risk management in the supply chain has become particularly important [Świerczek 2019, Wieteska 2018]. At the same time, the complexity of flows that take place within existing logistics networks is increasing [Turner et al. 2018]. Figure 3 shows a diagram that illustrates the complexity of flows. This complexity is due to the diverse supply chains in any logistics system.



Source: own study

Fig. 3. Complexity of flows in the supply chain

In the considered case, the logistics network model M_{LS} was analyzed. For this network, its modules were classified into two main groups: $P|k$ i $C|k$. The determination of exact affiliation was determined according to the classification criterion k. The point of reference is the customer, who is the recipient of the finished product. The classification criterion was defined as the assignment of possessed properties of a certain binary function in the set $\{0,1\}$. Then:

$$k \in \{0,1\} \tag{1}$$

where: k – classification criterion (binary one).

For $k = 1$ – any object (module) of the logistics system M_{LS} is a manufacturing company, i.e. there is at least one process that generates the value of the product from the customer's point of view. Otherwise: $k = 0$.

According to such a formal assignment, the modules of the logistics network M_{LS} in the first division are a set of two subsets: 1 – the subset of objects in which value is added to the product, and 2 – the subset of objects in which the necessary temporary storage of the product occurs. Then module of the logistics network M_{LS} is defined as:

$$M_{LS} = \{P|k, C|k\} \qquad (2)$$

where: $P|k$ – set of objects M_{LS}, in which there is at least one process generating value added to the product. The assignment of an object to a set $P|k$ depends on the criteria k met for $k = 1$; $C|k$ – set of objects M_{LS}, for which $k = 0$ – which means that the process that adds value from the customer's point of view is not implemented. In the presented investigations it was assumed that these are network M_{LS} objects in which the storage processes are carried out without distinguishing the length of the storage time.

The set of objects in the system M_{LS} includes both, manufacturing and mining enterprises. This set was formalized as follows:

$$P|k = \{P_i\}_{i \in I} \qquad (3)$$

where: I – all possible numbers identifying the enterprise type belonging to M_{LS}. There are two ways of numbering P_i: first - using numbers that denote the sequential assignment e.g.:
1 - production 2 - mining, 3 - other (others), etc.; the second - direct numbering and classification according to accepted markings, e.g..: $W_1, W_2, W_3, \ldots$ etc.

To the set $C|k$ are allocated objects owned by M_{LS}, in which there is a storage process. There are different types of such objects in this case: warehouse centres, distribution centres and logistics centres. However, for the purposes of this article, such differentiation is unnecessary. The analysis of multi-variant objects from set $C|k$ will be the subject of further research conducted by the authors. Currently, the set $C|k$ has been formalized in the overarching approach as follows:

$$C|k = \{C_i\}_{i \in J} \qquad (4)$$

where: J – all numbers of possible center types that appear in the analyzed M_{LS}.

ALGORITHM FOR DETERMINING PRIORITY VALUES

The priority value of any logistic system object is determined according to the three criteria: 1 – the level of use $L_{U(X|i)}$; 2 – the maximum possible retention time (and/or processing) in the area of the module under consideration $L_{T(X|R)}$; 3 – risk level participation indicator $L_{F(X|R)}$ determined on the basis of Customer Effect Factor [Wiegand et al. 2005, Zwolińska, Kubica 2017a, 2017b]. Priority value PV is determined as the product of three components $L_{U(X|i)}$, $L_{T(X|R)}$, $L_{F(X|R)}$. Hence:

$$PV = L_{U(X|i)} \cdot L_{T(X|R)} \cdot L_{F(X|R)} \qquad (5)$$

All three indicators and PV take values in the set $\langle 0,1 \rangle$. Accepting the level of individual: $L_{U(X|i)}$, $L_{T(X|R)}$ and $L_{F(X|R)}$ takes into account the multi-area influences of various factors. The determination of their value is discussed and formalized in the Subsections 3.1, 3.2, and 3.3, while Section 4 presents an example of determining their value.

Definition of the value of the indicator $L_{U(X|i)}$

The indicator $L_{U(X|i)}$ determines the level of the use of individual objects (modules) M_{LS}. In the developed analyses there is considered that each isolated module of network model M_{LS} is a shared system, i.e. there are at least two different clients (users) of the facility. The adopted assessment criterion depends on the module of M_{LS} ($P|k$ lub $C|k$), for which the value of $L_{U(X|i)}$ is being considered. For production systems – $P|k$, the percentage level of utilization of available capacity is determined. In warehouse modules – $C|k$, the percentage level of utilization of the available warehouse space is determined. For this reason, the largest parameter value of $L_{U(X|i)}$ defines the bottleneck of the entire system throughput. In such a module, time discipline is important, because each oversized exceeding of the task implementation time determines delays in delivery of the final product. Time discipline also applies to all modules of M_{LS}, that participate in the flow of the product and precede the bottleneck. It is also introduced index X to determine the level of use $L_{U(X|i)}$ of any module of M_{LS}. The index X takes determinations P_i or C_i depending on the analyzed object of M_{LS}. Therefore $U_{X|i}$ – set of shares in the X resources of the specified module:

$$U_{X|i} = \{u_{X|1}, u_{X|2}, ..., u_{X|K_X}\} \quad : \sum_{i=1}^{K_X} u_{X|i} = 1 \ \wedge \ \forall\, i = 1,...,K_X \ : u_{X|i} \in (0,1) \tag{6}$$

where: X – one module of M_{LS}, specifically P_i or C_i; $u_{X|i}$ – client's partial share in the X module resources allocated to him; i – customer number assigned to the module X, where:

$$i \in \{1,2,...,K_X\},\ K_X \in N_+, \tag{7}$$

K_X – maximum number of clients assigned to the module X.

The degree of utilization of the allocated resources $l_{u(X|i)}$ from the entire contribution is determined for a module X and an i client. Then: $\forall\ X\ \ \forall\ \ i = 1,...,K_X : l_{u(X|i)} \in \langle 0,1 \rangle$.

Value $l_{u(X|i)} = 1$ when the i-th client uses the maximum resources $u_{X|i}$ of module M_{LS} allocated to him. The $L_{U(X|i)}$ value is determined according to the formula:

$$L_{U(X|i)} = u_{X|i} \cdot l_{u(X|i)} \tag{8}$$

Finally, the $L_{U(X|i)}$ value determines the share of the i-th client in the total resources of the module X. Instead of $L_{U(X|i)}$, the $l_{u(X|i)}$ value can be used in the algorithm step, which concerns determining the value PV_X for a specific module X. Then the priority will be determined only to the contracted shares in resources (without taking into account the possibility of increasing the share in case of need).

Determining the value of the $L_{T(X|R)}$ indicator

The value of the $L_{T(X|R)}$ indicator is defined in terms of the time criterion. The $L_{T(X|R)}$ indicator determines the maximum possible "time window" for the processed material, which does not determine the delay in delivery of the final product. The $L_{T(X|R)}$ indicator is determined taking into account two areas of the investigated logistics system:

- the impact of potential time delays on a logistics system module that has been identified as a „bottleneck”,
- impact of potential delays in delivery of the finished product to the final customer.

It is necessary to determine a set of cumulative transition times to determine the indicator $L_{T(X|R)}$. This set is determined on the basis of elementary processing times $t_{y|R}$. Then:

$$T_{X|R} = \sum_{y \in A_{X|R}} t_{y|R} \tag{9}$$

where: $T_{X|R}$ – total transition time taking into account the X -th type of module and the R -th type of product; $t_{y|R}$ – elementary handling time for the R product in the X -th module; $A_{X|R}$ – the set of the all modules of M_{LS}, which occur in the R product flow from a fixed X module to the end of the supply chain $K_{P|R}$. The index y is a specific object of M_{LS} for a strictly defined product supply chain, which is the beginning of determining the transition time.

The value of the $L_{T(X|R)}$ indicator of module M_{LS} depends on the share of the value $T_{X|R}$ of the analysed part of the supply chain (i.e. from the determined module M_{LS} to the point $K_{P|R}$), relative to the maximum possible value of cumulative transition times (flow and/or processing) for a specific product R. Then:

$$L_{T(X|R)} = \frac{T_{X|R}}{\max\limits_{X} \left\{ T_{X|R} \right\}} \tag{10}$$

where: $\max\limits_{X}\left\{T_{X|R}\right\}$ – maximum possible value $T_{X|R}$, which results from the sum of elementary transition times (flow and/or processing) $t_{y|R}$, that occurred in the supply chain of product R.

Determining the value of the $L_{F(X|R)}$ indicator

The indicator Customer Effect Factor $F_{X|R}$ is determined on the basis of the limit level of loss, which results from the consequences of not delivering the product to the customer. The value of the Customer Effect Factor indicator can be determined by using one of three methods:

- intuitive estimation based on expert knowledge,
- using FMEA method - Failure Mode and Effects Analysis,
- using risk analysis techniques.

Different methods of determining the $L_{F(X|R)}$ indicator are used depending on the degree of complexity and the level of dynamics of changes in operating states of the analysed system. For modules characterized by stability of operating states in a given Δt, deterministic values of $F_{X|R}$ are assumed. Then they are defined as the average estimated value of the negative impact resulting from delivery delay. FMEA is used to determine the $F_{X|R}$ value for systems that show a higher level of structural complexity. The analysis of risk theory is used to determine the $F_{X|R}$ value for systems that are characterized by a relatively high level of functional complexity and/or flow.

The subject of the presented investigations is a system that is characterized by a relatively high dynamics of changes in the operating states and a high level of structural and functional complexity as well as flows. Therefore, determining the value of the value of the $L_{F(X|R)}$ indicator is estimated using risk theory and the theory of probability. The maximum unwanted random event, that causes a delay in delivery, is defined by $F_{X|R}$ for a given X module and a specific R product. Than:

$$F_{X|R} := \left| VaR_{\alpha}\left(X|R\right)\right| \tag{11}$$

where: $VaR_{\alpha}(X|R)$ – *value at risk*, that is, the loss value determined for the single X module and the specific R product at the α level of probability.

Then the value of the $L_{F(X|R)}$ indicator is determined by:

$$L_{F(X|R)} = \frac{F_{X|R}}{\max\limits_{X} \{F_{X|R}\}} \qquad (12)$$

where: $\max\limits_{X} \{F_{X|R}\}$ – maximum possible loss that occurred in all X modules for specific R product in the situation where we consider the M_{LS} system as a whole.

In the conducted research it is required, that a single event, for which the *value at risk* – VaR is determined, is a random variable, that is consistent with the probability distribution belonging to the class of elliptical distributions. For example, it can be a random variable with a normal distribution, which have any parameters μ and σ, being any component of a set multidimensional Gaussian distribution.

CASE STUDY

Determining the value PV_X of all the modules of any logistics system is a time-consuming task and belongs to the class of NP-hard task. The formalization of the algorithm for NP-hard tasks can be expressed by a polynomial equation, while the time for determining the solution increases exponentially with the increase in the number of elementary objects of M_{LS}. Therefore, the verification of the presented algorithm was carried out for single supply chain. It was assumed that the investigated exemplary supply chain consists of 7 modules involved in material flow stream performance, including 4 production systems in it.

In order to determine the PV_X value of the individual modules of the investigated supply chain, levels of indicators $L_{U(X|i)}$, $L_{T(X|R)}$ and $L_{F(X|R)}$ should be defined. These indicators were determined for selected numbers of module $X \in M_{LS}$ later in the article.

The value of $L_{U(X|i)}$ indicator defines the degree of utilization of the allocated share in resources of X module by the *i*-th client. Knowing that the resources of the X module are shared by 7 users, and each user has a strictly allocated share: $u_{(X|1)} = 32\%$, $u_{(X|2)} = 19\%$, $u_{(X|3)} = 15\%$, $u_{(X|4)} = 11\%$, $u_{(X|5)} = 9\%$, $u_{(X|6)} = 8\%$, $u_{(X|7)} = 6\%$; then for the customer number 1 for whom $l_{(X|1)} = 0{,}7$ the value $L_{U(X|1)}$ is determined according to:

$$L_{U(X|1)} = u_{(X|1)} \cdot l_{(X|1)} = 0{,}32 \cdot 0{,}7 = 0{,}224 \qquad (13)$$

Level $l_{(X|7)} = 0{,}7$ means that the first customer used 70% of the 32% of the X module resources allocated to him. However the value $L_{U(X|1)} = 0{,}224$ indicates the degree of complete use of the resources of X module only by the first customer.

The value of $L_{T(X|R)}$ indicator for the R product is determined by the cumulative share of transition, flow and/or processing time from the analysed X module to the end of the $K_{P|R}$ supply chain related to the maximum flow time that can occur for the R product in the examined supply chain. It should be noted that the elementary time values $t_{X|R}$ estimated for modules C_i and inter-operational buffers in the set P_i, are determined by customer's tact and the level of the R product inventory (or components needed to produce it).

Knowing that: $T_{1|R} = \sum_{y \in A_{1|R}} t_{y|R} = 15j$, $T_{2|R} = 10j$, …, $T_{4|R} = 17j$, …, $T_{7|R} = 5j$. Then:

$$L_{T(1|R)} = \frac{T_{1|R}}{\max_X \{T_{X|R}\}} = \frac{T_{1|R}}{T_{4|R}} = 0{,}882 \qquad (14)$$

and

$$L_{T(2|R)} = \frac{T_{2|R}}{\max_X \{T_{X|R}\}} = \frac{T_{2|R}}{T_{4|R}} = 0{,}588 \qquad (15)$$

The fourth module is the bottleneck in the examined case according to the criterion of flow time (and/or processing). For its $L_{T(4|R)} = 1$. Therefore, it is extremely important to adhere to the discipline of the time of completion of all tasks carried out in the area of this module and in the facilities preceding the fourth module.

The value of the Customer Effect Factor $F_{X|R}$ for a single object M_{LS} is determined on the basis of the limit level of loss that is a consequence of not delivering the recipient's product. *Value at risk* is referred to as:

$$VaR_\alpha(Y_{X|R}) = -\sup\{x \in R : P(Y_{X|R} \le x) \le \alpha\} = -q_\alpha^+(Y_{X|R})$$
(16)

where: $q_\alpha^+(Y_{X|R})$ – upper order quantile α of the variable $Y_{X|R}$.

Based on the definition (12) and formula (13) were obtained:

$$F(X|R) = \left| -q_\alpha^+(Y_{X|R}) \right| \qquad (17)$$

Then:

$$L_{F(X|R)} = \frac{\left| -q_\alpha^+(Y_{X|R}) \right|}{\max_X \left\{ \left| -q_\alpha^+(Y_{X|R}) \right| \right\}} \qquad (18)$$

Knowing the parameters of the distribution of the random variable $Y_{X|R}$ determining the value of loss defined for a single module X and a specific product R at a given level α, it is possible to designate $F_{X|R}$, when the parameters of the random variable $Y_{X|R}$ distribution estimating the value of the loss defined for the single X module and the specific R product at a predetermined α level are known. For each module X and for each R product, it is possible to set any α level. Then α is dependent on X and R, then: $\alpha_{X|R}$. For example, if the random variable $Y_{5|R}$ specifying the processing (or storage) time is defined by distribution $Y_{5|R} \sim Normal(7,1)$, while the risk protection is set at the level $\alpha_{5|R} = 95\%$, then:

$$VaR_{0,95}(Y_{5|R}) = -q_{0,95}^+(Y_{5|R}) = -8{,}64\,j \qquad (19)$$

Then:

$$F(5|R) = \left| -q_{0,95}^+(Y_{5|R}) \right| = 8{,}64 \qquad (20)$$

It is possible to specify the value of $L_{F(X|R)}$, if the value of all $F(X|R)$ for each module participating in the flow (or processing) of the R product is known. For fixed distribution parameters μ, σ of the random variable $Y_{X|R}$ determined in the analysed example: $F(1|R) = GGG$, $F(2|R) = GGG$, $F(3|R) = GGG$, …, $F(7|R) = GGG$; such that: $\max_X \{F_{X|R}\} = F_{3|R}$. Then:

$$L_{F(X|R)} = \frac{F_{X|R}}{\max_X \{F_{X|R}\}} = \frac{F_{X|R}}{F_{3|R}} \qquad (21)$$

For the third module: $X = 3$, the $L_{F(X|R)}$ indicator reaches a maximum value of one: $L_{F(3|R)} = 1$.

RESULTS

The algorithm for determining the priority value PV_X of logistics system modules has been defined in three areas: the use of level indicator $L_{U(X|i)}$, flow time indicator $L_{T(X|R)}$ and $L_{F(X|R)}$ - indicator of risk of loss incurred as a result of non-delivery of a product in accordance with the 7R principle (right product, right place, right quantity, right condition, right time, right customer, and right price). It is necessary to calculate all three indicators according to the presented method for each module separately in order to determine the module with the highest priority value. Then determine the values PV_X according to formula (5). In table 1 summarizes sample values $L_{U(X|i)}$, $L_{T(X|R)}$, $L_{F(X|R)}$ and PV_X .

Table 1. Summary of the values of the analyzed indicators

Indicators \ Modules	$X=1$	$X=2$	$X=3$	$X=4$	$X=5$	$X=6$	$X=7$
$L_{U(X\|i)}$	0.012	0.364	0.275	0.485	0.284	0.958	0.224
$L_{T(X\|R)}$	0.882	0.588	0.516	1	0.781	0.946	0.735
$L_{F(X\|R)}$	0.198	0.528	1	0.278	0.116	0.295	0.559
$PV_X = L_{U(X\|i)} \cdot L_{T(X\|R)} \cdot L_{F(X\|R)}$	0.002	0.113	0.141	0.134	0.025	0.267	0.092
$PV_X \cdot 10^3$	2.095	113.0	141.9	134.8	25.7	267.4	92.03

Source: own study

Due to the transparency of the determined values PV_X , they were scaled into a set of numbers in the scope of: $\langle 0,1000 \rangle$. In the presented example, the option of determining PV_X for the specified product for which the *i*-th customer's demand occurrence was considered. In the same way, one can considers values PV_X for orders consisting of several freely different products offered on the consumer market, taking into account proportional shares. The degree of difficulty in determining the value PV_X increases exponentially with the increase in the number of variables considered in the system and the number of components of the system.

CONCLUSIONS

The article presents the algorithm for determining the priority of any logistics network module. The presented method makes it possible to determine the critical elements of a complex system and at the same time considers it in a holistic approach. The method presented focuses on the implementation of operational level processes. For this reason, the presented algorithm belongs to the class of NP-difficult tasks, because it takes into account the comprehensiveness and hierarchical relationships of the components. The final value PV_x determined covers three different areas of assessment: use of owned (or contracted) resources, the effect of the flow of time (or processing) with respect to the bottleneck and / or shipping and the level of risk that results from the delayed delivery.

Further research of the authors will be focused on developing the model that was presented in the article. An area requiring further analysis is e.g. the impact of damage to selected machines on the level of customer service rendered depending on the adopted service strategy and the priority given to the customer. The possible development of the model may also take into account the impact of substitutability of the production materials used and the strategy of managing relations with suppliers..

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This work was supported funded by research project AGH University of Science and Technology 11.11.130.758.

REFERENCES

Attran M., Attran S., 2007. Collaborative supply chain management, the most promising practice for building efficient and sustainable supply chains. Business Process Management Journal, 13 (3), 390-404, http://doi.org/10.1108/14637150710752308

Burgess K., Singh P., Koroglu R., 2006. Supply Chain Management: A Structured Literature Review and Implications for Future Research. International Journal of Operations and Production Management, 26 (7), 703-729, http://doi.org/10.1108/01443570610672202

Campos L.M.S., Vazquez-Brust D.A., 2016. Lean and green synergies in supply chain management. Supply Chain Management, 21 (5), 627-641, http://doi.org/10.1108/SCM-03-2016-0101

Carter C., Rogers D., 2008. A framework of sustainable supply chain management: moving toward new theory. International Journal of Physical Distribution & Logistics Management, 38 (5), 360-387, http://doi.org/10.1108/09600030810882816

Ciesielski M., Konecka S., 2019. The main areas of methodological reflection in the supply chains research. LogForum 15 (3), 351-361, http://doi.org/10.17270/J.LOG.2019.341

Cooper M.C., Lambert D.M., Pagh J.D, 1997. Supply Chain Management. More Than a New Name for Logistics. The International Journal of Logistics Management, 8 (1), 1-13.

Hertz S., 2001, Dynamics of Alliances in Highly Integrated Supply Chain Networks. International Journal of Logistics: Research Applications, 4 (2), 237-256, http://doi.org/10.1080/13675560123649.

Huo B., Gu M., Wang Z., 2019. Grean or lean? A supply chain approach to sustainable performance. Journal of Cleaner Production, 216, 152-166, http://doi.org/10.1016/j.jclepro.2019.01.141

Klir J.G., 1976. Ogólna teoria systemów. Wydawnictwo WNT, Warszawa.

Kotzab H., Otto A., 2004. General process-oriented management principles to manage supply chains: theoretical identification and discussion, Business Process Management Journal, 10 (3), 336-349 http://doi.org/10.1108/14637150410539731

Lambert D., García-Dastugue S., Croxton K., 2005. An evaluation of process-oriented supply chain management frameworks. Journal of Business Logistics, 26 (1), 25-51, http://doi.org/10.1002/j.2158-1592.2005.tb00193.x.

Mauoumis S.M., Kazemi N., Abdul-Rashid S.A., 2019. Sustainable Supply Chain Management in the Automotive Industry: A Process-Oriented Review, Sustainability, 11 (14), 3945, http://doi.org/10.3390/su11143945

Mesarovic M.D., 1964. The Control of Multiverible Systems. New York, Wiley

Świerczek A., 2019. The effects of demand planning on the negative consequences of operational risk in supply chains, LogForum 15 (3), 315-329, http://doi.org/10.17270/J.LOG.2019.340

Turner N., Aitken J., Bozarth C., 2018, A framework for understanding managerial responses to supply chain complexity, International Journal of Operations & Production Management, 38 (6), 1443-1466, http://doi.org/10.1108/IJOPM-01-2017-0062

Wiegand B., Langmaack R., Baumgarten T., 2005. Lean Maintenance System Zero Maintenance Time – Full Added Value Workbook, Lean Institute, Portsmouth U.S.A.

Wieteska G., 2018, The domino effect – disrupttions in supply chains, LogForum 14 (4), 492-506, http://doi.org/10.17270/J.LOG.2018.302

Zwolińska B., Kubica Ł., 2017a. Model of designating the critical damages Part 1: Description and analysis of the production system, Journal of KONBiN, 42, 329–352, http://doi.org/10.1515/jok-2017-0032

Zwolińska B., Kubica Ł., 2017b. Model of designating the critical damages Part 2: The probabilistic model of shaping Machine's Priority Number, Journal of KONBiN, 42, 353–378, http://doi.org/10.1515/jok-2017-0033

Zwolińska, B., 2019, Modeling convergent processes in complex production systems, Wydawnictwa AGH, Kraków

ALGORYTM KSZTAŁTOWANIA PRIORYTETÓW W ŁAŃCUCHU DOSTAW

STRESZCZENIE. **Wstęp:** W pełni efektywne zarządzanie i organizacja dowolnego systemu produkcyjnego zakłada: zero zapasów w całym łańcuchu dostaw oraz zero postojów spowodowanych np.: oczekiwaniem na przetwarzany materiał bądź losowo występującymi awariami urządzeń wyposażenia technicznego. W wielu przedsiębiorstwach elementarne ograniczanie strat z grup: muri, mura i muda, przynosi doraźne efekty jedynie w usprawnianym obszarze. Należy pamiętać, że system wytwórczy zgodnie z teorią systemów złożonych jest organizacją, w której elementy składowe systemu występują względem siebie w ścisłej korelacji. Każdorazowa zmiana będąca obszarowym usprawnieniem systemu, determinuje również zmiany w innych (nie usprawnianych) obszarach. Stąd konieczne jest stosowanie wieloaspektowego ujęcia z jednoczesnym uwzględnieniem horyzontu czasowego i przestrzennego.

Materiały i rezultaty: Przedstawiony w artykule problem badawczy skupia się na obszarze poziomu operacyjnego (wykonawczego) i nie dotyczy rozwiązań taktycznych ani strategicznych. Przedstawiony w artykule algorytm kształtowania liczby priorytetowej obiektów, będących wyposażeniem dowolnie rozważanego systemu produkcyjnego, uwzględnia stany pracy w obszarach zewnętrznym i wewnętrznym analizowanego układu. Mianowicie uwzględnione zostały: wartości poziomów pracy w łańcuchu dostaw (do i z przedsiębiorstwa) oraz wartości poziomów pracy układu wewnątrz przedsiębiorstwa w obszarze ciągłości przepływu przetwarzanego materiału oraz poziomów awaryjności urządzeń wyposażenia technologicznego. Zaprezentowany algorytm oceny priorytetów obiektów obejmuje kompleksowe ujęcie występującej synergii pojedynczego elementu systemu z całym układem (z uwzględnieniem wpływów czasu i miejsca).

Opracowany algorytm poddano weryfikacji na wybranym przykładzie systemu produkcyjnego. Zaprezentowana metoda kształtowania priorytetów wymaga dostosowania metodyki oceny do indywidulanych cech rozważanego obiektu , przy każdorazowym jej zastosowaniu. Z tego też względu analiza uwzględnia między innymi: typ i rodzaj systemu, jego złożoności w obszarze strukturalnej, funkcjonalnej i złożoności współdziałania oraz wielkości strumieni przepływu materiałów i ich częstotliwość.

Przedstawiona w artykule metoda oceny priorytetów, umożliwia wyznaczenie krytycznych elementów złożonego systemu. Ocena kształtowana jest w układzie trójwymiarowym z uwzględnieniem awarii maszyn, procesów realizacji w obszarze analizowanego systemu wytwórczego, ale również z uwzględnieniem poziomów pracy systemów zasilających (łańcuchów dostaw). Ze względów na złożoność przedstawionego algorytmu, w artykule zaprezentowano wyniki dla układu cechującego się względnie wysokim poziomem elastyczności procesowej oraz posiadającym względnie dużą liczbę procesów technologicznych. Ważnym parametrem analizowanego systemu jest wysoki poziom jakości realizacji procesów osiągając skumulowaną jakość dla wytworzonych produktów ponad cztery sigma w kryterium oceny zgodnym z metodą Six Sigma. Ponadto układ cechuje się względnie dużą zmiennością asortymentową materiałów wejściowych, co w rezultacie determinuje wielką liczbę łańcuchów dostaw na wejściu do systemu produkcyjnego. Ponadto specyfika rozpatrywanej branży jest układem wykazującym konkurencyjność wytwarzanych wyrobów finalnych stąd występuje wysoki poziom dostosowania produktów do oczekiwań klientów przekładający się na elastyczność przedsiębiorstwa.

Wnioski: Opracowany algorytm uwzględnia rozważania ujęcia systemowego zgodnie z ogólną teorią systemów według Klira oraz Meserovicza. Zaprezentowany algorytm jest ogólnym ujęciem oceny elementarnych obiektów systemu z jednoczesnym uwzględnieniem występującej synergii między pozostałymi elementami całego układu. W kolejnych etapach badań zostaną opracowane algorytmy dla różnych układów produkcyjnych (konwergentnych i dywergentnych), o różnej specyfikacji wytwórczej (przedmiotowej i technologicznej) oraz wykazujących różne poziomy wartości elastyczności procesowej. Dla opracowanych algorytmów zostanie przeprowadzona walidacja i porównanie modeli dla danych empirycznych zgromadzonych w rzeczywistych obiektach wytwórczych.

Słowa kluczowe: priorytety obiektów, łańcuch dostaw

Bożena Zwolińska ORCID ID: https://orcid.org/0000-0002-8770-091X
AGH University of Science and Technology,
al. Mickiewicza 30, 30-059 Kraków, **Poland**
phone +48 600 393 943
e-mail: bzwol@agh.edu.pl

Agnieszka A. Tubis ORCID ID: https://orcid.org/0000-0003-2993-036X
Wroclaw University of Science and Technology
ul. Wyspiańskiego 27, 50-370 Wrocław, **Poland**
phone +48 71 3203427
e-mail: agnieszka.tubis@pwr.edu.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (3), 347-361

http://doi.org/10.17270/J.LOG.2020.479

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

HYBRID AND ALTERNATE MODES OF GOVERNANCE: IMPLICATIONS FOR RELATIONAL EMBEDDEDNESS IN THE THREE-TIER SUPPLY CHAINS

Artur Świerczek

University of Economics in Katowice, Katowice, **Poland**

ABSTRACT. **Background:** Leveraging the relational embeddedness perspective, we empirically investigate whether hybrid governance (perceived as a combination of market and hierarchy), and the alternate modes of governance (non-market and non-hierarchal) are capable of providing the social layer to governance within the three-tier supply chain framework.

Methods: The study covers two research stages. In the first stage, the variables that demonstrate two modes of formal governance (both market and hierarchy) are reduced through the Principal Component Analysis (PCA) to highlight the main underlying multi-item factors. In the second stage of our research, the cluster analysis is conducted to compare different clusters in terms of relational embeddedness. As our research is exploratory in nature, we used non-parametric tests to evaluate the significance of results.

Results: The results evidence that that along with the pure mechanisms of supply chain governance (market and hierarchy), one may also identify both the hybrid and alternate modes. It corresponds to four clusters embracing three-tier supply chains with different governance mechanisms: the alternate mode, market, hybrid and hierarchy. Likewise, the study shows that both market and hybrid governance demonstrate the strongest relational embeddedness of both dyads. On the other hand, though the alternate mode of governance, perceived as neither market nor hierarchy, demonstrates stronger relational embeddedness than pure hierarchy, nevertheless the strength of its relational embeddedness is significantly lower as compared to market governance.

Conclusions: The study shows that it is difficult to reveal clearly delineated tendencies regarding both the hybrid and alternate modes of governance in terms of relational embeddedness. In fact, the hybrid mode of governance should be rather linked to market as they both are very similar, while the alternate mode of governance demonstrates a moderate strength of relational embeddedness. On the other hand, the lowest strength of relational embeddedness is still reported by hierarchy.

Key words: governance, relational embeddedness, triadic supply chain.

INTRODUCTION

The issue of supply chain governance has been widely explored in the supply chain literature, [Lewis 2001, Blome et al. 2013, Luthra, Mangla 2018]. They cover both market and hierarchy as two distinct formal modes of governance involving standards, contracts, formalized processes, and control systems, such as audits [Tachizawa, Wong, 2015]. More specifically, market involves coordination mediated by a price mechanism, whereas hierarchy concerns a supervisory structure to impose integration and apply bureaucratic routines [Williamson 1985]. Likewise, to address the gap between these two poles, the other modes of governance have been recently introduced [Leuschner et al. 2014, Foerstl et al. 2016, Meinlschmidt et al. 2018]. In the course of time, a discussion unfolded as to whether the other modes of governance are simply a combination of the constructs of market and hierarchy, or whether it would be rather

Citation: Świerczek A., 2020. Hybrid and Alternate Modes of Governance : Implications for Relational Embeddedness in the Three-tier Supply Chains. LogForum 16 (3), 347-361, http://doi.org/10.17270/J.LOG.2020.479

Received: 24.04.2020, Accepted: 29.05.2020, on-line: 30.06.2020.

perceived as a unique, alternate mode of governance, anchored between non-market and non-hierarchy. To respond to these issues, a widely-known concept of relational governance has been developed to balance the negative effects of both market and hierarchy, and act as a sort of counterweight to these formal modes of governance [Dolci et al. 2017, Wallenburg and Schaffler 2014]. In the earlier studies, the discussion on the relationship between the modes of governance was framed into a polarized 'complements versus substitutes' dichotomy. In line with this research stream, the modes of governance either complement or substitute for each other [Reimann et al. 2017]. Consequently, by reference to this dichotomy, relational governance was considered as a combination of bipolar modes that simultaneously possesses the features of market and hierarchy or non-market and non-hierarchy [Ouchi 1991, Bradach, Eccles 1989, Powell 1990, Heide, 1994]. However, in line with the latest research, market, hierarchical and relational governance are depicted as three distinct modes that coexist together, and thus form a construct often referred to as network governance [Alvarez et al. 2010]. In other words, network governance assumes that relational governance is not the outcome of the constellation of market and hierarchy anymore, but requires specific and additional efforts to be undertaken to come in force. Accordingly, the major rationale behind this perspective is that as the hybrid modes cannot provide the social dimension of governance themselves, relational governance should be rather applied as an additional form. Despite this perspective, the paper aims to return to the conceptual roots of hybrid and alternate modes of governance and empirically recognize whether a combination of market and hierarchy (or non-market and non-hierarchy) is still capable of providing social layer to governance within the three-tier supply chain framework. To gain this goal, the paper seeks to advance the concept of hybrid and alternate modes of governance through the lens of relational embeddedness. Consequently, the logic of embeddedness suggests that higher levels of joint dependence necessarily increase the depth of economic interaction between exchange partners, jumpstarting a stronger relational orientation [Gulati, Sytch 2007]. To study embeddedness, we employed a three-tier structure as the example of the smallest multi-tier supply chain. In fact, the three-tier supply chain is a type of a triad and a triad has been argued to be the smallest unit of a network [Choi, Wu 2009, Dubois 2009]. There are two major contributions of our study. First, to the best of our knowledge, this is one of very few studies that treat relational embeddedness as a common theme, shared by all types of hybrid and alternate governance structures, anchored between market and hierarchy or non-market and non-hierarchy, respectively. Second, both hybrid and alternate structures are, at best referred to the dyadic arrangements [Heide 1994, Chelariu et al. 2014]. However, Watson [2001] indicates that complex supply chains, composed of several dyads, may be governed by different modes, as compared to the governance mechanism in dyadic arrangements. To respond to this challenge, our study moves the analysis on the network level, by investigating the three-tier supply chain, composed of two dyads. The paper starts with the overview of the role of relational embeddedness in the other governance structures, positioned either between market and hierarchy or between non-market and non-hierarchy as bipolar modes. This is followed by a description of the methodology used for gathering data within the triadic context. The next section introduces major findings derived from the analysis. Finally, we conclude with a discussion, demonstrate limitations of the study and implications for future research.

LITERATURE REVIEW AND HYPOTHESIS FORMULATION

Theoretically, it is important to recognize the three-tier supply chain as a triad. It represents an arrangement consisting of two dyads connected through the middle node. In our supply chain, this middle node is the one that initiates a triad and we there shall call it as the focal company, also known as ego, while the immediate modes, positioned on both sides of the triad are known as alters [Mentzer et al. 2007]. These three actors are directly linked by one or more of the upstream and downstream flows of products, information and finances in the three-tier supply chain [Wuyst et al. 2004].

In this study, the three-tier supply chain is composed of the manufacturer in the middle, its supplier on the upstream and its customer on the downstream. In such the triadic supply chain, the manufacturer through its privileged position between two disconnected actors, holds a key to running the mechanism of governance [Li, Choi 2009, Yang et al. 2011]. Governance can be defined as written or non-written rules that guide, regulate and control social life and features which are emanated from power [Barnett, Duvall 2005, Crisan 2016]. From the classical perspective of the Relational Contracting Theory and Transaction Cost Analysis (TCA), governance is viewed as the choice between market and hierarchy [Williamson 1985]. Conceptually, market involves formal, explicit and legally enforceable inter-organisational agreements that define the roles, rights and responsibilities of exchange actors and establish safeguards against potential opportunism [Poppo, Zenger, 2002]. Consequently, market governance revolves around the notion of price determined in the contract [Gereffi, Lee 2012]. Hierarchy, on the other hand, occurs in organizations and is based on control anchored in organizational structures. It has clear organizational boundaries, lines of authority, detailed report mechanisms, and formal decision-making procedures [Powell 1990]. It thus requires some form of overt rule-driven design and direction [Thompson 2003]. In line with hierarchy, individual companies operate under a regime of administrative procedures and work roles defined by the most powerful supply chain actor [Powell 1990]. Following the study of Bradach and Eccles [1991] we argue that market and hierarchy are not sole ideal types, distinctly existing as individual modes of supply chain governance. Quite the contrary, supply chain governance is a combination of these two mechanisms, as their content and strength define the specific configuration of enacted governance mechanism. Accordingly, we argue that the share of market and hierarchy in supply chain governance is diverse, and does not necessarily require all these modes to ensure balance. We also think that over time we would observe more than one mode of governance in a particular supply chain. In other words, the supply chain governance is dynamic, as the constructs of market and hierarchy may demonstrate a diverse content and relative strength. In fact, from the multi-tier perspective, they may overlap in the particular dyad as well as between dyads. As a consequence, supply chain governance may remain inherently idiosyncratic and unique [Brass et al., 2004, Huxham, Vangen, 2005]. What this means is that once a focal firm is able to establish a specific form of governance, it would be difficult for other firms to imitate [Czakon 2011, Christopher 1996, Foss, 1999]. For instance, Toyota has always been willing to share the knowledge about its supply chain practices, largely because it understands knowing and doing are two different issues [Liker 2004]. Thus, we postulate the following hypothesis:

H1: The three-tier supply chains differentiate in terms of governance mechanisms.

Beyond the recognition of market and hierarchy, as mutually exhaustive bipolar framework of governance, there have been numerous attempts to develop the hybrid or alternate modes to supplement the existing model with other characteristics [Williamson 2008, Hernandez-Espallardo et al. 2010, Skjoett-Larsen 2000]. Hybrid governance has been framed as a mode filling the gap between market and hierarchy. In line with the first approach, hybrid mode acts as relational governance which is placed between market and hierarchy [Heide, 1994, Gereffi et al., 2005]. It thus develops with the increasing number of recurring transactions when moving on in the continuum from market to hierarchy [Bensaou 1999]. Nonetheless, the other view usually acknowledges that the alternate modes of governance are non-market and non-hierarchical and thus possess neither market nor hierarchical characteristics [Ouchi 1980, Bradach, Eccles 1989]. According to this approach, hybrid governance can no longer be placed in the continuum between market and hierarchy, quite the contrary, is should be positioned on the continuum anchored between non-market and non-hierarchy. In the previous studies, the other than formal modes of governance were usually referred to relational governance which was supposed to add necessary social dimension to purely economic transactions performed between the exchange partners. However, they also show that relational governance should be rather developed as an independent mode whose antecedents are not anchored in market and hierarchy [Larson 1992]. In consequence, researchers started to move beyond the simplified relationships between the modes of governance in favor to investigate the conditions under which formal and relational governance interact in specific ways [Reimann et al., 2017]. To respond to this ambiguity, the study traces the conceptual roots of governance and empirically recognizes whether hybrid and alternate governance are still capable of providing social layer to governance within the three-tier supply chain framework. To offer a potential link between economical and sociological accounts of business behavior in supply chains, we turn to the concept of relational embeddedness, defined as a 'combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie' [Granovetter 1973]. Thus, relational embeddedness changes a partner's attitude from self-interest to credit and reduces the risk of egoistic behavior during the course of cooperation [Li, Yang 2017]. Appreciating the latest research findings on the role of relational governance as the extra third mode that forms a basic governance structure of supply chains, we tend to empirically investigate whether both hybrid and alternate modes of governance, still provide a requisite level of relational embeddedness. Consequently, as strong relational embeddedness is rarely accomplished automatically and spontaneously, we postulate that it requires establishing hybrid governance, anchored between market and hierarchy or alternate mode of governance, anchored between non-market and non-hierarchy: Thus, we offer the following hypothesis:

H2: Hybrid governance perceived as a combination of market and hierarchy demonstrates stronger relational embeddedness in comparison to the governance mechanisms composed of either market or hierarchy alone.

H3: Alternate governance perceived as neither market nor hierarchy demonstrates stronger relational embeddedness in comparison to the governance mechanisms composed of either market or hierarchy alone.

METHODOLOGY

Sample and Research Instrument

The process of data gathering that involves a multiple-respondent approach, consisted of several stages. More specifically, to collect data from all three actors forming the triadic supply chain, we combined methods based on probability and non-probability sampling. Firstly, to obtain data from the manufacturers, the stratified sampling method was applied, followed by the snowball sample method to gather information from the suppliers and the customers. Initially, the sample of 98 Polish manufacturers was targeted, out of which, a group of 10 companies refused to fill in the questionnaire, alleging that their suppliers or customers will not be willing to take part in this research. Likewise, a large group of 50 manufacturers encountered problems with a bad attitude of suppliers or customers towards the questionnaire. Finally, a group of 4 manufacturers managed to encourage their suppliers and customers to participate in the survey, however after receiving the questionnaire, they refused to take part in the research. Accordingly, the remaining portion of 34 triads that form a simultaneous relationship with both a supplier and a customer were investigated in the study.

The questionnaire, used in this survey, consisted of several measurement items covering the issues of market and hierarchy as two bipolar modes of governance, and relational embeddedness. Most of the measurement items were operationalized in prior research; however, some of them were also derived from the literature review. The structure of the survey questionnaire was adapted to certain groups of respondents – actors playing different roles in the examined triadic supply chains. Accordingly, depending on the function served in a triad, each responding company answered a specific set of questions. Due to its central location, the manufacturer answered the questions concerning different modes of governance in the upstream and downstream dyad and relational embeddedness, separately for both dyads – one formed with its supplier, and the other one established with its customer. The other two groups of actors in a triad, the suppliers and the customers, answered the questions concerning governance and relational embeddedness yielded in a certain dyad formed with the manufacturer. The obtained responses from both actors forming a dyad were then captured as averaged scores indicating modes of governance in a bilateral arrangement. Correspondingly, the measures of relational embeddedness were formed by the average scores obtained separately for both dyads.

Research Methods and Analysis

To explore the role of relational embeddedness in supply chain governance, a statistical analysis has been performed. In the first step, the variables indicating certain modes of governance and relational embeddedness of upstream and downstream dyads were narrowed down to the main underlying multi-item constructs through the Principal Component Analysis (PCA) with Varimax Rotation. In the second step, the factor scores, obtained through the PCA, for the certain modes of governance were used as criteria for classifying the sample into homogenous groups. As a classification method, a cluster analysis with a two-step approach recommended by Ketchen and Shook [1996] was employed. Consequently, we applied a hierarchical cluster analysis to determine the number of clusters, followed by K-means cluster analysis to perform a group profiling and make necessary comparisons of the obtained clusters in terms of the remaining constructs of relational embeddedness yielded in the upstream and downstream dyads.

Principal Component Analysis

To identify basic modes of governance in the investigated supply chains, the PCA was carried out originally in two groups of 11 variables each, which manifested governance of both upstream and downstream dyads. 1 variable from the group of variables concerning governance in the upstream dyad was dropped for its moderate exploratory relevance, as indicated by the factor loading that did not exceed 0.6 [Kline 1994]. In the second group, all variables were accepted for the further analysis demonstrating satisfying values of individual sampling adequacy and factor loadings. Based on the Kaiser criterion and eigenvalues for each factor, the analysis showed a clean factor-loading pattern with minimal cross-loadings and high loading on the one construct.

In both groups reflecting modes of governance in the upstream and downstream dyads, the PCA produced three constructs - two constructs of hierarchical governance and one construct of market governance – Table 1. More specifically, the constructs of governance in the upstream dyads (HUD_1, HUD_2, MUD) and downstream dyads (HDD_1, HDD_2, MDD) explain 77.90 and 76.44 of total variance, respectively. Interestingly, the constructs revealed in both groups are rather clearly delineated regarding the specific modes of governance, expect for one item, initially classified as the variable measuring market governance (M5). To check the internal consistency of extracted constructs, we calculated the Cronbach's alpha coefficients which indicated satisfying level of at least .7 for each construct. Apart from the factors manifesting the modes of governance, we also used the PCA with Varimax Rotation to extract the underlying factors of relational embeddedness.

Table 1. Rotated Component Matrices (left for the upstream dyad, right for the downstream dyad)

	Component		
	HUD_1	MUD	HUD_2
M5_UD	0.917		
H1_UD	0.898		
H2_UD	0.786		
H3_UD	0.694		
M1_UD		0.881	
M4_UD		0.834	
M2_UD		0.786	
H5_UD			0.927
H6_UD			0.893
H4_UD			0.737

The PCA was carried out in two groups of 19 variables each, which manifested relational embeddedness of both upstream and downstream dyads. Based on the results of anti-image correlation matrices and factor loadings, 4 and 2 items were dropped from the further analysis for the upstream and downstream dyad, respectively. In consequence, two constructs of relational embeddedness, composed of 15 and 17 variables for the upstream and downstream dyad, respectively were used in the further investigation.

Cluster Analysis

Interpretation of Clusters

The scores of factors manifesting governance were employed as clustering criteria in the second step of the analysis. At first, to determine the number of clusters a hierarchical cluster analysis with Ward's partitioning method and squared Euclidean distance was performed. The Ward's method attempted to minimize the sum of squares of any hypothetical clusters, which can be formed at each step. To determine the optimal number of groups, we used dendrogram to display dissimilarity levels between clusters. The heights of the links represent the distance at which each fusion is made, such that a greater dissimilarity between the objects indicates a greater distance between them and a taller link (Montalbano and Nenci, 2014). The optimal number of groups was derived by comparing the coefficients in the agglomeration schedule. The highest difference between the coefficients can be observed when four clusters are derived. To assign each case to the appropriate cluster, the number of 4 clusters was used to conduct K-means cluster analysis. The criterion of the cluster membership was the minimal Euclidean distance between each case and classification center represented by centroid (cluster center). In order to additionally validate the results of clustering, the outcome of K-means cluster analysis was compared with the class assignment obtained from the hierarchical cluster analysis. The Rand Index showed that 78.4 percent pairs of objects are placed in the same class. It means a high level of agreement and confirming the correct choice of K-means cluster analysis as the leading clustering method (Krieger and Green, 1999). The obtained clusters contain a diverse share of the research sample. To determine the statistical significance of criteria for 4 groups, the Kruskal Wallis H test was applied – Table 2.

Table 2. Kruskal-Wallis H Test for the governance constructs in four clusters

Test Statistics

	HUD_1	MUD	HUD_2	MDD	HDD_1	HDD_2
Kruskal-Wallis H	22.906	13.511	8.142	14.448	20.455	6.223
df	3	3	3	3	3	3
Asymp. Sig.	0.000	0.004	0.043	0.002	0.000	0.101

As depicted in Table 2, 1 construct (i.e. HDD_2) should be eliminated from the further analysis as it turned out to be insignificant at $p < .05$. Figure 1 depicts the final cluster centers (medians) obtained from the governance constructs.

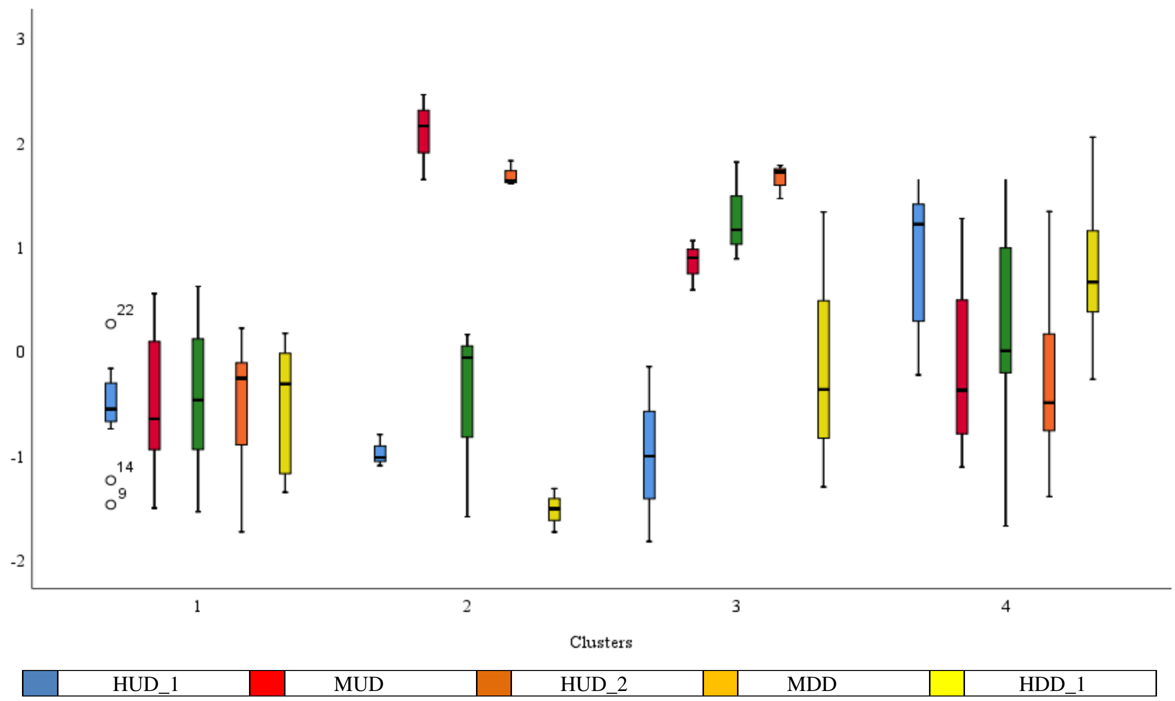


Fig. 1. Boxplots for clusters depicting the intensity of the modes of governance

The remaining set of 5 constructs of governance in the upstream and downstream dyads significantly differentiates the four clusters. Our study shows that regarding the intensity of the modes of governance across the investigated triads, some indicative tendencies may be revealed. Drawing upon the median scores of factors depicting the intensity of the modes of governance across 4 clusters, we conclude that cluster 1 covers the group of triads that apply neither market nor hierarchy, and thus it can be referred to as the alternate governance cluster. Cluster 2 groups the triads that are governed by market in the upstream and downstream dyads, whereas cluster 4 represents the triads that apply hierarchical governance in both dyads. Interestingly, cluster 3 includes the triads that share the modes of governance by simultaneously applying some market and some hierarchy. Consequently, cluster 2 will be referred to as the market governance cluster, cluster 3 as the hybrid group, while cluster 4 will be termed as the hierarchical governance cluster.

Profiling of the Clusters in terms of relational embeddedness

In order to reveal the strength of relational embeddedness in the three-tier supply chains applying different modes of governance, we first tested whether the differences among clusters are significant for relational embeddedness of upstream and downstream dyads. Table 3 depicts the Mann-Whitney U Test statistics for three clusters.

As indicated in Table 3, there are significant differences among clusters. This means that the modes of governance significantly differ the groups of three-tier supply chains. However, Table 3 also shows that governance does not differ two clusters (at $p < .05$) - one cluster governed by market, and another governed by the hybrid mode.

Table 3. Mann-Whitney U test statistics for clusters

Cluster		Upstream dyad	Downstream dyad
Alternate governance (neither market nor hierarchy) - market governance	Mann-Whitney U	0.000	0.000
	Z	-2.625	-2.625
	Asymp. Sig. (2-tailed)	0.009	0.009

Alternate governance (neither market nor hierarchy) - Hybrid governance (combination of market and hierarchy)	Mann-Whitney U	0.000	0.000
	Z	-2.625	-2.625
	Asymp. Sig. (2-tailed)	0.009	0.009
Alternate governance (neither market nor hierarchy) - hierarchical governance	Mann-Whitney U	41.000	51.000
	Z	-2.603	-2.142
	Asymp. Sig. (2-tailed)	0.009	0.032
Market Governance - Hybrid governance (combination of market and hierarchy)	Mann-Whitney U	2.000	2.000
	Z	-1.091	-1.091
	Asymp. Sig. (2-tailed)	0.400	0.400
Market Governance - hierarchical governance	Mann-Whitney U	0.000	0.000
	Z	-2.666	-2.666
	Asymp. Sig. (2-tailed)	0.008	0.008
Hybrid governance (combination of market and hierarchy) - hierarchical governance	Mann-Whitney U	0.000	0.000
	Z	-2.666	-2.666
	Asymp. Sig. (2-tailed)	0.008	0.008

Table 4. Mann-Whitney U test ranks for clusters in the upstream and downstream dyads

		Upstream embeddedness		Downstream embeddedness	
Cluster *(governance mechanism)*	N	Mean rank	Sum of ranks	Mean rank	Sum of ranks
Alternate governance (neither market nor hierarchy)	13	7.00	91.00	7.00	91.00
Market governance	3	15.00	45.00	15.00	45.00
Total	16				
Alternate governance (neither market nor hierarchy)	13	7.00	91.00	7.00	91.00
Hybrid governance (combination of market and hierarchy)	3	15.00	45.00	15.00	45.00
Total	16				
Alternate governance (neither market nor hierarchy)	13	18.85	245.00	18.08	235
Hierarchical governance	15	10.73	161.00	11.4	171
Total	28				
Market governance	3	2.67	8.00	2.67	8.00
Hybrid governance (combination of market and hierarchy)	3	4.33	13.00	4.33	13.00
Total	6				
Market governance	3	17.00	51.00	17.00	51.00
Hierarchical governance	15	8.00	120.00	8.00	120.00
Total	18				
Hybrid governance (combination of market and hierarchy)	3	17.00	51.00	17.00	51.00
Hierarchical governance	15	8.00	120.00	8.00	120.00
Total	18				

As shown in Table 4, the Mann-Whitney U test mean ranks suggest that the clusters covering both market and hybrid governance indicate the highest and similar strength of relational embeddedness across the four groups. Moreover, the cluster of alternate governance indicates a moderate strength, while the group covering hierarchy, reports the lowest strength of relational embeddedness as compared to other groups.

RESULTS AND DISCUSSION

The study sought to investigate whether hybrid governance as a combination of market and hierarchy, and the alternate modes of governance that are non-market and non-hierarchical are still capable of providing social dimension to governance within the three-tier supply chain framework. To achieve this aim, we first examined whether the three-tier supply chains differentiate in terms of the different modes of governance. Our study confirmed that along with the pure mechanisms of supply chain governance (market and hierarchy), one may also identify both the hybrid and alternate modes. Consequently, the hybrid mechanism demonstrates that market and hierarchy can be intertwined and combined together in various ways. The spectacular evidence for that is delivered by cluster 3 that gathers the three-tier supply chains, governed by the mechanism that simultaneously shares some portion of market and some portion of hierarchy. On the other hand, cluster 1 consists of the triads that are simultaneously governed by non-market and non-hierarchical modes. This group clearly shows that distinct mechanisms of governance in the three-tier supply chains also exist. Interestingly, however, the pure mechanism of market and hierarchy may be also identified in supply chains, represented by clusters 2 and 4. These two latter clusters fit into the concept of substitutive nature of governance mechanisms, which posits that the use of one governance mode makes the other less useful or even superfluous [Wallenburg, Schaffler, 2014]. In line with this view, market and hierarchy as two formal modes of governance undermine social processes, hamper the formation of trust and destroy establishing a deeper commitment covered by relational governance. This tendency is even more preserved in clusters 2 and 4, when hierarchy is analysed. In case of these two clusters, the influence of both constructs manifesting hierarchy in the upstream dyad goes in the same direction with the positive or negative intensity. Moreover, it is also worth noting that in case of clusters demonstrating pure mechanisms of supply chain governance (i.e. market and hierarchy), certain mechanisms are coherent regarding both dyads. For instance, in the market governance cluster, both dyads are governed by the market, while in case of cluster applying hierarchy, both dyads of three-tier supply chains are governed by hierarchy. This may stem from the fact that the focal company, that in charge of the triadic arrangement, tends to unify the modes of governance across the triad. In other words, the manufacturer, positioned centrally in its three-tier supply chain, shifts the similar modes of governance from one dyad to another. This tendency might be even enhanced when the manufacturer reaps substantial benefits from the particular mode of governance in a certain dyad. For that reason, through its privileged position as a gate-keeper between suppliers and customers, the manufacturer can be especially encouraged to adapt a similar mode of governance to the other dyadic arrangements in its triad.

In case of hybrid governance, there is an interplay between market and hierarchy which results in yielding relational embeddedness. This may demonstrate the complementary nature between two formal modes of governance as illustrated by Peppo and Zenger [2002]. However, it is also worth mentioning that not only can this interplay be observed between market and hierarchy, but also between specific modes of governance. Hierarchy serves as a very good example in cluster 3 by showing that the intensity of two constructs of hierarchy in the upstream dyads goes in the opposite direction. This indicates a trade-off relationship in the womb of specific governance mechanism. Interestingly however, this interplay also exists between both dyadic arrangements in the hybrid governance cluster. Therefore, according to the complementary nature of the formal modes of governance, the emergence of relational embeddedness in the hybrid governance cluster may contribute to covering so called the blank spots typical for the formal modes of market and hierarchy, especially when planning and in-advance designing may turn out to inefficiently respond to unexpected events. Consequently, performing joint actions, based on social interactions and relational norms, may fill in the gap of the disadvantages of either pure market or pure hierarchy [Wallenburg and Schaffler, 2014]. In the light of the aforementioned, we conclude that the three-tier supply chains differentiate in terms of governance mechanisms composed of both formal modes (pure market and pure hierarchy) and other modes (hybrid and alternate) of governance. The obtained outcome gives support to H1.

Further on, the study also shows that two clusters of three-tier supply chains, governed either by market or the hybrid structure significantly differ from the remaining clusters covering supply chains with the alternate and hierarchical modes of governance in terms of relational embeddedness. Both the market and hybrid governance clusters demonstrate the strongest relational embeddedness of both dyads. Following Jones et al. [1997], we argue that both modes of governance may arise from increasing complexity and thus the need to negotiate with many social actors. In other words, the cluster including supply chains governed by the depicts a retreat from the pure market and hierarchy to more socialized ways of governance, covering the pluralistic perspective. It thereby shows a movement from formal authority to collective coordinating, social steering and influencing. Following Ouchi [1980], we argue that hierarchy can add some aspects of relational embeddedness (such as trust) to governance, as actors can assume some commonality of purpose. The congruence of goals is developed through establishing long-term relationships, typical for hierarchy, that will reward good performance and reduce the opportunistic behavior of actors in supply chains. The obtained findings may suggest that incorporating some market and some hierarchy contributes to higher relational embeddedness of both dyads in the three-tier supply chains. This may serve as a good starting point for a development of relational governance. The socialization process reflects the extent to which an interorganizational relationship is governed by the social relations and shared norms, such as informal structures and self-enforcement [Mirkovski et al., 2016]. On the other hand, the alternate modes of governance are still capable of providing some relational embeddedness however its strength is profoundly limited as compared to market and the hybrid mode governance. The most interesting outcome can be revealed while analysing the role of relational embeddedness in hierarchy. Williamson [1981] argues that the level of collaboration in case of hierarchy is higher than in market governance, so by analogy, one may suspect that the strength of relational embeddedness will be higher in the three-tier supply chains governed by hierarchy. However, our study appears to contradict the commonly held assumption by showing that it is actually market governance that demonstrates higher strength of relational embeddedness. This might be further substantiated by the findings of Mena et al. [2009] who analyse case studies indicating that hierarchy leads to the lower level of collaboration than market.

To sum up, our study shows that the hybrid mode of governance, anchored between bipolar modes of market and hierarchy contributes to establishing strong relational embeddedness. Though, the cluster of three-tier supply chains, governed by this mode demonstrates significantly higher mean ranks for relational embeddedness of both dyads, as compared to the clusters implementing the alternate mode and hierarchy, it still does not significantly differ from the cluster covering market governance. In this light, we give partial support to H2 by evidencing that hybrid governance, perceived as a combination of market and hierarchy, demonstrates stronger relational embeddedness than the governance mechanisms composed of hierarchy alone. Likewise, it shows similar strength of relational embeddedness to market governance. On the other hand, our study also partially support H3 by showing that the alternate mode of governance, perceived as neither market nor hierarchy, demonstrates stronger relational embeddedness than hierarchy alone. However, the strength of its relational embeddedness is significantly lower as compared to market governance.

In the light of the aforementioned, it is worth noting that it is difficult to reveal clearly delineated tendencies regarding both the hybrid and alternate modes of governance in terms of relational embeddedness. In fact, the hybrid mode of governance should be rather linked to market as they both are very similar, while the alternate mode of governance demonstrates a moderate strength of relational embeddedness. On the other hand, the lowest strength of embeddedness is still indicated by hierarchy.

LIMITATIONS OF THE STUDY AND FURTHER RESEARCH AVENUES

The limitations of this study pave the way for new research opportunities. First, though, in line with the multi-tier view, the supply chains are classically studied via the incremental examination of multiple dyadic relationships, emanating from the focal actor, this perspective may not accurately reflect the complexity of contemporary supply chains. To embrace the full complexity of supply chains, the study should go beyond the triadic perspective, and thus incorporate a larger number of actors involved in the flow of products, information and finances in supply chains. Second, apart from extending the number of actors forming the overall structure of network, future research should also address the issue of sample size. In other way, moving forward the empirical validation, the number of the units of network, forming the research sample, should be taken into account. This will contribute to increasing the reliability of sample and the validity of research findings. Finally, though our study showed that both the hybrid and alternate modes of governance yield some strength of relational embeddedness, it would be worthwhile to investigate the quality and constitutive features of embeddedness obtained from these two modes in comparison to embeddedness obtained from relational governance as the third additional and complementary mode of governance.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The study was financed by the National Science Centre, Poland as a research project no. 2015/18/M/HS4/00388.

REFERENCES

Alvarez G., Pilbeam C., Wilding R., 2010. Nestle Nespresso AAA sustainable quality program: An investigation into the governance dynamics in a multi-stakeholder supply chain network. Supply Chain Management: An International Journal, 15, 2, 165-182. http://doi.org/10.1108/13598541011028769

Barnett M., Duvall R., 2005. Power in global governance, Cambridge University Press.

Bensaou M., 1999. Portfolios of buyer-supplier relationships, Sloan Management Review, 40, 4, 35-44.

Blome C., Schoenherr T., Kaesser M, 2013. Ambidextrous governance in supply chains: The impact on innovation and cost performance. Journal of Supply Chain Management, 49, 4, 59-80. http://doi.org/10.1111/jscm.12033

Bradach J.L., Eccles R.G., 1989. Price, authority, and trust: From ideal types to plural forms. Annual Review of Sociology, 15, 97–118.

Bradach J., Eccles R., 1991. Price, Authority and Trust: From Ideal Types to Plural Forms in G. Thompson, J. Frances, R. Levacic and J. Mitchell (eds.) Markets, Hierarchies and Networks: The Co-ordination of Social Life, London: Sage Publications.

Brass D.J., Galaskiewicz J., Greve H.R., Tsai W., 2004. Taking stock of networks and organizations: A multilevel perspective. Academy of Management Journal, 47, 6, 795-817.

Chelariu C., Asare A.K., Brashear-Alejandro T., 2014. A Rose, by any other name"...: Relationship typology and performance measurement in supply chains. Journal of Business & Industrial Marketing, 29, 4, 332-343.

Choi T.Y., Wu Z., 2009. Triads in supply networks: theorizing buyer-supplier-supplier relationships. Journal of Supply Chain Management, 45, 1, 8-25. http://doi.org/10.1111/j.1745-493X.2009.03151.x

Christopher M., 1996. Networks and logistics: managing supply chain relationships. Asia-Australia Marketing Journal, 4, 1, 19-24.

Cousins P., Lamming R., Lawson B., Squire B., 2008. Strategic Supply Management: Principle, Theories and Practice, Pearson Education Limited, Harlow.

Crisan E., 2016. A separation between supply chain management and supply chain governance. Revista De Management Comparat International, 17, 3, 240-249.

Dolci P., Maçada A., Paiva E., 2017. Models for understanding the influence of Supply Chain Governance on Supply Chain Performance, Journal of Supply Chain Management, 22, 5, 424-441. http://doi.org/10.1108/SCM-07-2016-0260

Dubois A., 2009. Comment on "Taking the leap from dyads to triads: Buyer-supplier relationships in supply networks" by Choi and Wu – To leap or not to leap: Triads as arbitrary subsets of networks of connected dyads. Journal of Purchasing & Supply Management, 15, 267-268. http://doi.org/10.1016/j.pursup.2009.08.002

Foerstl K., Kirchoff J.F., Bals L., 2016. Reshoring and Insourcing: Drivers and Future Research Directions. International Journal of Physical Distribution & Logistics Management, 46, 5, 492-515. http://doi.org/10.1108/IJPDLM-02-2015-0045

Foss N.J., 1999. Networks, capabilities, and competitive advantage, Scandinavian Journal of Management, 15, 1-15.

Gereffi G., Humphrey J., Sturgeon T., 2005. The governance of global value chains, Review of International Political Economy, 12, 1, 78-104.

Gereffi G., Lee J., 2012. Why the World Suddenly Cares About Global Supply Chains. Journal of Supply Chain Management, 48, 24-32. http://doi.org/10.1111/j.1745-493X.2012.03271.x

Granovetter M.S., 1973, The Strength of Weak Ties. American Journal of Sociology, 78, 6, 1360-1380.

Gulati R., Sytch M., 2007. Dependence Asymmetry and Joint Dependence in Interorganizational Relationships: Effects of Embeddedness on a Manufacturer's Performance in Procurement Relationships. Administrative Science Quarterly, 52, 32-69. http://doi.org/10.2189/asqu.52.1.32

Heide J.B., 1994. Interorganizational Governance in Marketing Channels. Journal of Marketing, 58, 1, 71-85.

Hernández-Espallardo M., Rodríguez- Orejuela A., Sánchez-Pérez M., 2010, Inter-organizational governance, learning and performance in supply chains. Supply Chain Management: An International Journal, 15, 2, 101-114. http://doi.org/10.1108/13598541011028714

Huang M.C., Cheng H.L., Tseng C.Y., 2014. Re-examining the direct and interactive effects of governance mechanisms upon buyer–supplier cooperative performance. Industrial Marketing Management, 43, 4, 704-716. http://doi.org/10.1016/j.indmarman.2014.02.001

Huxham C., Vangen S., 2005. Managing to Collaborate. Routledge, London.

Ireland D., Webb J.W., 2007. A multi-theoretic perspective on trust and power in strategic supply chains. Journal of Operations Management, 25, 482-497. http://doi.org/10.1016/j.jom.2006.05.004

Jones C., Hesterly W., Borgatti S., 1997. A General Theory of Network Governance: Exchange Conditions and Social Mechanisms, Academy of Management Review, 22, 4, 911-945. http://doi.org/10.2307/259249

Ketchen D.J., Shook Ch.L., 1996. The application of cluster analysis in strategic management research: an analysis and critique, Strategic Management Journal, 17, 6, 441-458. http://doi.org/10.1002/(SICI)1097-0266(199606)17:6<441::AID-SMJ819>3.0.CO;2-G

Kline P., 1994. An Easy Guide to Factor Analysis, TJ Press, Padstow.

Krieger A.M., Green P.E., 1999. A generalized rand-index method for consensus clustering of separate partitions of the same data base. Journal of Classification, 16, 1, 63-89. http://doi.org/10.1007/s003579900043.

Lambert D.M., García-Dastugue S.J., Croxton K.L., 2005. An evaluation of process-oriented supply chain management frameworks. Journal of Business Logistics, 26, 25-51. http://doi.org/10.1002/j.2158-1592.2005.tb00193.x

Larson A., 1992. Network dyads in entrepreneurial settings: A study of the governance of exchange relationships. Administrative Science Quarterly, 37, 1, 76-104.

Leuschner R., Carter C.R., Goldsby T.J., Rogers Z.S., 2014. Third-Party Logistics: A Meta-Analytic Review and Investigation of its Impact on Performance. Journal of Supply Chain Management, 50, 1, 21-43. http://doi.org/10.1111/jscm.12046

Lewis I., 2001. Logistics and electronic commerce: An interorganizational systems perspective. Transportation Journal, 40, 4, 5-13.

Li D., Yang J., 2017 The effect of dual relational embeddedness and trust on alliance governance, International Journal of Business in Society, 17, 5, 913-926. http://doi.org/10.1108/cg-10-2016-0193

Li.M.,.Choi.T.Y.,.2009..Triads.in.Services.Outsourcing: Bridge, Bridge Decay and Bridge Transfer Journal of Supply Chain Management, 45, 3, 27-39. http://doi.org/10.1111/j.1745-493X.2009.03169.x

Liker J., 2004. The Toyota Way. Mcgraw-Hill Education Ltd.

Luthra S., Mangla S.K., 2018. Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies, Process Safety and Environmental Protection, 117, 168-179. http://doi.org/10.1016/j.psep.2018.04.018

Malhotra D., Lumineau F., 2011. Trust and collaboration in the aftermath of conflict: The effects of contract structure. Academy of Management Journal, 54, 981-998. http://doi.org/10.5465/amj.2009.0683

Meinlschmidt J., Schleper M.C, Foerstl K., 2018. Tackling the sustainability iceberg: a transaction cost economics approach to lower tier sustainability management. International Journal of Operations & Production Management 38, 10, 1888-1914. http://doi.org/10.1108/IJOPM-03-2017-0141

Mena C., Humphries A., Wilding R., 2009, A comparison of inter- and intra-organizational relationships: Two case studies from UK food and drink industry, International Journal of Physical Distribution & Logistics Management, 39, 9, 762-784. http://doi.org/10.1108/09600030911008193

Mentzer J., Stank T.P., Myers M.B., 2007. Why Global Supply Chain Management? SAGE Publications, Inc.

Mirkovski K., Lowry P.B., Feng B., 2016. Factors that influence interorganizational use of information and communications technology in relationship-based supply chains: evidence from the Macedonian and American wine industries, Supply Chain Management: An International Journal, 21, 3, 334-351. http://doi.org/10.1108/SCM-08-2015-0343.

Montalbano P., Nenci S., 2014. The Trade Competitiveness of Southern Emerging Economies: A Multidimensional Approach Through Cluster Analysis. World Economy, 37, 6, 783-810. http://doi.org/10.1111/twec.12195.

Ouchi W., 1991. Markets, Bureaucracies and Clans, in G. Thompson, J. Frances, R. Levacic, J. Mitchell (eds), Markets, Hierarchies and Networks: The Co-ordination of Social Life, Sage, London.

Poppo L., Zenger T., 2002. Do formal contracts and relational governance function as substitutes or complements? Strategic Management Journal, 23, 707-725.

Powell W.M., 1990. Neither Market nor Hierarchy; Network Forms of Organization. In B. M. Staw, L. L. Cummings (Eds.), Research in Organizational Behavior. Greenwich, CT: JAI Press.

Reimann F., Kosmol T., Kaufmann L., 2017. Responses to Supplier-Induced Disruptions: A Fuzzy-Set Analysis. Journal of Supply Chain Management, 53, 4, 37-66. http://doi.org/10.1111/jscm.12141.

Ritter T., Wilkinson I.F., Johnston W.J., 2004. Managing in complex business networks, Industrial Marketing Management, 33, 3, 175-183. http://doi.org/10.1016/j.indmarman.2003.10.016.

Skjoett-Larsen T., 2000. Third party logistics – from an interorganizational point of view. International Journal of Physical Distribution & Logistics Management, 30, 2, 112-27. http://doi.org/10.1108/09600030010318838

Tachizawa E.M., Wong C.Y., 2015. The performance of green supply chain management governance mechanisms: a supply network and complexity perspective, Journal of Supply Chain Management, 51, 3, 18-32. http://doi.org/10.1111/jscm.12072

Thompson G.F., 2003. Between Hierarchies and Markets: The Logic and Limits of Network Forms of Organization, Oxford University Press, New York, NY.

Wallenburg C.M., Schäffler T., 2014. The Interplay of Relational Governance and Formal Control in Horizontal Alliances: A Social Contract Perspective. Journal of Supply Chain Management, 50, 2, 41-58. http://doi.org/10.1111/jscm.12041

Watson G., 2001. Subregimes of power and integrated supply chain management. Journal of Supply Chain Management, 37, 1, 36-41. http://doi.org/10.1111/j.1745-493X.2001.tb00098.x

Williamson O.E., 2008. Outsourcing: transaction cost economics and supply chain management. Journal of Supply Chain Management, 44, 5-16. http://doi.org/10.1111/j.1745-493X.2008.00051.x

Williamson O.E., 1981. The modern corporation : origins, evolution, attributes. Journal of Economic Literature, 19, 1537-1568.

Williamson O.E., 1985. The Economic Institutions of Capitalism, Free Press, New York, NY.

Wuyst S., Stremersch S., Van Den Bulte C., Franses, P.H., 2004, Vertical marketing systems for complex products: A triadic perspective. Journal of Marketing Research, 41, 4, 479-487. http://doi.org/10.1509/jmkr.41.4.479.47015

Yang H., Sun S..L., Lin Z., Peng M. W., 2011. Behind M&As in China and the United States: Networks, learning, and institutions. Asia Pacific Journal of Management, 28, 2, 239-255. http://doi.org/10.1007/s10490-009-9188-6

HYBRYDOWE I ALTERNATYWNE MECHANIZMY KOORDYNACJI DZIAŁAŃ WIELOPODMIOTOWYCH: IMPLIKACJE DLA ZAKORZENIENIA RELACYJNEGO W TRIADYCZNYCH ŁAŃCUCHACH DOSTAW

STRESZCZENIE. **Wstęp:** Artykuł podejmuje próbę zbadania czy hybrydowe (postrzegane jako kombinacja rynku i hierarchii) oraz alternatywne (nierynkowe i niehierarchiczne) mechanizmy koordynacji umożliwiają wyłonienie aspektu społecznego, wzbogacającego proces regulacji działań wielopodmiotowych w triadycznych łańcuchach dostaw

Metody: W warstwie empirycznej badania obejmują dwa etapy. W pierwszym etapie dokonano redukcji zmiennych manifestujących dwa formalne mechanizmy koordynacji działań wielopodmiotowych (rynek i hierarchię) za pomocą analizy głównych składowych. W kolejnym etapie badania przeprowadzono analizę skupień w celu porównania zróżnicowanych grup łańcuchów dostaw ze względu na zakorzenienie relacyjne. W celu identyfikacji poziomu istotności w artykule wykorzystano nieparametryczne testy statystyczne.

Wyniki: Badanie pokazało, że obok stricto rynkowych i hierarchicznych mechanizmów koordynacji działań w badanych łańcuchach dostaw występują również mechanizmy hybrydowe i alternatywne. Korespondują one ze zidentyfikowanymi czterema grupami łańcuchów dostaw. Ponadto, rynkowy, jak i hybrydowy mechanizm koordynacji wyróżnia najwyższy stopień zakorzenienia relacyjnego obu diad w badanych strukturach triadycznych. Z drugiej strony, mimo że alternatywny mechanizm koordynacji, postrzegany jako nierynkowy i niehierarchiczny, wskazuje wyższy stopień zakorzenienia relacyjnego w stosunku do mechanizmu hierarchicznego, to jednak siła jego zakorzenienia relacyjnego jest istotnie niższa w stosunku do zakorzeniania relacyjnego wskazywanego przez mechanizm rynkowy.

Podsumowanie: Przeprowadzone badania pokazują, że trudno jest praktycznie wskazać określone tendencje dotyczące zarówno hybrydowego, jak i alternatywnego mechanizmu koordynacji działań wielopodmiotowych w kontekście zakorzenienia relacyjnego diad w strukturach triadycznych. Niemniej, hybrydowy mechanizm koordynacji powinien być raczej łączony z mechanizmem rynkowym, Z kolei, alternatywny mechanizm koordynacji pokazuje umiarkowaną, a mechanizm hierarchiczny najniższą siłę zakorzenienia relacyjnego.

Słowa kluczowe: koordynacja, zakorzenienie relacyjne, triadyczny łańcuch dostaw.

Artur Swierczek ORCID ID: https://orcid.org/0000-0001-6198-6377
Department of Business Logistics
University of Economics in Katowice
1 Maja 50, 40-287 Katowice, **Poland**
e-mail: artur.swierczek@uekat.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (3), 363-372

http://doi.org/10.17270/J.LOG.2020.467

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

BLOCKCHAIN AND SUPPLY CHAIN SUSTAINABILITY

Abderahman Rejeb[1], Karim Rejeb[2]

1) Széchenyi István University, Győr, **Hungary**, 2) Higher Institute of Computer Science, Ariana, **Tunisia**

ABSTRACT. **Background:** Supply chain sustainability is a central concern of most organizations. The main objective of sustainable supply chains is to create and maintain long term economic, social, and environmental value for all stakeholders involved in delivering products and services to markets. As sustainability constitutes one of the critical drivers of innovation, the recent emergence of blockchain technology typifies the disruptive impact of digital innovation on supply chain sustainability. Blockchain is a foundational technology that poses a shift in the development of supply chain sustainability.

Methods: Despite the increasing importance of blockchain in improving supply chain efficiencies and bringing societal changes, research investigating its potentialities from the lens of sustainability is scarce. Therefore, the primary goal of this paper is to fill this knowledge gap and synthesize the literature from leading journals on the topic of blockchain and its relation to supply chain sustainability. Papers were collected from different scientific databases and carefully analyzed. The possibilities of blockchains are identified and classified according to the triple bottom line framework, namely the economic, social, and environmental dimensions of sustainability.

Results and conclusions: The majority of studies focused on the economic implications of blockchains on supply chains. The sustainable economic aspects of the technology identified in the reviewed literature are mostly the transformational potentials of blockchains and their capabilities to drive new disintermediated business models, higher operational efficiencies, cost advantages, and additional sources of value creation. The social empowerment of supply chains is found through the ability of blockchain to create trustful relationships among supply chain partners, increase food safety, support humanitarian logistics, and promote social equity. Moreover, firms attempting to move forward in their environmental policies and strategies can use blockchain to extend their efforts to improve their environmental practices across the supply chain, reduce the strain on energy and natural resources, and offer environmentally friendly products.

Key words: blockchain technology, supply chain, sustainability, economic, social, environmental.

INTRODUCTION

The recent emergence of blockchain technology typifies the disruptive impact of digital innovations on supply chain sustainability. Blockchain is defined as a "digital, decentralized and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamper-proof records" [Treiblmaier 2018]. Similarly, blockchain technology can also be described as a distributed database of records, transactions, and digital events that have been executed and shared among networked participants. Blockchain is not a standalone technology; instead, it is a configuration of multiple technologies, tools, and methods that address specific problems or use cases [Rejeb et al., 2018]. Unlike several digital solutions, blockchain technology breaks away from traditional centralized approaches allowing to securely managing chain data across a distributed and interlinked network of nodes. The first application of blockchain was the cryptocurrency Bitcoin, where the technology underpins the mechanism of recording transactions. Cryptocurrency systems remain the most significant use case of the concept, however, blockchain technology can be applied to diverse fields such as healthcare,

Citation: Rejeb A., Rejeb K., 2020. Blockchain and supply chain sustainability. LogForum 16 (3), 363-372, http://doi.org/10.17270/J.LOG.2020.467

Received: 19.02.2020, Accepted: 24.04.2020, on-line: 30.06.2020.

insurance, identity management, smart energy grids, logistics and supply chain management [Fosso Wamba et al., 2020].

In this paper, we view blockchain as a foundational technology [Iansiti, Lakhani 2017] that poses a shift in the development of supply chain sustainability. From this perspective, we seek to investigate the relationship between blockchain technology and the triple bottom line (TBL) approach of sustainability, namely, the economic, social, and environmental performance of supply chains. Although the scholarly interest in the blockchain phenomenon is continually increasing, there is still a lack of research exploring the application of the technology for supply chain sustainability. Most academics who studied blockchain in the context of supply chain management and logistics majorly focused on the economic implications of the technology while barely discussing the non-quantifiable benefits (e.g., social values, human and environmental sustainability) resulting from the incorporation of blockchain into supply chain networks. To fill this knowledge gap, this paper aims to examine and synthesize the landscape of current literature on blockchain and sustainable supply chain practices. The research is designed to answer the following research question:

"How can blockchain technology facilitate supply chain sustainability?"

In order to uncover this important interlink of key trends, we conducted a systematic literature review [SLR] to identify and analyze relevant publications. To our best knowledge, no other researchers have investigated and synthesized the existing body of knowledge from the lens of sustainability, making this study one of the earliest attempts to explore the sustainability-induced changes generated by the leveraging of blockchain in supply chains and logistics. The remainder of this paper is organized as follows. Section 2 describes the review methodology used for the SLR. Section 3 provides a detailed discussion of the possibilities of blockchain technology based on the findings of the review. The last section concludes the paper and presents the research contributions and limitations.

METHODOLOGY

To investigate how blockchain technology influences supply chain sustainability, we employed a systematic literature methodology following the guidelines proposed by Denyer & Tranfield [2009]. An SLR is a helpful tool for learning more about new topics, resolving uncertainties, providing a synthesis of previous studies, discovering research gaps, and highlighting the boundaries of knowledge. Similarly, this approach is useful to identify, select, and evaluate existing contributions. The SLR is also suitable for establishing rigor, completeness, and reporting quality.

Table 1. Research protocol

Research protocol	Details description
Research online databases	Searches were carried out in 5 leading databases which were Scopus, ScienceDirect [Elsevier], Web of Science, EmeraldInsight, and Taylor and Francis.
Publication types	Only peer-reviewed literature was considered. The search was limited to journal articles in order to ensure the academic nature of the sources. Book chapters, books, white papers, editorial notes, and doctoral theses were excluded.
Language	Only publications in English were considered to expand the coverage of literature.
Date range	No specific date range
Search fields	Title, abstract and keywords
Search keywords	["blockchain*" AND ["supply chain*" OR logistic*]] AND [sustainable OR sustainability OR green OR environment* OR social OR ethic*]
Inclusion criteria	Only articles that studied blockchain in the supply chain management and logistics context were selected.
Exclusion criteria	Publications treating blockchain technology with a deep and pure technical focus were considered beyond the scope of the study.

The authors undertook an iterative cycle identifying appropriate search keywords, surveying the relevant literature, and carrying out the analysis of the findings. A review protocol has been developed to determine procedures of the review conducting stage and necessary rules to follow. Table 1 presents in detail the selection of online search databases, the collection of articles, and the filtering criteria.

Data Collection

According to the surveyed online databases, the initial search queries resulted in a total number of 133 articles. To filter the results further, we eliminated the redundant publications that appeared in different databases. The articles were analyzed using the inclusion and exclusion criteria already mentioned in Table 1. The authors screened the titles and abstracts for relevance retaining only 90 publications for full-text review. A total number of 79 studies were eventually considered relevant for the scope of research. Out of those we will only cite the ones that we regarded to be the most useful. Figures 1 presents the process of data collection.

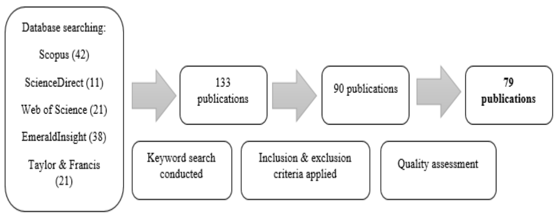


Fig. 1. Schematic presentation of data collection

REVIEW FINDINGS

Elkington [1998] coins the concept of the “triple bottom line” (TBL), indicating that organizations have to emphasize the importance of economic, social, and environmental performance. Carter & Rogers [2008] suggest that firms who pursue the three foundational dimensions of the TBL would be able to achieve better economic performance. In the context of the supply chain, the organization's vision of sustainability implies that these dimensions are equally important. In this review, we relied on the TBL framework to investigate how blockchain technologies could potentially influence the different facets of supply chain sustainability.

Economic Sustainability

Market Disintermediation

Disintermediation is a crucial advantage of applying blockchain technologies to supply chain management. As such, blockchain technologies offer disintermediation [Zamani & Giaglis, 2018], which can support several business transactions by connecting buyers and sellers without the need for intermediaries [Betti et al., 2019]. The flows of products and materials that are monopolized by fewer intermediaries may result in additional costs, increased system complexity, and product rejection by customers [Kouhizadeh et al., 2019]. However, blockchain technology could help to overcome these issues by eliminating these intermediaries serving as a central authority whose primary function is to validate transactions [Hald, Kinra 2019, Kamble et al., 2019]. For example, The Bitcoin Blockchain system removes the third party that is concerned with monitoring the authenticity of cryptocurrency transactions using asymmetric encryption [Rahmanzadeh et al., 2019]. The combination of smart contracts and blockchain is a viable and workable solution to substitute intermediaries or trusted third parties in the case of transshipment operations in a global supply chain setting [Hasan et al., 2019].

Operational Efficiencies

Blockchains can dramatically streamline entire business processes and make the whole supply chain more responsive and efficient [Faria 2019]. Through a blockchain-enabled supply chain, firms can benefit from increased levels of verification efficiencies and automation [Cole et al., 2019]. For example, blockchain facilitates the digital traceability and authentication of food products throughout the entire supply chain from suppliers to store shelves and finally to end consumers [Tijan et al., 2019]. Blockchain technology ensures end-to-end product tracking and enables multiparty authentication of the possession of goods [Treiblmaier 2018] and information sharing in real time. With such enhanced visibility, supply chain partners can eliminate several non-value adding activities as they will be able to see the progress of goods and their movements along the supply chain [Hald, Kinra 2019]. The traceback capability of blockchain allows companies to quickly identify the inventory level of their products and raw materials and to make more integrated and well-informed decisions across all stages of the supply chain. As a result, blockchain technology has a time-saving advantage and can simplify many business tasks and eliminate inefficiencies resulted from archaic processes, trade-related paperwork, complex bureaucratic procedures, and stringent institutional requirements. As noted by Wong et al. [2019], familiarity with blockchain can lead to short task completion time, more simplicity, and enhanced job performance.

Blockchain leads to the formation of strong integration links between supply chain partners and allows rapid verification of outsourcing chain partners' documents such certificates, licenses, proofs of records, transactions, processes, and events [Pankowska 2019]. In trade finance, blockchain technology can ensure real-time approval and payments of transactions [Kamble et al. 2019]. A system for efficient supply chain management was developed by Hasan et al. [2019] using the features of smart contracts in Ethereum blockchain to manage items shipped via smart containers, govern and orchestrate interactions between the sender and receiver. Therefore, blockchain can substantially enhance operational efficiency, optimize resource allocation, and free up resources that can be used to soften the variability of supply chain demand and supply [Schmidt, Wagner 2019].

Cost Efficiency

The effective application of blockchain technology to supply chains can reduce several costs associated with the verification of product quality, the distortion of business processes, and the transfer of ownership among supply chain partners. The disintermediated approach of blockchains can dramatically reduce the costs of transactions that were economically unfeasible [Ashley, Johnson 2018]. Moreover, the pressure to reduce the costs of products and services constitutes an impetus for firms to use the technology for removing the overhead costs which are required for the exchange of assets. For example, Ko et al. [2018] note that blockchain technology can decrease manufacturing firms' networking costs and usher in the construction of new market platforms in the manufacturing industry. Results of before and after blockchain adoption have also shown that firms could improve their profits through the transparency and cost-saving nature of blockchain [Ko et al., 2018]. Because of these key characteristics, companies can be profitable and produce at smaller marginal and competitive costs when they incorporate blockchain technology into their business processes. The costless verification enabled by blockchain can benefit all the actors in the supply chain through eliminating or reducing the costs related to the certification of products and their ingredients [dos Santos et al., 2019]. As a result, supply chain partners would have the opportunity to generate significant savings on costs associated with enforcement, such as labor expenses, legal fees, taxes, and court costs. Moreover, companies may realize cost savings from the reduction of waste and all adverse outcomes. Information on the blockchain can then be used to take proactive actions, mitigate process frictions, and shorten the time-to-market.

Value Creation Opportunities

A promising application of blockchain is its potential to allocate resources among supply chain partners efficiently. As such, sharing models powered by blockchain technology allow businesses to have visibility into the availability of all underutilized logistics assets (e.g., trucks, vehicles, machinery and equipment, warehouse capacity, etc.). Likewise, blockchain has the appropriate digital capabilities to create a new world of collaborative and decentralized logistics [Meyer et al., 2019], which hosts a vast network of supply chain actors, matches firms on-demand, and delivers improved availability and better utilization of logistics resources. Blockchain helps to create a fair economic business model and preserve the benefits of the sharing economy because companies that are based on resource sharing will be under strict monitoring and scrutiny [Sicilia, Visvizi 2019].

This approach prepares the fertile ground for entrepreneurship and the development of new business ventures and companies. Unlike traditional IT platforms, blockchain can significantly contribute to the simplification of crowdfunding [Veuger 2018] and the reduction of entry barriers and costs. This implies that both small and small and medium enterprises would be able to attract cheaper capital and funding from investors all over the world. Regardless of their size, businesses also can majorly benefit from the economic incentives provided by the application of blockchain. For instance, it is highly likely that the enforcement of intellectual property rights will increase the incentives to invest, create wealth and growth, and to generate competitive resources. Clear property rights would allow companies to add new business values and allow potential investors to increase their access to capital [Kshetri 2017]. Furthermore, firms have incentives to adopt blockchain technology because, if not, they risk to be outperformed by their competitors [Ko et al., 2018], not live up to the expectations of their customers, and to lose the preferential financing, subsidies, and tax incentives that can be otherwise obtained as a result of increased transparency and disclosure of sustainability claims. The extent to which blockchain can ensure transparency unlocks other economic advantages such as branding benefits and positive signaling to consumers. Therefore, blockchain discerns a branding narrative that communicates several corporate values to all supply chain partners, and particularly to customers, and this unfolding can result in a high willingness to pay and high-value perception of service or product quality [Keyser et al., 2019].

Social Sustainability

Empowering Trust

In a review study by Wang et al. [2018], trust is considered the most influential factor for awaking the interest in the blockchain within supply chain management. Blockchain technology offers a universally trusted computing platform [Ramkumar 2018] where untrusted parties can reach agreement on a secured, distributed, and transparent ledger [Rahmanzadeh et al. 2019]. Blockchains place more trust and authority in decentralized networks, representing a total shift away from the conventional ways of orchestrating and managing supply chains. With the blockchain-enabled trust, supply chain risks and contingencies can be significantly reduced among exchange partners. The completeness and transparency of information and transactions on the blockchain constitute the necessary ingredients for establishing mutual trustful relationships between supply chain stakeholders [Veuger 2018]. Moreover, blockchain technology creates an atmosphere of trust, continued ethical behavior, fairness, and honesty. This trust is often a necessary antecedent of information and resource sharing in supply chains. For instance, Lemieux [2016] noted that blockchain technology ensures trustworthiness of records, which is a necessity in a range of different contexts where record systems provide the critical underlying infrastructure necessary to achieve development objectives. In business relations, blockchain solves the problem of missing trust between a large number of untrusted stakeholders [Wang et al. 2018]. The technology acts as a foundation for cooperative and collaborative supply chain connections. Trust is gained through blockchain-enabled data integrity, security, and protection against fraud, infringements, and cybercrime [Modic et al., 2019]. Therefore, blockchain promotes a new ecosystem where shared values on goals and policies, strong regulations and control mechanisms, reputation, and healthy relationships all enhance the firm's social capital, namely, trust.

Food Safety

Food safety is an increasingly important public health issue [Aung, Chang 2014]. Considering the potential of increased transparency, efficiency, and accountability that blockchain-enabled traceability can provide, it is expected that there would be a significant reduction in healthcare costs and improvements in public perception of the food industry [Astill et al., 2019]. Wang et al. [2018] argue further that blockchain-based tracking enables food retailers and manufacturers to respond quickly to recalls and other safety issues, thus reducing the spread of foodborne illnesses. The use of blockchain technology in the development of agri-food supply chain traceability can secure all data entries regarding food products and allow end-to-end traceability of any food item that reaches the consumer in a quick time [Keyser et al., 2019]. For example, Walmart and nine other firms (e.g., Nestle, Dole, Tyson Foods, Unilever, etc.) have established business partnerships to leverage blockchain technology in order to track and trace provenance so that they guarantee food safety and more responsiveness to food recalls. By increasing traceability, the source of any contaminations during foodborne crises can be quickly identified, resulting in a low number of affected people and causing less anxiety and panic for consumers. Therefore, the societal implications of blockchain are rooted in its ability to respond to the increasing demands of consumers for more food safety, to support the expansion of global food chains while at the same meeting the quality requirements and standards of food products.

Humanitarian Causes & Social Empowerment

Beyond the economic considerations, organizations are also recognizing the importance of social responsibilities and the need to sustain humanitarian supply chain operations. There is tremendous potential for blockchain technology to make humanitarian aids more productive and agile. During times of crises and disasters, the technology can be used to streamline the process of financial aids (e.g., medications) and eliminate delays caused by bureaucracy, paperwork, or political barriers [Al-Saqaf, Seidler 2017]. To encounter supply chain disasters and support humanitarian activities, blockchain technology creates an adequate information infrastructure that can manage all humanitarian eventualities at the field level, reduce the delivery time of required goods or services to the beneficiaries, and optimize the accuracy in terms of the quality and quantity of the most important items. For example, the application of smart contract-enabled blockchain can facilitate the transfer of remittances automatically and in a pre-programmed fashion [Al-Saqaf, Seidler 2017]. In their study, Wang et al. [2018] indicate that blockchain was piloted at the Azraq Refugee Camp for Syrian refugees. In critical emergencies, the technology can improve trust and promote more solidarity among people, helping to encourage mutual communications and to transparently track donations. More important is also the fact that blockchain enhances the transparency of supply chains, which is useful to counteract human rights abuses, child labor, and corruption. Blockchain also promotes more financial inclusion by supporting the integration of the unbanked population and the smallholding farmers and businesses [Kamble et al., 2019].

Environmental Sustainability

In many aspects, the adoption of blockchain technology can strengthen the ecological dimension of sustainability by reducing the environmental logistic footprint [Wong et al., 2019]. By leveraging blockchain and smart contracts, it would be possible to incorporate several environmental protection and control initiatives through the careful monitoring of production parameters such as energy consumption, raw materials processing, and emissions. In this regard, Ashley & Johnson [2018] note that blockchain can simplify the participation of stakeholders in low-carbon energy initiatives, facilitate the implementation of environmental protection programs, and increase consumer access to clean energy. Blockchain technology has the potential to unlock environmentally sustainable manufacturing. To specify, the use of the technology, according to Kouhizadeh et al. [2019], helps firms determine the materials and products that use non-renewable resources and remove them or invest in alternative renewable and green resources to benefit the circularity of energy.

Blockchain drives the transition towards the efficient and sustainable use of energy and the delivery of sustainable products. The transparency enabled by blockchain could be used to ensure that purportedly green products are environmentally friendly [Saberi et al., 2019]. Similarly, the engagement in the blockchain network emphasizes the commitment of businesses to several environmental issues such as climate change, pollution, and depletion of energy resources. Blockchain could foster sustainability by building close environmental cooperation with supply chain partners and allow the firm to efficiently allocate resources based on precise scheduling and real-time data collection from the production processes. Unnecessary transportation processes can be avoided by the collaborative capabilities of blockchain. As such, supply chain partners would be able to effectively collaborate and coordinate several actions related to the shipment and transportation of products. According to Saberi et al. [2019], blockchain technology enables to trace the carbon footprint of products and gives organizations the opportunity to cooperate and trade their carbon assets efficiently in the green-asset markets. Through mapping the journey of the product across the supply chain, blockchain can precisely identify the carbon tax that should be charged on the company. As a result, blockchain technology can significantly contribute to the reduction of carbon emissions and air pollution through accurate and easily traceable greenhouse footprint analyses.

CONCLUSIONS

In this paper, we have comprehensively analyzed the possibilities for blockchain technology in supply chain sustainability. The aim of the study was to synthesize the current academic literature on the topic of blockchain and its relationships to sustainable supply chains by performing an SLR on selected publications. The findings of the review indicate that blockchain technology is a promising paradigm for sustaining supply chain operations. Academic research on blockchain technology is continuously progressing in terms of the number of studies published in leading journals over the last recent years. The possibilities of the technology for sustainability identified from the review and classified according to the TBL approach are a valuable contribution to the growing literature on the applications of blockchains for improving the economic performance of organizations, empowering the social aspects of supply chains, and sustaining the environmental practices among the stakeholders of the ecosystem. The majority of studies focused on the economic implications of blockchains on supply chains. The sustainable economic aspects of the technology identified in the reviewed literature are mostly the transformational potentials of blockchains and their capabilities to drive new disintermediated business models, higher operational efficiencies, cost advantages, and additional sources of value creation. The social empowerment of supply chains is found through the ability of blockchain to create trustful relationships among supply chain partners, increase food safety, support humanitarian logistics, and promote social equity. Moreover, firms attempting to move forward in their environmental policies and strategies can use blockchain to extend their efforts to improve their environmental practices across the supply chain, reduce the strain on energy and natural resources, and offer environmentally friendly products.

Although this paper, to the authors' best knowledge, is among the first attempts to synthesize the literature published in leading journals and contribute to the existing and increasing body of knowledge regarding the role of blockchain in leveraging sustainable supply chains, there remain several limitations. The selection of search databases might omit articles that might be relevant to the scope of this study. In addition, we have only focused on reviewing journal articles neglecting other equally important sources of knowledge such as conference papers and book chapters. Therefore, review studies in the future may consider synthesizing the different types of literature and rely on databases with extensive coverage such as Google Scholar. The findings of this study and the conclusions drawn here should be validated with other methodologies such as quantitative research and expert interviews.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

Abderahman Rejeb is grateful to Professor László Imre Komlósi, Dr. Katalin Czakó and Ms. Tihana Vasic for their valuable support. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Al-Saqaf W., Seidler, N., 2017. Blockchain technology for social impact: Opportunities and challenges ahead. Journal of Cyber Policy, 2(3), 338–354.

Ashley M.J., Johnson M.S., 2018. Establishing a Secure, Transparent, and Autonomous Blockchain of Custody for Renewable Energy Credits and Carbon Credits. IEEE Engineering Management Review, 46(4), 100–102. http://doi.org/10.1109/EMR.2018.2874967

Astill J., Dara R.A., Campbell M., Farber J.M., Fraser E.D.G., Sharif S., Yada R.Y., 2019. Transparency in food supply chains: A review of enabling technology solutions. Trends in Food Science & Technology, 91, 240–247. http://doi.org/10.1016/j.tifs.2019.07.024

Aung M.M., Chang Y.S., 2014. Traceability in a food supply chain: Safety and quality perspectives. Food Control, 39, 172–184. http://doi.org/10.1016/j.foodcont.2013.11.007

Betti Q., Khoury R., Hallé S., Montreuil B., 2019. Improving Hyperconnected Logistics with Blockchains and Smart Contracts. https://arxiv.org/abs/1904.03633v1

Carter C.R., Rogers D.S., 2008. A framework of sustainable supply chain management: Moving toward new theory. International Journal of Physical Distribution & Logistics Management, 38(5), 360–387. http://doi.org/10.1108/09600030810882816

Cole R., Stevenson M., Aitken J., 2019. Blockchain technology: Implications for operations and supply chain management. Supply Chain Management: An International Journal, 24(4), 469–483. http://doi.org/10.1108/SCM-09-2018-0309

Denyer D., Tranfield D., 2009. Producing a systematic review. In The Sage handbook of organizational research methods, 671–689. Sage Publications Ltd.

dos Santos R.B., Torrisi N.M., Yamada E.R.K., Pantoni R.P., 2019. IGR Token-Raw Material and Ingredient Certification of Recipe Based Foods Using Smart Contracts. Informatics, 6(1), 11. http://doi.org/10.3390/informatics6010011

Elkington J., 1998. Partnerships from cannibals with forks: The triple bottom line of 21st-century business. Environmental Quality Management, 8(1), 37–51. http://doi.org/10.1002/tqem.3310080106

Faria I., 2019. Trust, reputation and ambiguous freedoms: Financial institutions and subversive libertarians navigating blockchain, markets, and regulation. Journal of Cultural Economy, 12(2), 119–132. http://doi.org/10.1080/17530350.2018.1547986

Fosso Wamba S., Kamdjoug K., Robert J., Bawack R., G Keogh J., 2020. Bitcoin, Blockchain, and FinTech: A Systematic Review and Case Studies in the Supply Chain. Production Planning and Control, 31(2–3), 115–142.

Hald K.S., Kinra A., 2019. How the blockchain enables and constrains supply chain performance. International Journal of Physical Distribution & Logistics Management. http://doi.org/10.1108/IJPDLM-02-2019-0063

Hasan H., AlHadhrami E., AlDhaheri A., Salah K., Jayaraman R., 2019. Smart contract-based approach for efficient shipment management. Computers & Industrial Engineering, 136, 149–159. http://doi.org/10.1016/j.cie.2019.07.022

Iansiti M., Lakhani K.R., 2017. The truth about blockchain. Harvard Business Review, 95(1), 118–127.

Kamble S.S., Gunasekaran A., Sharma R., 2019. Modeling the blockchain enabled traceability in agriculture supply chain. International Journal of Information Management, In press. https://doi.org/10.1016/j.ijinfomgt.2019.05.023

Keyser A.D., Köcher S., Alkire L., Verbeeck C., Kandampully J., 2019. Frontline Service Technology infusion: Conceptual archetypes and future research directions. Journal of Service Management, 30(1), 156–183.

http://doi.org/10.1108/JOSM-03-2018-0082

Ko T., Lee J., Ryu D., 2018. Blockchain Technology and Manufacturing Industry: Real-Time Transparency and Cost Savings. Sustainability, 10(11), 4274. http://doi.org/10.3390/su10114274

Kouhizadeh M., Sarkis J., Zhu Q., 2019. At the Nexus of Blockchain Technology, the Circular Economy, and Product Deletion. Applied Sciences, 9(8), 1712. http://doi.org/10.3390/app9081712

Kshetri N., 2017. Will blockchain emerge as a tool to break the poverty chain in the Global South? Third World Quarterly, 38(8), 1710–1732. http://doi.org/10.1080/01436597.2017.1298438

Lemieux V.L., 2016. Trusting records: Is Blockchain technology the answer? Records Management Journal, 26(2), 110–139. http://doi.org/10.1108/RMJ-12-2015-0042

Meyer T., Kuhn M., Hartmann E., 2019. Blockchain technology enabling the Physical Internet: A synergetic application framework. Computers & Industrial Engineering, 136, 5–17. http://doi.org/10.1016/j.cie.2019.07.006

Modic D., Hafner A., Damij N., Zajc L.C., 2019. Innovations in intellectual property rights management. European Journal of Management and Business Economics. http://doi.org/10.1108/EJMBE-12-2018-0139

Pankowska M., 2019. Information Technology Outsourcing Chain: Literature Review and Implications for Development of Distributed Coordination. Sustainability, 11(5), 1460. http://doi.org/10.3390/su11051460

Rahmanzadeh S., Pishvaee M.S., Rasouli M.R., 2019. Integrated innovative product design and supply chain tactical planning within a blockchain platform. International Journal of Production Research, 0(0), 1–21. http://doi.org/10.1080/00207543.2019.1651947

Ramkumar M., 2018. Executing large-scale processes in a blockchain. Journal of Capital Markets Studies, 2(2), 106–120. http://doi.org/10.1108/JCMS-05-2018-0020

Rejeb A., Sűle E., Keogh J.G., 2018. Exploring new technologies in procurement. Transport & Logistics: The International Journal, 18(45), 76–86.

Saberi S., Kouhizadeh M., Sarkis J., Shen L., 2019. Blockchain technology and its relationships to sustainable supply chain management. International Journal of Production Research, 57(7), 2117–2135. http://doi.org/10.1080/00207543.2018.1533261

Schmidt C.G., Wagner S.M., 2019. Blockchain and supply chain relations: A transaction cost theory perspective. Journal of Purchasing and Supply Management, 25(4), 100552. http://doi.org/10.1016/j.pursup.2019.100552

Sicilia M.-A., Visvizi A., 2019. Blockchain and OECD data repositories: Opportunities and policymaking implications. Library Hi Tech, 37(1), 30–42. http://doi.org/10.1108/LHT-12-2017-0276

Tijan E., Aksentijević S., Ivanić K., Jardas M., 2019. Blockchain Technology Implementation in Logistics. Sustainability, 11(4), 1185. http://doi.org/10.3390/su11041185

Treiblmaier H., 2018. The impact of the blockchain on the supply chain: A theory-based research framework and a call for action. Supply Chain Management: An International Journal, 23(6), 545–559. http://doi.org/10.1108/SCM-01-2018-0029

Veuger J., 2018. Trust in a viable real estate economy with disruption and blockchain. Facilities, 36(1/2), 103–120. http://doi.org/10.1108/F-11-2017-0106

Wang Y., Hungh H.J., Paul B.-D., 2018. Understanding Blockchain technology for future supply chains a systematic literature Review and Research Agenda. Supply Chain Management: An International Journal, 24(1), 62–84. http://doi.org/10.1108/SCM-03-2018-0148

Wong L.-W., Leong L.-Y., Hew J.-J., Tan G.W.-H., Ooi K.-B., 2019. Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs. International Journal of Information Management. http://doi.org/10.1016/j.ijinfomgt.2019.08.005

Zamani E.D., Giaglis G.M., 2018. With a little help from the miners: Distributed ledger technology and market disintermediation. Industrial Management & Data Systems, 118(3), 637–652.

BLOCKCHAIN I ZRÓWNOWAŻONOŚĆ ŁAŃCUCHA DOSTAW

STRESZCZENIE. **Wstęp:** Zrównoważoność łańcucha dostaw leży w centrum zainteresowania większości organizacji. Głównym celem zrównoważonych łańcuchów dostaw jest stworzenie i utrzymanie długoterminowych ekonomicznych, socjalnych i ekologicznych zysków dla wszystkich akcjonariuszy w trakcie dostaw produktów i usług na rynek. Rozwój zrównoważony wydaje się być jednym z krytycznych czynników innowacyjności, ostatnio pojawiające się technologie blockchain mają istotny wpływ na zrównoważoność łańcuchów dostaw. Blockchain jest technologią, która może istotnie przyczynić się do rozwoju zrównoważonego łańcucha dostaw.
Metody: Pomimo rosnącego zainteresowania znaczenie blockchainu dla poprawy efektywności łańcuchów dostaw, istnieje bardzo mało badań I publikacji na ten temat. Dlatego ten celem tej pracy było wypełnienie istniejącej luki i stworzeni syntezy literatury naukowej na blockchain oraz jego relacji ze zrównoważonym łańcuchem dostaw. Prace badawcze były uzyskane z różnych baz publikacyjnych i poddane wnikliwej analizie. Możliwości wynikające ze stosowania blockchain zostały zidentyfikowane i sklasyfikowane w odniesienie do wymiaru ekonomicznego, socjalnego, środowiskowego oraz rozwoju zrównoważonego.
Wyniki i wnioski: Większość prac badawczych skupia się na ekonomicznych wpływach blockchainu na łańcuch dostaw. Zrównoważone ekonomiczne aspekty technologii zidentyfikowane w badanej literaturze głównie dotyczą możliwości transformacji przez blockchain oraz możliwości zmiany modelu biznesowego, zwiększenie efektywności operacyjne, korzyści kosztowych oraz dodatkowych źródeł finansowania. Zalety socjalne łańcuchów dostaw są widziane głównie w możliwości stworzenie zaufanych relacji między partnerami biznesowymi, wzroście bezpieczeństwa żywności, wspomożeniu logistyki humanitarnej oraz promocji równości socjalnej. Jednocześnie firmy starają się zmienić swoją politykę środowiskową używając blockchainu dla zwiększenie swoich praktyk ekologicznych w obrębie łańcuchów dostaw, redukcję zużycia energii i zasobów naturalnych oraz wprowadzenie produktów przyjaznych środowisku.

Słowa kluczowe: technologia blockchain, łańcuch dostaw, rozwój zrównoważony, ekonomiczny, socjalny, środowiskowy

Abderahman Rejeb ORCID ID: https://orcid.org/0000-0002-2817-5377
Széchenyi István University
Kautz Gyula Faculty of Economics
9026 Győr, **Hungary**
e-mail: abderrahmen.rejeb@gmail.com

Karim Rejeb
Higher Institute of Computer Science El Manar,
2, Rue Abou Raïhan El Bayrouni, 2080
Ariana, **Tunisia**
e-mail: karim.rejeb@etudiant-isi.utm.tn

LogForum

> Scientific Journal of Logistics <

2020, 16 (3), 373-383

http://doi.org/10.17270/J.LOG.2020.450

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

POTENTIAL OF TRUCK PLATOONING FOR TRANSPORTING EMPTY TRUCKS CONSIDERING INTERCITY FREIGHT DEMAND IMBALANCES

Terumitsu Hirata, Taiki Fukaya

Ibaraki University, , Ibaraki, **Japan**

ABSTRACT. **Background:** In Japan, nearly 30% of trucks run empty despite the recent difficulties in recruiting truck drivers, especially in the intercity freight transport market. If we consider the inevitable imbalance in intercity freight demand, the efficient transport of empty trucks becomes necessary to a certain extent. One such promising technology is truck platooning, which enables trucks to automatically follow the lead vehicle while maintaining minimal headway to reduce fuel consumption and minimize the burden imposed on drivers. This study proposes a new business model to utilize truck platooning technology to transport empty trucks, based on the intercity freight demand imbalances.

Methods: After analyzing the actual intercity freight transport demand imbalance in Japan, we developed an analytical model to quantify the impact of truck platooning to transport empty trucks on labor and vehicle costs. We further analyzed its impact on the intercity freight transport market and applied the model to the actual intercity freight transport market data (logistics census) in Japan.

Results: From the analysis results using the actual freight flow data collected through surveys within 3 days in Japan, the cost reduction is estimated to be 16% in the required number of trucks and 44% in the number of taking a rest time in a truck. They indicate that the proposed empty truck platooning operation has significant benefits for inter-regional freight transport, including transport-related cost and working environment of the truck drivers on long-haul routes.

Conclusions: In this paper, we proposed a new operational concept to utilize truck platooning technology for transporting empty trucks based on the intercity freight demand imbalances. Although the proposed operation has potential significant benefits, the operation assumes the relaxation of “on-duty time” regulation in the labor standard act by considering the future introduction of autonomous driving and truck platooning. As the benefit of the pro-posed operation is significant according to our analysis, this relaxation of the labor regulation is worth considering by carefully investigating the safety of the platoon operation and its impact on the driver’s working environment.

Key words: truck platooning, empty truck, intercity freight demand imbalances, on-duty time regulation, working environment of the truck drivers, vehicle cost.

INTRODUCTION

In Japan, long-haul trucking faces severe driver shortage due to harsh working conditions and an aging population. Meanwhile, the average load factor, empty running rate, and utilization rate of truck freight transport in Japan was approximately 40%, 30%, and 65%, respectively, in 2017 [Ministry of Land, Infrastructure, and Transport, 2017]. These figures show that freight transport efficiency for trucks is presently very low, and improvement in freight transport efficiency for trucks is essential to overcome the severe problem of driver shortage as well as to reduce CO_2 emissions. Regarding the empty trucks being run, this problem was created owing to the difficulty in finding loads for returning vehicles, since a fundamental difference between passenger and freight transport is that people generally return to their starting point. In contrast, almost all freight consignments move in one direction,

Citation: Hirata T., Fukaya T., 2020. Potential of truck platooning for transporting empty trucks considering intercity freight demand imbalances. LogForum 16 (3), 373-383, http://doi.org/10.17270/J.LOG.2020.450

Received: 12.05.2020, Accepted: 08.06.2020, on-line: 30.06.2020.

from the point of production to the point of consumption [McKinnon, Ge, 2006]. The past several studies identified the factors concerning the empty running of trucks [McKinnon 1996] to examine trends and assess the potential for further reduction [McKinnon, Ge, 2006] and proposed optimization models to minimize empty truckloads [Patrick 2013]. One of the main factors for empty truckloads is the geographical imbalance in traffic flow [McKinnon, Ge, 2006]. This study assumes that the efficient transport of empty trucks itself is necessary to a certain ex-tent if the macroscopic situation of the geographical imbalance in in-ter-regional road freight flows. This study proposes a novel idea to transport empty trucks as well as truck drivers efficiently by utilizing truck platooning technology, which has been recently developed and tested on highways worldwide (e.g. CHAUFFEUR [Fritz et al, 2004], California PATH Program, SARTRE, COMPANION, Energy ITS in Japan [Shladover 2010, Tsugawa et al. 2016], and European Truck Platooning Challenge). Truck platooning is one of the most promising technologies which comprises virtually linked trucks that drive closely behind one another using automated driving technology. The benefits of truck platooning include cost savings, reduced emissions, and more efficient use of road capacity [Bhoopalam et al. 2018]. Regarding fuel saving reported from field experiments, for example, fuel savings of 10-12% and 5-10%, respectively, for the trailing truck and leading truck when the intervehicle spacing was 3-10m in a two-truck platoon system [Browned et al. 2004]. Recently, several studies have proposed methodologies and models for better planning of vehicles, accommodating for truck platooning to maximize benefits, such as fuel and CO_2 emission reductions [Lars-son et al. 2015, Bhoopalam et al. 2018, Zhang et al., 2020]. Zhang et al [2017] propose a platoon coordination and departure time scheduling problem under travel time uncertainty for off-road coordination that is cost minimization framework accounting for travel time cost, schedule miss penalties and fuel cost. From their results, it indicates that travel time uncertainty reduces the threshold schedule difference for platooning to be beneficial and platooning in networks is less beneficial on converging routes than diverging routes. Regarding the aspects to diminish the benefit of platooning, Boysen et al. [2018] investigates the impact of the diffusion of platooning technology, the maximum platoon length, and the tightness of time windows and shows that these factors can considerably reduce the positive effects of truck platooning especially with regard to fuel saving alone from comprehensive computational study. Also they point out that only if all follower trucks to the lead vehicle in platoon will be able to be unmanned driving, the additional wage savings seem substantial enough to justify the investment into platooning technology, but driverless follower trucks lose a lot of flexibility such as heading further to their next destinations after they have left a platoon. However, to the best of our knowledge, a study is yet to investigate the potential of truck platooning for improving the efficiency of truck freight transport, considering empty truck forwarding and related “Hours of Service” regulations for truck drivers in the labor standard act. In contrast, most papers deal with coordination, scheduling, and optimization of multiple trucks loaded with goods.

With this background, this study aims to investigate the potential benefit of introducing truck platooning technology to the long-haul freight transport market considering the geographical imbalance of inter-regional freight volume. In the following chapters, first, the actual situation surrounding the geographical imbalance in the inter-regional freight volume in Japan is investigated by using the inter-regional freight transport census. Next, a simple analytical model is developed to quantify the benefit of introducing truck platooning in terms of truck utilization and driver’s working environment. Finally, the developed model is applied to actual city pairs in Japan, and the benefits of introducing truck platooning for transporting empty trucks are assessed.

GEOGRAPHICAL IMBALANCE ANALYSIS IN INTER-REGIONAL FREIGHT VOLUME IN JAPAN

Before analyzing the benefits of introducing truck platooning, the actual situation surrounding the imbalance in inter-regional freight in Japan is investigated by using freight census data. The data used is the inter-regional freight census, which was conducted in 2015 in Japan. The data include the volume, type of items, origin and destination, time of departure and arrival, and transport mode of goods transport-ed on October 20–22, 2015, around the country. We aggregated the OD (Origin-Destination) freight volume (ton) for items that can be transported, mainly by a van-body truck type, between the Tokyo metropolitan area (TMA: Tokyo, Kanagawa, Saitama, and Chiba Prefectures) and five major local regions (i.e., Aichi, Osaka, Ishikawa, Niigata and Miyagi prefecture). Table 1 shows the results of the imbalance in inter-regional freight volume for each city pair. Among the city pairs, a substantial freight volume can be observed in the direction of the TMA, which is the most significant point of consumption in Japan, rather than in the return direction to each local region. This implies that the empty trucks or low load factor trucks tend to be operated along the route from the TMA to local cities in Japan.

Table 1. Geographical imbalance in actual inter-regional freight volume between the Tokyo Metropolitan Area (TMA) and major local regions in Japan (2015)

Origin-Destination	Freight ton	Origin-Destination	Freight ton
Aichi-TMA	10,626 (t)	TMA-Aichi	8,457 (t)
Osaka-TMA	7,633 (t)	TMA-Osaka	4,780 (t)
Ishikawa-TMA	1,178 (t)	TMA-Ishikawa	605 (t)
Niigata-TMA	4,497 (t)	TMA-Niigata	2,943 (t)
Miyagi-TMA	5,370 (t)	TAM-Miyagi	3,710 (t)

DEVELOPMENT OF THE NOVEL CONCEPT OF EMPTY TRUCK FORWARDING BY TRUCK PLATOONING CONSIDERING GEOGRAPHICAL IMBALANCE IN FREIGHT FLOW

According to the aggregate analysis of the geographical imbalance in inter-regional freight flows, it appears that a certain number of empty vehicles are operated owing to the lack of backloads (no return cargo). If the driver or logistics firm believes that it is better to transport some cargo than return empty, they often search for cargo even in it results in an extra running distance, increasing the burden on the driver. In long-haul freight transportation, after completing the outbound transportation, drivers are often forced to stay in their trucks or locations other than their homes. This constitutes a disadvantage while recruiting drivers. If the geographical imbalance in inter-regional freight flow is inevitable, no matter how much intelligent cargo search systems are promoted through inter-company cooperation or IT system utilization, a certain number of empty or low load-factor trucks will follow.

It is possible to utilize platooning technology to solve the problem of empty truck forwarding. For example, as shown in Figures 1 and 2, during a return trip from the Tokyo metropolitan area to a local area, instead of competing for a limited size of cargo (small pie), is it possible to send forward a certain number of empty trucks by means of platooning, immediately after finishing an outbound transportation?

This operation can reduce driver fatigue by having a sleep at home more frequently. Since empty trucks carry no cargo, the arrival time constraints are relatively loose, and it is easier to adjust the time re-quired to schedule for platooning. The returned empty trucks can immediately be used again for outbound transportation demands to the metropolitan area, and thus vehicle utilization efficiency can also be improved. Even if autonomous vehicles are to be introduced in the future, the cost of introducing such advanced vehicles for platooning might be high. Therefore, the fixed cost of the vehicle would be a burden on financial management, and improving vehicle utilization efficiency will be necessary to ensure price competitiveness.

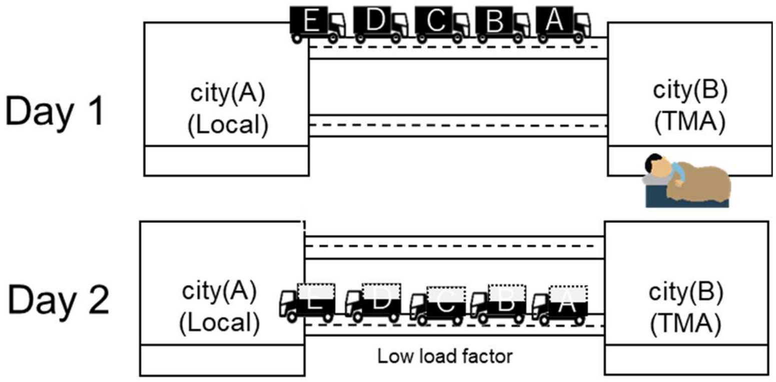


Fig. 1. Current normal operation in the case where the return cargo volume is 60% of outbound (all drivers must stay in the city (B) during rest hours for the next shift and low load factor on a return route)

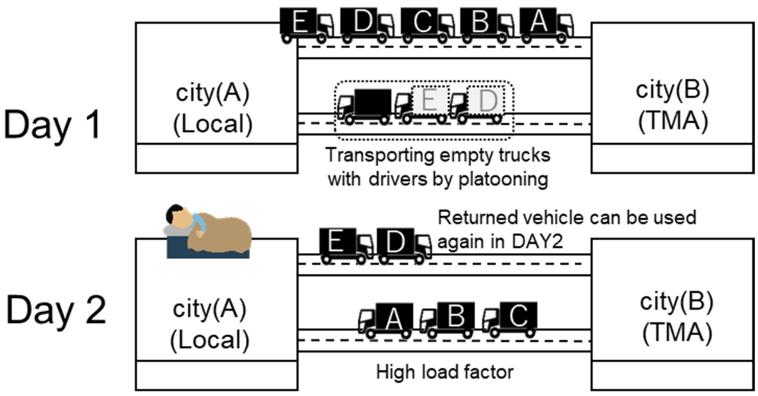


Fig. 2. Proposed operation employing empty truck forwarding with drivers by means of truck platooning in cases where the return cargo volume is 60% of the outbound (driv-ers returned with platooning truck can rest in their homes, and the returned vehicles can be used the next day, ensuring high load factor on return route)

However, for this proposed operation, Hours of Service regulations for truck drivers, provided in the labor standard act, can be a possible bottleneck, especially for long-haul routes. This regulation limits the number of daily and weekly hours spent driving and working and regulates the minimum amount of time drivers must spend resting be-tween driving shifts. In Japan, the maximum "on-duty time" is 13 hours and minimum "off-duty time (resting time)" until the next shift is 8 hours. Therefore, for example, in the case of an outbound route (e.g., city (A) to city (B)) that takes 7 hours, counted as on-duty time, drivers cannot return to their home city (A) without resting for more than 8 hours in city (B), if the time taken during autonomous platooning driving is regarded as "on-duty time." However, if the time spent during automated driving, while platooning, can be regarded as "quasi-resting time" and is exempted from the "on-duty time" regulation, especially in the case that drivers can have a normal rest at home after "quasi-resting time", drivers and trucks can be returned to their home city (A) without spending resting at city (B). Similar concept regarding resting in platoon is also discussed in the existing study [Bhoopalam et al., 2018] that proposes the classification to describe different levels of human involvement in platooning (Human driven platooning with in-platoon resting, Hybrid platooning, and Driverless platooning) and discusses about the benefit of travel time saving by finishing required break time as a following truck of the platoon ("in-platoon resting"). Although our proposing concept of platoon operation is similar to this existing idea, platooning for transporting empty trucks considering geographical imbalance in inter-regional freight flow is unique idea. In this study, we assume this special exemption for the regulation of "on-duty time" can be applied to drivers in autonomously driven vehicles employing platooning (followers).

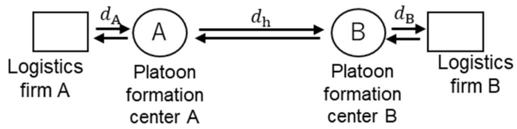


Fig. 3. Case (1): Non-consolidated cargo flow case (one driver runs from logistics firm A to B)

MODELS FOR THE EVALUATION OF THE BENEFIT OF EMPTY TRUCK PLATOONING

In this chapter, simple models are formulated for evaluating the benefits of introducing empty truck platooning. There are two main types of transport for long-haul trucks, one is non-consolidated transport (Case (1)) and the other is consolidated transport (Case (2)) as shown in Figures 3 and 4. In case (1), we assume that one driver operates throughout, from logistics firm A to logistics firm B, and the driver then proceeds to the dedicated point where the platoon is formed. In case (2), we assume that there are logistics bases where cargo is consolidated, and platoon formation can also be implemented, with dedicated drivers operating between the logistics bases.

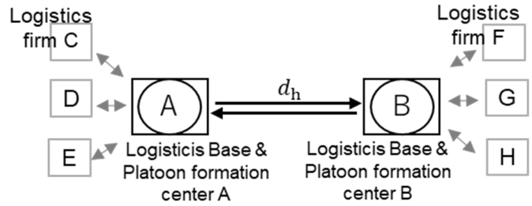


Fig. 4. Case (2): Consolidated cargo flow case (dedicated drivers operating between logistics bases)

For these two cases, we formulate models to calculate the travel time by considering both empty truck forwarding by means of platooning and normal operation without platooning, as shown in equations (1) - (8).

Platooning – Case (1):

$$T_{emp}^{pl(1)} = t_{l(A)} + \frac{d_A}{v_G} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + \frac{d_B}{v_G} + t_{u(B)} + \frac{d_B}{v_G} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + \frac{d_A}{v_G} + t_{s(A)} \quad (1)$$

$$T^{pl(1)} = t_{l(A)} + \frac{d_A}{v_G} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + \frac{d_B}{v_G} + t_{u(B)} + t_{s(B)} \quad (2)$$
$$+ t_{l(B)} + \frac{d_B}{v_G} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + \frac{d_A}{v_G} + t_{u(A)} + t_{s(A)}$$

Platooning – Case (2):

$$T_{emp}^{pl(2)} = t_{l(A)} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + \frac{d_B}{v_G} + t_{u(B)} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + t_{s(A)} \quad (3)$$

$$T^{pl(2)} = t_{l(A)} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + t_{u(B)} + t_{s(B)} + t_{l(B)} + t_{pc} + \frac{d_h}{v_h} + t_{ps} + t_{u(A)} + t_{s(A)} \quad (4)$$

Normal – Case (1):

$$T_{emp}^{nor(1)} = t_{l(A)} + \frac{d_A}{v_G} + \frac{d_h}{v_h} + \frac{d_B}{v_G} + t_{u(B)} + t_{s(B)} + \frac{d_B}{v_G} + \frac{d_h}{v_h} + \frac{d_A}{v_G} + t_{s(A)} \quad (5)$$

$$T^{nor(1)} = t_{l(A)} + \frac{d_A}{v_G} + \frac{d_h}{v_h} + \frac{d_B}{v_G} + t_{u(B)} + t_{s(B)} + t_{l(B)} + \frac{d_B}{v_G} + \frac{d_h}{v_h} + \frac{d_A}{v_G} + t_{u(A)} + t_{s(A)} \quad (6)$$

Normal – Case (2):

$$T_{emp}^{nor(2)} = t_{l(A)} + \frac{d_h}{v_h} + t_{u(B)} + t_{s(B)} + \frac{d_h}{v_h} + t_{s(A)} \quad (7)$$

$$T^{nor(2)} = t_{l(A)} + \frac{d_h}{v_h} + t_{u(B)} + t_{s(B)} + t_{l(B)} + \frac{d_h}{v_h} + t_{u(A)} + t_{s(A)} \quad (8)$$

$T_{emp}^{pl(i)}$ travel time for a round trip of an empty truck in platooning in case (*i*) (hour),

$T^{pl(i)}$ travel time for a round trip of a loaded truck in platooning in case (*i*) (hour),

$T_{emp}^{nor(i)}$ travel time for a round trip of an empty truck in normal operation in case (*i*) (hour),

$T^{nor(i)}$ travel time for a round trip of a loaded truck in normal operation in case (*i*) (hour),

$t_{l(j)}$ loading time at center $j = \{A, B\}$ (hour),

$t_{u(j)}$ loading/unloading time at center $j = \{A, B\}$ (hour),

$t_{s(j)}$ resting time at $j = \{A, B\}$ (hour),

t_{pc} time for platoon formation (hour),

d_j distance between logistics firm $j = \{A, B\}$ to platoon formation center (km),

d_h distance between platoon formation centers (km),

v_g travel speed on-road (=30 km/h),

v_h travel speed on highway (=80km/h),

t_{ps} time for platoon decoupling (hour).

With these formulations, we can obtain the travel time for each driver in each case and correspondingly the number of necessary trucks with frequency of resting at home for a given inter-regional car-go volume by considering Hours of Service regulation in Japan, such as the maximum on-duty time and the minimum amount of resting time. Table 2 shows an example of the calculation results for different distances. In the case where the cargo volume for an outbound route is 60 trucks and that for return route is 30 trucks (half of outbound) and departure time should be between 4:00 and 6:00 pm as is the usual case shown in the next chapter. From this simple calculation, we can find that empty truck platooning has significant benefits in reducing the required number of trucks for any route distance and also for reducing the number of drivers for relatively shorter distances. These benefits can link to improvements in vehicle utilization efficiency and drivers' working environment. For longer distances, the benefits re-duce because the returned vehicles and drivers cannot be employed the next day due to long travel time and departure between 4-6 pm.

Table 2. Example of calculation results of the required number of trucks and drivers for different distances

	Normal Operation		Empty Truck Platooning: Case (1)		Empty Truck Platooning: Case (2)	
Distance between platoon formation centers (km)	Required number of trucks	Required number of drivers	Required number of trucks	Required number of drivers	Required number of trucks	Required number of drivers
240 km	360	360	270	270	270	270
320 km	360	360	270	270	270	270
400 km	360	360	270	330	270	270
480 km	360	360	270	360	270	270
560 km	360	360	270	360	270	330
640 km	360	360	-	-	270	360
720 km	360	360	-	-	270	360

BENEFIT EVALUATION OF TRUCK PLATOONING: A CASE STUDY

In this chapter, we apply the abovementioned model to inter-regional freight transport in the real world. We select the inter-regional freight data between Tokyo and Aichi (around 300 km distance) as a case study OD pair since the distance is in the optimal range, from the analysis results in the previous chapter, and the OD pair is one of the largest freight transport markets in Japan. Figures 5 and 6 show the aggregate data of the departure time distribution of the actual freight volume from Tokyo to Aichi and Aichi to Tokyo, respectively, in 3 days (Oct. 20–23, 2015), which is the latest survey period of the inter-regional freight transport census in Japan. The freight volume is converted to the number of trucks by assuming that all the cargo was transported by a 15-ton heavy truck. As shown in these figures, we can find the geographical imbalance in freight volume in different directions and the concentration of the departure time of freight transport on late evening time. Although this three-day survey is too short to draw general conclusions, especially on long-term phenomena such as seasonality of demand, we try to grasp the order of the benefit of introducing empty truck platooning operation due to the data limitation (there is no other freight transport data available in Japan). Additionally, the concentration of the departure time of freight transport on late evening time seems to be a common phenomenon in other days, which is important factor for our pro-posed operation.

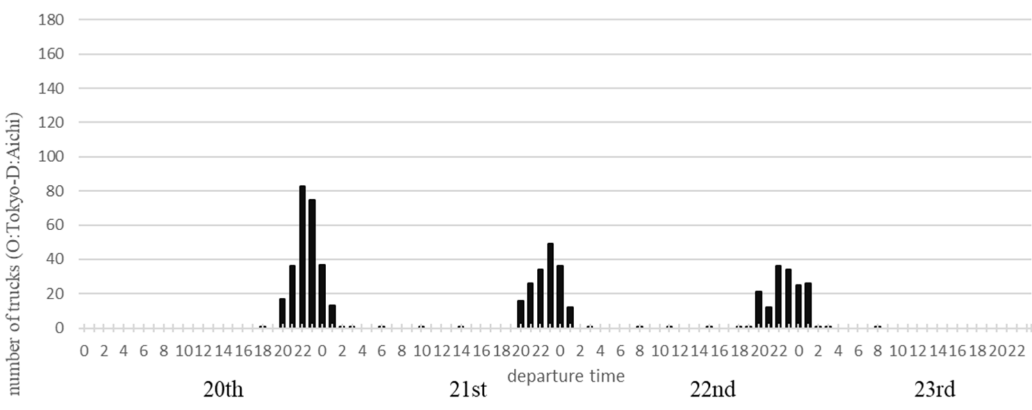


Fig. 5. Departure time distribution of the actual freight volume from Tokyo to Aichi in 3 days (Oct. 20–23, 2015)

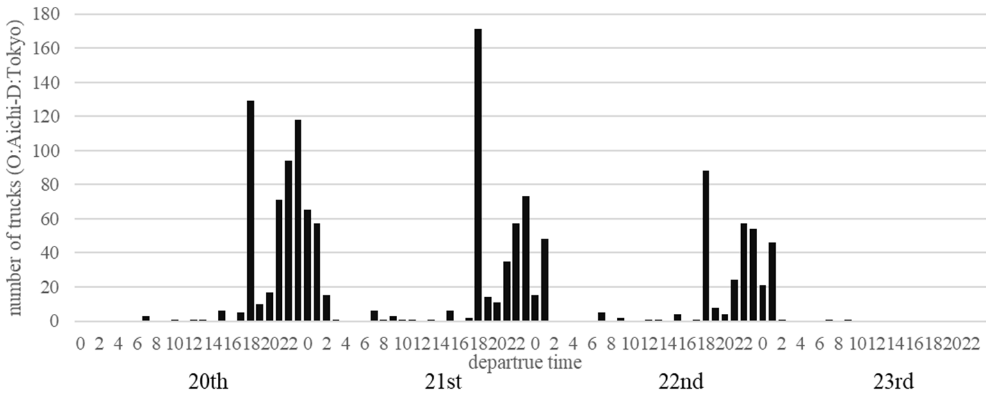


Fig. 6. Departure time distribution of the actual freight volume from Aichi to Tokyo in 3 days (Oct. 20–23, 2015)

Based on this inter-regional freight volume between Aichi and Tokyo, we calculated the required number of trucks and the total amount of rest taken in the truck or Tokyo, during these 3 days. The results are shown in Figures 7 and 8. The required number of trucks can be reduced by 16% and the total number of taking a resting time in a truck can be also reduced by 44%, based on the three-day inter-regional freight volume between Aichi and Tokyo. These results show that the proposed empty truck platooning operation has a significant benefit for inter-regional freight transport, including transport-related cost and the working environment of the truck drivers on long-haul routes.

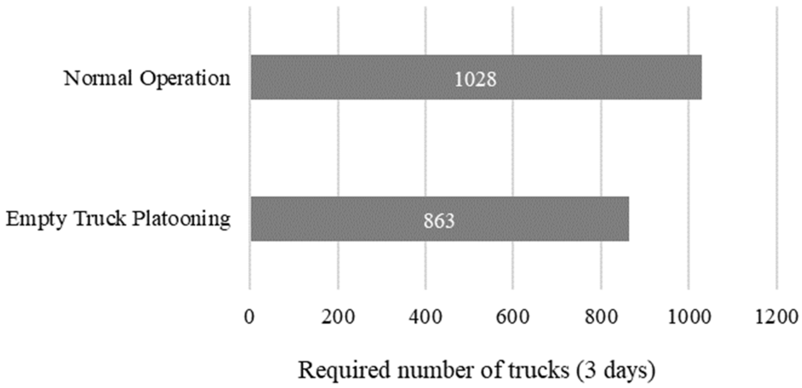


Fig. 7. Comparison of the required number of trucks (3 days between Tokyo and Aichi region)

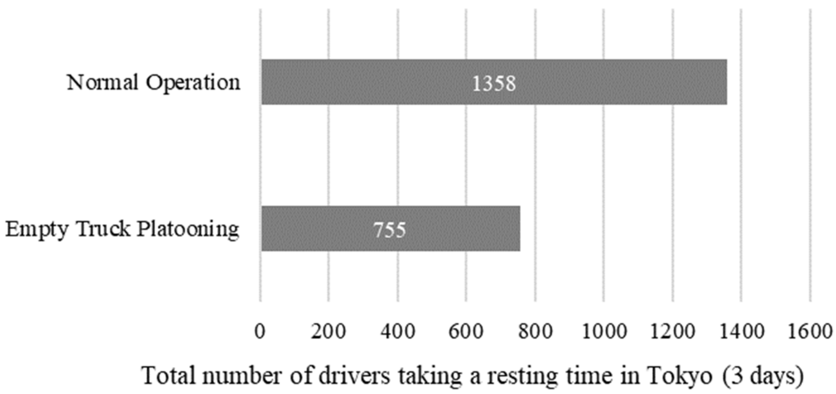


Fig. 8. Comparison of the total number of trucks taking a resting time in Tokyo (3 days between Tokyo and Aichi region)

To determine the total cost of inter-city freight transport, we define four cost as shown in the following equations. The total cost consists of highway toll fee, fuel cost, driver's cost, and truck cost (equation (9)). Highway toll fee is calculated based on the policy of Central Nippon Expressway Company (NEXCO) (a Japanese highway company) as shown in equation (10). The reduced fuel consumption, due to the reduction in air-drug owing to truck platooning, is considered in the calculation as shown in equation (11) (the coefficient is assumed to be 0.88 with reference to Browned et al. (2004). Finally, the cost of each truck is assumed to be a constant value, calculated from the standard price of a heavy truck (Hino Motors, Ltd.) and its durable life in a depreciation policy (5 years) (around 79,000 yen/week/vehicle).

$$\text{TotalCost} = \sum_i c_{h(i)} + \sum_i c_{f(i)} + \sum_j c_{d(j)} + \sum_k c_{v(k)} \quad (9)$$

$$c_{h(i)} = 150 + (24.6 \times 1.65 \times \sum_i d_{h(i)}) \quad (10)$$

$$c_{f(i)} = a \times w_f \, / \, \text{fuel\_eff.} \times \sum_i d_{h(i)} \quad (11)$$

$$c_{d(j)} = w_c \times w_d \times \sum_j t_{d(j)} \quad (12)$$

$c_{h(i)}$	highway toll fee for truck travel *i* (yen)
$c_{f(i)}$	fuel cost for truck travel *i* (yen)
$c_{d(i)}$	driver's cost for truck driver *j* (yen)
$c_{v(k)}$	vehicle cost for truck *k* (yen)
$d_{h(i)}$	driving distance on highway of truck travel *i*
a	air drug reduction coefficient (0.88)
w_f	fuel price (115.6 yen/l)
fuel_eff	fuel efficiency (4.05 km/l)
w_c	wage reduction coefficient (0-1)
w_d	hourly wage (3.323 yen/hour)
$t_{d(j)}$	on-duty time of driver *j* (hour)

Figure 9 shows the result of calculating the total cost in both scenarios, normal and platooning operation. It indicates that a large portion of the cost reduction is in the driver and truck cost, but the drive's cost is dependent on the reduction coefficient. In this analysis, the highway toll fee in the platooning case is the same as that of the normal case (e.g. three times of one vehicle if the platooning consists of three vehicles). Again, the truck cost can be significantly reduced by using the proposed new operation model.

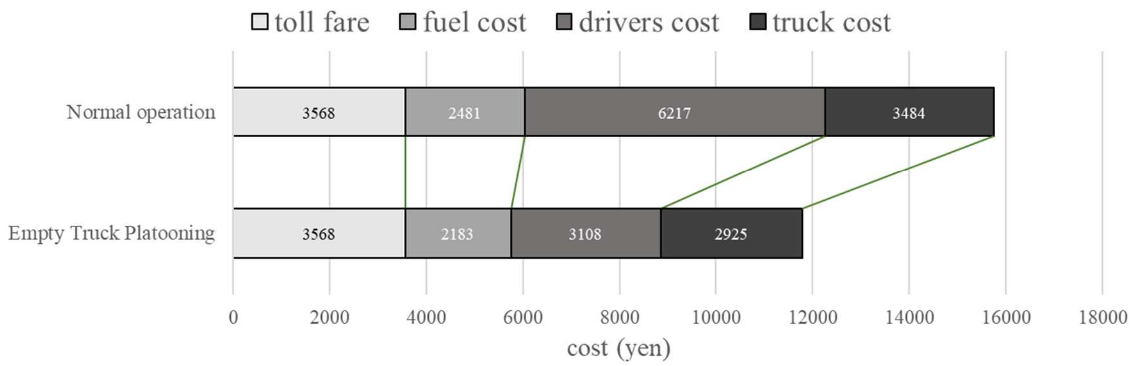


Fig. 9. Comparison of the total cost (3 days between Tokyo and Aichi region)

CONCLUSIONS

In this paper, we proposed a new operational concept to utilize truck platooning technology for transporting empty trucks based on the intercity freight demand imbalances in Japan and then analyzed the potential benefit of the proposed model, in terms of labor cost, efficiency of truck use, and drivers' working environment. From the analysis results using the actual freight flow data collected through surveys within 3 days in Japan, the cost reduction is estimated to be 16% in the required number of trucks and 44% in the number of taking a rest time in a truck. These results are some of the examples from the analysis using the 3-day freight transport survey data. However, they indicate that the proposed empty truck platooning operation has significant benefits for inter-regional freight transport, including transport-related cost and working environment of the truck drivers on long-haul routes. Although the proposed operation has potential significant benefits, the operation assumes the relaxation of "on-duty time" regulation in the labor standard act by considering the future introduction of autonomous driving and truck platooning. As the benefit of the proposed operation is significant according to our analysis, this relaxation of the labor regulation is worth considering by carefully investigating the safety of the platoon operation and its impact on the driver's working environment.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This work was supported by JSPS KAKENHI, Grant Number 19H02255.

REFERENCES

Bhoopalam A.K., Agatz N., Zuidwijk R., 2018. Planning of truck platoons: A literature review and directions for future research, Transportation Research Part B: Methodological, 107, 212¬228, http://doi.org/10.1016/j.trb.2017.10.016.

Boysen N., Briskorn D., Schwerdfeger S., 2018. The identical-path truck platooning problem, Transportation Research Part B, 26–39, http://doi.org/10.1016/j.trb.2018.01.006.

Browned F., McArthur J., Radovich C., 2004. Fuel Saving Achieved in the Field Test of Two Tandem Trucks. California PATH Research Report UCB-ITS-PRR-2004-20. University of Southern California, available on the internet: https://merritt.cdlib.org/d/ark:%2F13030%2Fm5gb258k/2/producer%2FPRR-2004-20.pdf (05/11/2020)

COMPANION–COoperative dynamic for Mation of Platoons for sAfe and eNergy-optImized gOods transportatioN, http://www.companion-project.eu/ (5/11/2020)

European Truck Platooning Challenge - EU Truck Platoon Challenge, https://www.eutruckplatooning.com/ (05/11/2020)

Fritz H., Bonnet C., Schiemenz H., Seeberger D., 2004. Electronic tow-bar based platoon control of heavy duty trucks using vehicle-vehicle communication: Practical results of the CHAUFFEUR2 project, Proc. of 11th ITS World Congress.

Hirsch P., 2011. Minimizing empty truck loads in round timber transport with tabu search strategies, International Journal of Information Systems and Supply Chain Management, 4(2), 15–41, http://doi.org/10.4018/jisscm.2011040102.

Larsson E., Sennton G., Larson J., 2015, The vehicle platooning problem: computational complexity and heuristics, Transportation. Research Part C, 60, 258-277, http://doi.org/10.1016/j.trc.2015.08.019.

McKinnon A.C., 1996. The empty running and return loading of road goods vehicles, Transport Logistics, Vol. 1 No. 1, 1–19, http://doi.org/10.1163/156857096300150518.

McKinnon A., Ge Y., 2006. The potential for reducing empty running by trucks: a retrospective analysis, International Journal of Physical Distribution & Logistics Management, 36, 5, 391–410, http://doi.org/10.1108/09600030610676268

Ministry of Land, Infrastructure and Transport, http://www.mlit.go.jp/statistics/pdf/23000000x012.pdf (05/11/2020)

Shladover S.E., 2010, Truck automation operational concept alternatives, 2010 IEEE Intelligent Vehicles Symposium, 1072-1077, http://doi.org/10.1109/IVS.2010.5548061.

Tsugawa S., Jeschke S., Shladovers S.E., 2016. A review of truck platooning projects for energy savings, IEEE Transactions on Intelligent Vehicles, 1, 1, 68-77, http://doi.org/10.1109/TIV.2016.2577499.

Zhang L., Chen F., Ma X., Pan X., 2020, Fuel economy in truck platooning: a literature overview and directions for future research, Journal of Advanced Transportation, 2020, 2604012, http://doi.org/10.1155/2020/2604012.

Zhang W., Jenelius E., Ma X., 2017. Freight transport platoon coordination and departure time scheduling un-der travel time uncertainty, Transportation Research Part E, 98, 1-23, http://doi.org/10.1016/j.tre.2016.11.008.

SZANSA WYKORZYSTANIA TRUCK PLATOONING DLA TRANSPORT PUSTYCH SAMOCHODÓW W OBLICZU BRAKU RÓWNOWAGI ILOŚCI PRZEWOZÓW

STRESZCZENIE. **Wstęp:** W Japonii prawie 30% ciężarówek jeździ bez ładunku pomimo trudności w rekrutacji odpowiedniej ilości kierowców, szczególnie zjawisko to występuje w transporcie międzymiastowym. Biorąc pod uwagę nierównomierne rozłożenie potrzeb przewozowych, wydaje się nieuniknione występowanie pustych przewozów bez ładunków. Obiecującą technologią dla rozwiązanie tego problemu jest truck platooning (zintegrowane konwoje), dzięki które samochody dostawcze automatycznie podążają za pierwszym pojazdem, dzięki czemu umożliwiają oszczędność zużywanego paliwa oraz ograniczają konieczny wkład ze trony kierowcy. W pracy zaproponowano model biznesowy umożliwiający zastosowanie technologii truck platooning do transportu pustych samochodów, istnieje, których wynika z niezrównoważonego zapotrzebowania na transport ładunków.

Metody: Po przeanalizowaniu popytu na usługi transportowe w Japonii, wykazujący brak równowagi, stworzono model analityczny określający wpływ zastosowania truck platooning do przewozu pustych samochodów na koszt robocizny oraz samochodów. Następnie przeanalizowano wpływ na rynek transportowy i przetestowano model na danych pochodzących z obecnego rynku transportowego w Japonii.

Wyniki: Na podstawie wyników analizy, w której użyto danych pozyskanych przez okres 3 dni w Japonii, oszacowano redukcję kosztów o 16% odnośnie zapotrzebowania na samochody oraz o 44% odnośnie czasu odpoczynku. Zaproponowany model operacyjny truck platooning dla pustych samochodów daje więc istotne benefit w transporcie międzyregionalnym, obejmując koszty transportowe oraz środowisko pracy kierowców na długich trasach.

Wnioski: W pracy zaproponowano nową koncepcję zastosowania technologii truck platooning dla transportu pustych samochodów wynikającą ze niezrównoważonego popytu na usługi transportowe. Aczkolwiek proponowana operacja daje potencjalnie istotne benefity, metoda ta zakłada poluzowanie regulacji czasu pracy poprzez uwzględnienie autonomicznych przewozów i truck platooning. Uzyskane benefity z zastosowania tej metody są istotne i w związku z tym warte jest rozważenie poluzowania regulacji dotyczących czasu pracy, uwzględniając bezpieczeństwo operacji truck platooning i jej wpływu na środowisko pracy kierowcy.

Słowa kluczowe: truck platooning, pusty przewóz, nierównomierne rozłożenie potrzeb przewozowych, regulacja czasu pracy, środowisko pracy kierowców, koszt samochodu

Terumitsu Hirata ORCID ID: https://orcid.org/0000-0001-5136-3010
Ibaraki University
Department of Urban and Civil Engineering
4-12-1, Nakanarusawa, Hitachi, Ibaraki 3168511, **Japan**
e-mail: terumitsu.hirata.a@vc.ibaraki.ac.jp

Taiki Fukaya ORCID ID: https://orcid.org/0000-0001-7989-5123
Ibaraki University
Department of Urban and Civil Engineering
4-12-1, Nakanarusawa, Hitachi, Ibaraki 3168511, **Japan**
e-mail: 20nm821n@vc.ibaraki.ac.jp

LogForum
> Scientific Journal of Logistics <
2020, 16 (3), 385-396
http://doi.org/10.17270/J.LOG.2020.453
http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X
ORIGINAL PAPER

DETERMINANTS OF FREIGHT VOLUME AND EFFICIENCY IN TRANSPORTATION AND STORAGE SECTOR

Büşra Gezikol, Hakan Tunahan, Seren Özsoy

Sakarya University, Sakarya, **Turkey**

ABSTRACT. **Background:** It is observed, in the studies on the factors affecting productivity and performance of the firms, that foreign firms are more successful than domestic firms thanks to their advantages of technological know-how, easy access to capital and modern management practices. Based on these findings, this study aims to measure the efficiency and performance of the companies in transportation and storage sector, which has an increasing share in the GDP of countries, with other industry-specific variables such as nationality and freight volume which are not in the literature.

Methods: To reveal the determinants of the freight volume and efficiency of the transportation and storage sector, the study employs Fixed Effect Model for analyzing the aggregate data of the companies in 30 European countries obtained from Eurostat from 2008 to 2018.

Results: The main findings in this study indicate that foreign controlled enterprises make a significant difference in terms of both efficiency and freight volume in the sector compared to domestic firms. The empirical results also suggest that investment in tangible goods and apparent productivity of labor serve as factors that are effective on both international and national freight volume. However, we have not found out any evidence for an impact of national enterprises on international and national freight volume.

Conclusions: The study shows the importance of nationality of the companies, loaded national and international transportation and apparent labor productivity as the determinants of freight volume and efficiency of the transportation and storage sector. The future researches can extend this study by conducting a firm level analysis.

Key words: transportation and storage sector, foreign companies, efficiency, freight volume, fixed effect model.

INTRODUCTION

The globalization which has evolved rapidly with the competition between Anglosphere and Sinosphere in the last 40 years has changed the firms into a multinational structure and has caused blurring the concept of nation state. Foreign capital and multinationalism have been an important area of discussion both in national economic and political discourses and in the literature. Although cultural, economic and political problems emerging with the globalization have harmed the internal dynamics of the countries and relations with each other, the presence of foreign capital and foreign direct investments in countries have led domestic and foreign firms to interact and compete with each other implicitly or explicitly.

There is vast literature especially on macro base studying the effects of both foreign direct investments (FDI). Studies show that foreign firms can greatly contribute to economic development by increasing domestic competition and consequently lead to further productivity, lower prices and more efficient resource distribution thanks to the advantages of technological know-how, easy access to capital and modern management practices. FDI also has a significant effect on the employment conditions in the domestic markets.

Citation: Gezikol B., Tunahan H., Özsoy S., 2020. Determinants of freight volume and efficiency in transportation and storage sector. LogForum 16 (3), 385-396, http://doi.org/10.17270/J.LOG.2020.453
Received: 12.02.2020, Accepted: 10.04.2020, on-line: 30.06.2020.

Multinational corporations employ high skilled workers, pay higher prices and offer better working conditions. Indeed, OECD [2008] confirms that foreign-owned firms in host countries seem to be improving in terms of wages and employment conditions such as working hours.

Addressing the factors and their impact levels that affect productivity and performance at the firm level in the context of nationality of the firms provides a valuable instrument to business managers and policy makers. However, these studies are not very common in the literature. Based on the competition and interaction among domestic and foreign companies, the existing literature shows that foreign firms perform better than domestic firms in one or more of the various fields such as efficiency, trade volume, investment amount, access to international markets, etc.

Furthermore, there are only a few studies on ownership comparison for transportation and storage sector which is a critically important sector for the flow of goods in an economy. In order to overcome a deficiency in the literature and the main purpose of this study is to analyze the factors that affect the national or international freight volume and efficiency of the transportation and storage sector in the countries on the basis of nationality of the companies. The reason for the inclusion of freight volume in the transportation and storage sector in the study is that we assume that this factor will be a good variable in representing the power to reach international markets. Efficiency is chosen because it is one of the main factors in comparing the performance of companies.

To this end, we conduct the study in two stages. Firstly, in order to reveal the determinants of the freight volume, the effect of number of foreign controlled and national enterprises, amount of investment and sector productivity on the national or international freight volume is analyzed. Secondly, the impacts of selected variables such as number of foreign controlled and national enterprises, amount of investment and average personnel cost is examined to determine the factors affecting efficiency in transportation and storage sector.

It is thought that the study will contribute to the literature in two ways and offers originality: First one is to contribute to close the study gap on the effect of foreign companies and efficiency factors in the transportation and storage sector which has been developing rapidly in the national economies and globally, and its share in the gross product of the countries has increased rapidly. Second one is that this study analyzes this sector by using freight volume and efficiency variables that are not found in the literature.

ON THE PERFORMANCE AND EFFECT OF FOREIGN COMPANIES IN THE HOST COUNTRY

Existing literature shows that FDI have positive effects on both competition and domestic firms in the host country in the long run. Because, domestic firms can increase their performance by observing and benchmarking foreign ones in the country. Also, increasing competition in the domestic market with the appearance of foreigners pushes domestic firms to search for new technology, which increases research and development (R&D) investments and as a result, increases productivity and competitive power of the companies. For instance, Liu and Wang [2003], Harris and Catherine [2003], Görg and Strobl [2005] observe the positive effects of FDI on productivity respectively in Ireland, China and United Kingdom. Newman et al. [2015]'s study on the Vietnamese manufacturing industry clearly shows that domestic firms cooperating with foreigners have positive results in terms of productivity. Foreign companies affect the domestic firms not only in terms of productivity but also in different fields. For instance, in the studies of Wang and Wong [2016], they have observed that foreign firms increase technical efficiency in their industry including domestic firms. Elmawazini et al. [2018] have emphasized that FDI can have an impact not only in terms of productivity and technical efficiency, but also in macro labor productivity. Innovation performance affecting productivity is another factor that can be addressed. In their studies, Joe et al. [2019], have stated that the innovation activities of the foreign companies in Korea encourage the Korean domestic companies. Both the above-mentioned studies and recent studies prove that foreign companies affect productivity and innovation and encourage domestic companies to improve themselves. In Karentina [2019]'s study, it is seen that FDI also affects productivity in capital-intensive domestic enterprises. Even if the effects don't occur in the short term, it has been determined that they cause positive effects on productivity in the long term. The effects of productivity differ according to the structure of the workforce and the size of the firm. Apostolov and Scagnelli [2019]'s study in Macedonia and Bentivogli and Mirenda [2017]'s study in Italy show that well performed foreign firms force domestic firms to compete, however, there is an increase in the employment and export-oriented initiatives in domestic firms. As it is seen, the performance of foreign companies forces many domestic companies to encourage competition and to develop in terms of innovation, workforce, size and capital.

However, foreign firms to gain superiority in many areas in the short time and gain more efficiency after entering the market. Literature indicates that the performance and efficiency of foreign or multinational firms are better than domestic firms in many sectors.

Beaumont, Schroder and Sohal [2002] observe that foreign firms operating in the manufacturing sector in Australia and Canada perform better than domestic firms, and also these firms are faster for using and managing the advanced manufacturing technology than others. The reason is that foreign-owned firms can draw from a wider knowledge base, have economies of scale, have more skilled and experienced managers and/or have a more highly skilled labor force [Chamarbagwala et al., 2000]. Unlike other studies, Ito [2011] deals with the performance comparison of domestic and foreign companies in the service industry. In the study, it is stated that foreign firms operating in the service industry in Japan perform better than domestic firms in terms of efficiency. Bournakis et al. [2019] state that multinational companies in the field of R&D in the UK perform better than domestic companies.

Researchers also have been interested in developing countries on the subject. Dimelis and Louri [2002] state that foreign firms have a more efficient structure than many domestic firms, especially in the workforce, through the example of Greece. The study of Takıı [2004] also supports the above studies and expresses that that foreign-owned plants are more productive than locally owned plants. At the same time, differences in productivity are related to the degree of foreign ownership in Indonesian manufacturing is the another result. Douma, George and Kabir [2006] have investigated the performance of firms in emerging markets. They claim that foreign firms perform better than firms with other ownership structures and their productivity is noticeably higher due to financial strength and strength of partnerships. Kosova [2010] who presents a different perspective, states that the entry of foreign firms into the market has an important effect on the growth and efficiency of the market. Although domestic firms are negatively affected by this situation. The study of Greenaway, Guariglia and Yu [2014] show that foreign firms are better than domestic firms in terms of productivity in China, but also the joint venture of foreign and domestic firms can lead to better results in terms of performance. Peluffo [2015] expresses that variables such as labor productivity, total factor productivity, wages are more prominent in foreign companies in Uruguay. In addition, it is observed that foreign firms pay more wages to their workers in line with their abilities. Consequently, productivity also increases. Vu [2016] states that foreign firms have 60% more technical efficiency than domestic firms in Vietnam. Konara and Wei [2017] conclude that multinational companies have good performance than others in Sri Lanka. Marinescu et al. [2019] reveal that foreign firms in Romania perform better than domestic firms in terms of profitability and investments.

Although different countries, years and sectors have been addressed about productivity and foreign capital in the literature, it has almost been obtained as a result of foreign firms being more efficient and performing better than domestic firms. In fact, this can be explained by several factors which are discussed in measuring efficiency. The amount of capital, the structure of the workforce, the size of the company, and the structure of income sources and the management culture of the company [The Manufacturer's Organization, 2018] are all considered as important indicators of companies' efficiency and performance.

As we mentioned in the previous parts, FDI creates a revival in many sectors in the country. Nevertheless, this recovery is thought to be more effective in some sectors. The impact of FDI is more important on competition in the market for services such as telecommunications, retail trade where exports are not a general option, because service needs to be started at the delivery point [OECD, 2002]. As stated in the report, FDI generally concentrate on the telecommunication and retail sectors, but they also have reflections in the logistics sector. According to the EY European Investment Monitor Report [2019], supply chain reorganization strategies that started two years ago across Europe maintained a high level of FDI in logistics projects (+5%) last year. In addition, the market share of logistics among all FDIs is 9%. After sales-marketing, production and R&D in Europe, the area where the most investments are made is logistics. But there is very limited amount of literature on the FDI on logistics sector. Yang and Luqian [2010] analyses the impact of investments on the workforce in the logistics sector. This study shows that foreign firms are more competitive than domestic firms in providing investment and employment. Maggi and Mariotti [2010] state in their studies that FDI in the logistics sector have increased by 26% in Italy, and these investments are made especially by the logistics and cargo companies originating from China, Japan and Singapore. In addition, the power of the market and the benefit of the economies of scale are the elements that encourage investment. In another study, Maggi and Mariotti [2012] claim that the internationalization of production has expanded the logistics sector and the growth has caused foreign companies to be willing to operate in that country.

DATA, MODELS AND ESTIMATION TECHNIQUE

This study aims to analyze the factors that affect the national and international freight volume and efficiency of the transportation and storage sector in the countries on the basis of nationality of the companies. To this end, we use "Loaded National and International Transportation" as a proxy for "national and international freight volume" and "Apparent Labor Productivity" as a proxy for efficiency of transportation and storage sector.

We conduct the study in two stages. Firstly, in order to reveal the determinants of the freight volume, it is analyzed the effect of number of foreign controlled and national enterprises, amount of investment and sector productivity on the national or international freight volume. Secondly, the impacts of selected variables such as number of foreign controlled and national enterprises, amount of investment and average personnel cost is examined to determine the factors affecting efficiency in transportation and storage sector.

The data used in the analysis covers the years 2009-2018 for the first research question and the period 2008-2016 for the second research question. Due to existing data constraints, the data set is limited to 30 countries (EU 27- except Malta because of lack of data problem- Norway, Switzerland, Liechtenstein). Following Table 1 presents definitions of variables. LNT and LINT data are taken from Eurostat [2019] - Transport database and other variables are from Eurostat [2019] - Structural Business Statistics.

In the line with our research purpose, we create four different regression models. In first regression model which is built in accordance with the first research question of the study; LINT in transportation and storage sector is dependent variable; FCNE, NE, GITG and ALP are used as independent variables. In order to compare this model, an alternative model has been developed in which the same independent variables are included and only the dependent variable changes to the LNT.

Table 1. Definitions of Variables

Variables	Definitions
LNT	Logarithm of Loaded National Transport (1000 tonnes)
LINT	Logarithm of Loaded International Transport (1000 tonnes)
FCNE	Logarithm of Foreign Controlled Enterprises (number)
NE	Logarithm of National Enterprises (number)
GITG	Logarithm of Gross Investment in Tangible Goods (million Euro)
ALP	Logarithm of Apparent Labour Productivity (Gross value added per person employed - thousand Euro)
APC	Logarithm of Average Personnel Costs (personnel costs per employee - thousand Euro)
SWALP	Logarithm of Simple Wage Adjusted Labour Productivity (Gross value added by personnel costs – percentage)
FCSWALP	Logarithm of Simple Wage Adjusted Labour Productivity for Foreign Controlled Enterprises (Gross value added by personnel costs – percentage)
TE	Turnover per Enterprise - thousand euro
TFCE	Turnover per Foreign controlled enterprise - thousand euro

Note: The values of all variables in the study are limited to the transport and storage sector

In second regression model which is built in accordance with the second research question of the study; ALP in transportation and storage sector is dependent variable; FCNE, NE, GITG and APC are used as independent variables. In addition, the dependent variable in this model has been changed to SWALP and the regression has been re-run in order to strengthen estimated results.

In this study, based on the claims of the studies in the literature and the descriptive statistics in our data set, it is accepted that foreign firms have superior features from national firms. Table 2 shows the selected descriptive statistics about our data set. In this table, it can be seen that the Wage Adjusted Labor Productivity for Foreign Controlled Enterprises is higher than the sector productivity average. In addition, when the average turnover per enterprise and average gross investments in tangible goods amounts per enterprise are compared, there are values above the sector average for foreign controlled enterprises. Another striking point in the table is that national transportation in the sector in the relevant years and countries is more than international transportation.

Table 2. Selected Descriptive Statistics about the Data Set

Variables	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Loaded National Transportation (1000 tonnes)	298	873798.9	2311744	14384	1.43E+07
Loaded International Transportation (1000 tonnes)	289	61733.73	162098.6	17	1197205
Number of National Enterprises	290	65025.14	169160.4	553	1246259
Number of Foreign Controlled Enterprises	249	792.5783	2045.517	26	14537
Gross Investment in Tangible Goods per Enterprise (Million Euro)	289	0.1881425	0.3159924	0.006308	2.472875
Gross Investment in Tangible Goods per Foreign Controlled Enterprise (Million Euro)	240	1.090801	1.490115	0.021027	10.09811
Simple Wage Adjusted Labour Productivity for All Enterprises (%)	279	150.2703	25.65276	90.7	222.3
Simple Wage Adjusted Labour Productivity for Foreign Controlled Enterprises (%)	242	196.7694	87.76861	122.9	1213.6
Turnover per Foreign Controlled enterprise	241	20850.42	21402.42	272.8	124372
Turnover per Enterprise	289	1721.417	2196.636	179.9	13015.3

Panel data consists of units that are put together for certain periods. It gives the opportunity to use both time series and cross sectional data together. Some of the advantages of using panel data are that the unit change can be added to the model, creating fewer multi-collinearity problems, reducing the estimate deviation. In addition, it enables more comprehensive models to be established in cases where time series is short or cross-sectional observation is insufficient [Tatoğlu, 2016]. Panel data analysis also clarifies the country-wide heterogeneity and the complex consequences invisible in cross-sections [Greene, 2012].

The two most obvious methods used in panel data analysis are Fixed Effect Model (FEM) and Random Effect Model (REM) [Gujarati, 2003]. In FEM, it is assumed that the cross-sectional units in the model have their own characteristics, these properties may differ between the units and these differences may affect the result variables. Therefore, FEM is appropriate for models with correlation between error term and explanatory variables in the model [Gujarati, 2003]. Fixed effects (FE) should be used when analyzing the effect of variables that change over time. FE removes the effects of properties that do not change over time, thus enabling predictors to evaluate the net effect on the outcome variable [T. Reyna, 2007]. In REM, unlike the fixed effects model, the changes between units are assumed to be random and unrelated to the explanatory variables in the model [T. Reyna, 2007]. "The crucial distinction between fixed and random effects is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not" [Green, 2008].

Formally, the choice between FEM and REM is made as applying Hausman test. It basically tests whether the error terms are correlated with the explanatory variables. The null hypothesis is that the preferred model is random effects whereas the alternate hypothesis is that the more appropriate model is fixed effects. Considering Hausman test statistics and the structure of dataset, we decide to use FEM.

The functional representation of FEM is written as

$$Y_{it} = \beta_1 X_{it} + v_i + u_{it}$$

where "i" represents the countries, "t" denotes years. (Equation 1)

In equation 1, "y" is the dependent variable, "x" refers to the independent variable, "u_{it}" is the error term, "v_i" is the effect of country-specific variables that do not change over time (the unit effect that is constant over time). In this model country effects (vi) are assumed to be handled as fixed, not random. It is also assumed that "u_{it}" and "x_{it}" are uncorrelated.

Since panel data includes cross-section and time dimensions, the problems of cross-section data (e.g. heteroscedasticity, cross-sectional dependency) and time series data (e.g. non-stationarity) need to be addressed [Gujarati, 2003]. To this end, we use FEM with "robust" option. The option "robust" is used in order to create heteroscedasticity-robust standard errors [T. Reyna, 2007] By this way, it is prevented heteroscedasticity problem that is sourced by cross-sectional dependency. Also, due to the shortness of the time dimension of the data set, unit root tests that control the assumption that all series are stationary, which is the basic assumption of time series analysis, cannot be applied.

RESULTS AND INTERPRETATIONS

As mentioned before, the aim of this study is to analyze the factors that affect the national and international freight volume and efficiency of the transportation and storage sector. In the first step of estimations, we analyze the impact of selected determinants of freight volume (FCNE, NE, APL and GITG) on international and national freight volume (LNT and LINT). To this end, we conduct following two regression models.

$$LINT_{i,t} = \alpha + \beta_1 FCNE_{i,t} + \beta_2 NE_{i,t} + \beta_3 ALP_{i,t} + \beta_4 GITG_{i,t} + \varepsilon_{it} \qquad \text{(Equation 2)}$$

$$LNT_{i,t} = \alpha + \beta_1 FCNE_{i,t} + \beta_2 NE_{i,t} + \beta_3 ALP_{i,t} + \beta_4 GITG_{i,t} + \varepsilon_{it} \qquad \text{(Equation 3)}$$

The estimated results of these models are presented in Table 3. In this table, first three columns show the results where dependent variable is LINT, whereas last three columns indicate the results where dependent variable is LNT. As seen from the table, FCNE, GITG and ALP have positive and statistically significant effect on LINT. However, NE doesn't have any significant impact on LINT. Moreover, both ALP and GITG have positively significant impact on LNT, while NE is still insignificant. Surprisingly, unlike LINT, there is no statistically significant impact of FCNE on LNT. The results show that foreign controlled enterprises contributes more to the international freight volume of the countries compared to domestic ones; because of their advanced technologies, knowledge and skills in transportation and storage sector. We also find out that investments in Transportation and Storage Sector and labor productivity seem determinants of both international and national freight volume of the countries. Finally, the model shows that there is no evidence for an impact of national enterprises on international and national freight volume.

Table 3. The Impact of Selected Determinants of Freight Volume on Freight Volume

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	**LINT**	**LINT**	**LINT**	**LNT**	**LNT**	**LNT**
FCNE	0.225*		0.234**	-0.0327		-0.0335
	(0.113)		(0.111)	(0.0718)		(0.0710)
GITG	0.152**	0.165**	0.150**	0.123**	0.103*	0.123**
	(0.0654)	(0.0704)	(0.0623)	(0.0514)	(0.0536)	(0.0508)
ALP	0.461**	0.740**	0.376*	-0.211*	-0.186	-0.204
	(0.197)	(0.284)	(0.215)	(0.118)	(0.131)	(0.138)
NE		0.0928	0.0797		0.0128	-0.00684
		(0.103)	(0.0670)		(0.0509)	(0.0445)
Constant	5.714***	5.003***	5.184***	12.37***	12.10***	12.41***
	(1.234)	(1.580)	(1.327)	(0.464)	(0.673)	(0.607)
Observations	213	236	213	222	246	222
Number of id	29	30	29	29	30	29

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In the second step of analysis the impacts of selected variables such as number of foreign controlled enterprises (FCNE) and national enterprises (NE), amount of investment (GITG) and average personnel cost (APC) is examined to determine the factors affecting efficiency in transportation and storage sector (ALP). To do so, firstly, we run following regression model is given in Equation 4. The findings from this estimation are presented in first three Columns of Table 4.

$$ALP_{i,t} = \alpha + \beta_1 FCNE_{i,t} + \beta_2 NE_{i,t} + \beta_3 APC_{i,t} + \beta_4 GITG_{i,t} + \varepsilon_{it} \quad \text{(Equation 4)}$$

In Table 4, the first column shows only the results that only the effect of FCNE is controlled on the ALP, whereas column (2) indicates the results that the impact of NE is controlled, solely. Column (3) gives results in which both the effect of FCNE and NE are measured in the same model. When these three columns are evaluated together, it is seen that both FCNE and NE have a statistically significant and positive effect on ALP. Since the coefficient of FCNE is higher than NE in the third column, we can deduce that the contribution of foreign controlled enterprises to the transportation and storage sector is higher compared to national enterprises. In addition, APC has a statistically positive significant effect on ALP in all three columns. However, GITG has no significant effect on ALP. These results show that the increase in average personnel costs may increase the productivity of the sector, while investments in tangible goods may not have a direct effect on the productivity of the transportation and storage sector.

Based on the result of "average personnel costs have a significant impact on productivity", we take the analysis one step further. Considering that the difference in productivity resulting from wage differences between enterprises can change the effect of other variables, we re-estimate our model using a simple wage adjusted efficiency variable (SWALP). In this model, which is expressed in the Equation 5, we take the simple wage adjusted apparent labor productivity as a dependent variable. In this model, we don't include APC as an explanatory variable, since the effect of the wage, which we consider covers most of the personnel costs, is excluded by the dependent variable.

$$SWALP_{i,t} = \alpha + \beta_1 FCNE_{i,t} + \beta_2 NE_{i,t} + \beta_3 GITG_{i,t} + \varepsilon_{it} \quad \text{(Equation 5)}$$

In Table 4, columns (4), (5) and (6) show the estimated results that the dependent variable is SWALP. In this table, columns (4) and (5) show the results in which FCNE and NE have been added to the model separately, while column (6) shows the results where FCNE and NE have joined the model together. According to these results, both FCNE and NE have a statistically significant and positive effect on SWALP. However, GITG has no any significant effect on SWALP as in ALP. Also, the fact that FCNE's coefficient is higher than NE in column (6) indicates that FCNE is a more effective variable than NE in terms of magnitude on SWALP. In summary, these results indicate that, even when the determinative impact of the wage differences on productivity is controlled, foreign controlled enterprises may make a higher contribution to sector productivity than national enterprises.

Table 4. The Factors Affecting Efficiency in Transportation and Storage Sector

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	**ALP**	**ALP**	**ALP**	**SWALP**	**SWALP**	**SWALP**
FCNE	0.155***		0.156***	0.135***		0.130***
	(0.0317)		(0.0347)	(0.0382)		(0.0405)
GITG	0.0219	0.0258	0.0187	0.00672	0.00247	0.00441
	(0.0306)	(0.0338)	(0.0294)	(0.0213)	(0.0222)	(0.0212)
APC	0.756***	0.780***	0.634***			
	(0.137)	(0.120)	(0.110)			
NE		0.0777***	0.0789***		0.0416***	0.0383**
		(0.0173)	(0.0175)		(0.0142)	(0.0142)
Constant	0.116	0.139	-0.272	4.154***	4.563***	3.813***
	(0.417)	(0.372)	(0.396)	(0.265)	(0.186)	(0.291)
Observations	221	244	221	220	243	220
R-squared	0.396	0.372	0.432	0.141	0.020	0.159
Number of id	29	29	29	29	29	29

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

CONCLUSIONS

The transportation and storage sector, which is an important key factor for countries to gain superiority in international trade, is rapidly changing in terms of size and competition all over the world. This paper aims to explore the factors that affect the national or international freight volume and efficiency of the transportation and storage sector on the basis of nationality of the companies by conducting panel data including 30 European countries.

The empirical results suggest that investment in tangible goods and apparent productivity of labor serve as factors that are effective on both international and national freight volume. Besides, foreign controlled enterprises contribute only to international freight volume, unlike national freight volume. However, there is no evidence for an impact of national enterprises on international and national freight volume.

Moreover, the main findings in this study indicate that factors such as foreign controlled enterprises, national enterprises and average personnel cost can increase efficiency in transportation and storage sector. Indeed, the results suggest that foreign controlled enterprises seem to be a more influential than national enterprises in terms of contributing to the level of efficiency of transportation and storage sector. These results do not change even when the effect of wage differences on productivity is eliminated.

Based on the results, it can be inferred that foreign controlled enterprises make a significant difference in terms of both efficiency and freight volume in the sector compared to other firms.

On the one hand, this study provides important information for the players of the transportation and storage sector, on the other hand, it provides valuable information for the academicians working in this field. First of all, it will be useful to emphasize the fact that the foreign controlled enterprises in the sector, which are mentioned in the literature and supported by the analysis results, are more efficient than the others. Accordingly, national enterprises which would like to gain competitive advantages in international arenas should more invest in tangible assets that provide technical progress and knowledge intensity. Secondly, companies that would like to increase their freight volumes should take more strategic investment decisions and take initiatives to increase their efficiency, since investment in tangible assets in the sector and apparent labor productivity affects both national and international freight volumes. Moreover, the fact that the average personnel costs incurred by companies in this sector contributes to the efficiency, indicates that firms should pay attention to satisfactory personnel requirements such as education, wage, social security, rather than their investments in tangible assets. Finally, the study is also guiding in academic sense. As far as we know, this study is the first study to examine the freight volume and efficiency of the transportation and storage sector, it adds a new dimension to relevant literature.

In this paper, results shouldn't be generalized in terms of the impact of determinants of transportation and storage sector because of the limitation of determinants. Therefore, the future research, can extend this study with using other potential determinants of this sector. Besides, a firm level analysis can provide stronger results for the link between factors that effect on freight volume and efficiency of transportation and storage sector.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Apostolov, M., Scagnelli, S.D., 2019. Foreign-Versus Domestic-Owned firms in the Predicament â ˜Cui bono?â ™, Business systems research journal: international journal of the Society for Advancing Business & Information Technology (BIT), 10(2), 18-36. http://doi.org/10.2478/bsrj-2019-015

Beaumont N., Schroder R., Sohal A., 2002. Do foreignâ owned firms manage advanced manufacturing technology better?, International Journal of Operations & Production Management. http://doi.org/10.1108/01443570210433535

Bentivogli, C., Mirenda, L., 2017. Foreign ownership and performance: evidence from Italian firms, International Journal of the Economics of Business, 24(3), 251-273. http://doi.org/10.1080/13571516.2017.1343542

Bournakis I., Papanastassiou M., Pitelis C., 2019. The impact of multinational and domestic enterprises on regional productivity: evidence from the UK, Regional Studies, 53(2), 159-170. http://doi.org/10.1080/00343404.2018.1447661

Chamarbagwala R., Ramaswamy S., Wunnava P. V., 2000. The role of foreign capital in domestic manufacturing productivity: empirical evidence from Asian economies, Applied Economics, 32(4), 393-398. http://doi.org/10.1080/000368400322561

Dimelis S., Louri H., 2002. Foreign ownership and production efficiency: a quantile regression analysis, Oxford Economic Papers, 54(3), 449-469. http://doi.org/10.1093/oep/54.3.449

Douma S., George R., Kabir R., 2006. Foreign and domestic ownership, business groups, and firm performance: Evidence from a large emerging market, Strategic Management Journal, 27(7), 637-657. http://doi.org/10.1002/smj.535

Elmawazini K., Saleeby E.G., el Farouk A.I., Bashayer A.N., 2018. Tripartite decomposition of labor productivity growth, FDI and human development:

evidence from transition economies, Economic Change and Restructuring, 51(2), 153-171. http://doi.org/10.1007/s10644-016-9197-7

Ernest & Young, 2019. How can Europe raise its game?, EY Attractiveness Survey Europe, https://www.ey.com/Publication/vwLUAssets/ey-europe-attractiveness-survey-2019/$File/ey-europe-attractiveness-survey-2019.pdf

GĂśrg H., Strobl E., 2005. Foreign direct investment and local economic development: Beyond productivity spillovers, does foreign direct investment promote development, 137-55. ISBN 0-88132-381-0

Greenaway D., Guariglia A., Yu Z., 2014. The more the better? Foreign ownership and corporate performance in China, The European Journal of Finance, 20(7-9), 681-702. http://doi.org/10.1080/1351847X.2012.671785

Greene W.H., 2008. Econometric analysis, 6th ed., Upper Saddle River, N.J.: Prentice Hall.

Greene W.H., 2012, Econometric Analysis (7th Ed.), Harlow: Pearson.

Gujarati D.N., 2003, Basic Econometrics (4th Ed.), Boston: McGraw-Hill.

Harris R., Catherine R., 2003, Foreign Ownership and Productivity in the United Kingdom Estimates for U.K. Manufacturing Using the ARD, Review of Industrial Organization, 22(3): 207 -223, http://doi.org/10.1023/A:1023622407571

Ito K., 2017. Entry of Foreign Multinational Firms and Productivity Growth of Domestic Firms: The Case for Japanese Firms, In Competition, Innovation, and Growth in Japan (pp. 225-250), Springer, Singapore. http://doi.org/10.1007/978-981-10-3863-1_11

Joe D.Y., Oh F.D., Yoo H., 2019. Foreign Ownership and Firm Innovation: Evidence from Korea, Global Economic Review, 48(3), 284-302. http://doi.org/10.1080/1226508X.2019.1632729

Karentina R., 2019. The spillover effects of foreign direct investment on labor productivity, Economic Journal of Emerging Markets, 11(1), 32-45. http://doi.org/10.20885/ejem.vol11.iss1.art4

Konara P., Wei Y., 2017. Foreign direct investment as a catalyst for domestic firm development: The case of Sri Lanka, Transnational Corporations, 23(3), 1-32. http://doi.org/10.18356/d3e73f33-en

Kosova R., 2010. Do foreign firms crowd out domestic firms? Evidence from the Czech Republic, The Review of Economics and Statistics, 92(4), 861-881. http://doi.org/10.1162/REST_a_00035

Liu X., Wang C., 2003. Does foreign direct investment facilitate technological progress? - Evidence from Chinese industries, Research Policy, 32 (6): 945-953. http://doi.org/10.1016/S0048-7333(02)00094-X

Maggi E., Mariotti I., 2010. Logistics FDI in Italy: integration strategies and motivations, European Transport Research Review, 2(1), 13-24. http://doi.org/10.1007/s12544-010-0024-3

Maggi E., Mariotti I., 2012. Globalization and the rise of logistics FDI: the case of Italy, Foreign Investment: Types, Methods and Impacts, 29-60.

Marinescu N., Constantin C., Haar L.N., 2019. The relative performance of foreign-owned subsidiaries and domestic companies, Post-Communist Economies, 31(2), 161-180. http://doi.org/10.1080/14631377.2018.1505692

Newman C., Rand J., Talbot T., Tarp F., 2015. Technology transfers, foreign investment and productivity spillovers, European Economic Review, 76, 168-187. http://doi.org/10.1016/j.euroecorev.2015.02.005

OECD, 2002, Foreign direct investment for development: maximizing benefits, minimizing costs, Paris.

OECD, 2008, OECD benchmark definition of foreign direct investment, Paris

Peluffo, A., 2015. Foreign direct investment, productivity, demand for skilled labour and wage inequality: An analysis of Uruguay, The World Economy, 38(6), 962-983. http://doi.org/10.1111/twec.12180

Takii S., 2004. Productivity differentials between local and foreign plants in Indonesian manufacturing, 1995, World Development, 32(11), 1957-1969. http://doi.org/10.1016/j.worlddev.2004.06.010

The Manufacturer Organization, 2018, Piecing Together the Puzzle- Getting UK Manufacturing Productivity Growth Back On Trend, https://www.makeuk.org/insights/reports/2018/make-uk-productivity-report-2018

Torres-Reyna O., 2007. Panel data analysis fixed and random effects using Stata (v. 4.2), Data & Statistical Services, Princeton University, 112.

Vu, H. D., 2016, Technical efficiency of FDI firms in the Vietnamese manufacturing sector, Review of Economic Perspectives, 16(3), 205-230.

Wang M., Wong M.S., 2016. Effects of foreign direct investment on firm-level technical efficiency: stochastic frontier model evidence from Chinese manufacturing firms, Atlantic Economic Journal, 44(3), 335-361. http://doi.org/10.1007/s11293-016-9509-3

Yang W., Luqian W, 2010. Analysis on the employment effects of FDI in logistics industry, In The 2nd International Conference on Information Science and Engineering (pp. 2651-2654). IEEE. http://doi.org/10.1109/ICISE.2010.5689434

Yerdelen Tatoğlu F, 2016, Panel Veri Ekonometrisi. İstanbul, İnkılap Kitapevi Yayın San. Tic. A.Ş, 2-15.

WYZNACZNIKI WIELKOŚCI PRZEWOZÓW I SPRAWNOŚCI W TRANSPORCIE I MAGAZYNOWANIU

STRESZCZENIE. **Wstęp:** Na podstawie analizy publikowanych prac dotyczących czynników mających wpływ na ich produktywność można stwierdzić, że firmy o kapitale zagranicznym osiągają większe sukcesy aniżeli firmy krajowe, dzięki posiadanemu technologicznemu know-how, łatwiejszemu dostępu do kapitału oraz nowoczesnych sposób zarządzania. Celem pracy jest, w oparciu o te badania, zmierzenie efektywności i sprawności przedsiębiorstw w sektorze transportowym oraz magazynowym, mający coraz większy udział w GDP w porównaniu do innych specyficznych dla przemysłu zmiennych takich jak narodowość czy wielkość przewozów, niewystępujących jednak w literaturze naukowej.
Metody: W celu wytypowania determinantów wielkości przewozów i efektywności dla sektora transportowego i magazynowania, do badania użyto modelu Fixed Effect Model. Za jego pomocą poddano analizie zagregowane dane z przedsiębiorstw w 30 krajach europejskich, uzyskanych na podstawie Eurostatu z okresu 2008-2018.
Wyniki: Uzyskane w pracy wyniki wskazują, że przedsiębiorstwa zagraniczne wykazują istotną różnice w stosunku do przedsiębiorstwach krajowych w obszarze zarówno efektywności jak i wielkości przewozów w badanych obszarach. Dane empiryczne sugerują, że inwestycje w dobra materialne jak również wzrost produktywności pracy to czynniki mające wpływ na wielkość transportu zarówno krajowego, jaki międzynarodowego. Nie stwierdzono jednak wpływy czynnika narodowościowego na wielkość transportu zarówno krajowego, jaki międzynarodowego.
Wnioski: Praca wykazuje istotność czynnika narodowościowego dla przedsiębiorstw, udziału krajowego jak i międzynarodowego w transporcie, produktywności pracy, jako determinantów wielkości przewozów oraz efektywności branży transportowej i magazynowej. Badania te powinny być kontynuowane przy uwzględnieniu w analizie poziomu przedsiębiorstwa.

Słowa kluczowe: sektor transportowy i magazynowania, przedsiębiorstwa zagraniczne, sprawność, wielkość przewozów, stały model efektywności

Büşra Gezikol ORCID ID: https://orcid.org/0000-0002-3131-0162
Sakarya University
Business School
Department of International Trade
Sakarya, **Turkey**
e-mail: bgezikol@sakarya.edu.tr

Hakan Tunahan ORCID ID: https://orcid.org/0000-0002-9556-214X
Sakarya University
Business School
Department of International Trade
Sakarya, **Turkey**
e-mail: htunahan@sakarya.edu.tr

Seren Özsoy ORCID ID: https://orcid.org/0000-0001-6642-7195
Sakarya University
Business School
Department of International Trade
Sakarya, **Turkey**
e-mail: serenozsoy@sakarya.edu.tr

LogForum

2020, 16 (3), 397-408

> Scientific Journal of Logistics <

http://doi.org/10.17270/J.LOG.2020.493

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

SOLVING FOUR-INDEX TRANSPORTATION PROBLEM WITH THE USE OF A GENETIC ALGORITHM

Volodymyr Skitsko, Mykola Voinikov

Kyiv National Economic University named after Vadym Hetman, Kyiv, **Ukraine**

ABSTRACT. **Background:** Under conditions of digital transformation, the effective decision-making process should involve the usage of different mathematical models and methods, one of which is the transportation problem. The transportation problem, as the problem of resource allocation, is applicable in such domains as manufacturing, information technologies, etc. To get more precise solutions, the multi-index transportation problem can be applied, which allows taking into account several variables.

Methods: This paper develops an approach for applying the genetic algorithm for solving four-index transportation problems.

Results: The steps of the genetic algorithm for solving four-index transportation problems are outlined. The research has proved the steps of the genetic algorithm to be the same for all four-index transportation problem types, except for the first step (initialization), which is described for every type of transportation problem separately.

Based on the theoretical results, the program implementation of the genetic algorithm for solving four-index symmetric transportation problems has been developed with the open-source programming language typescript.

Conclusions: The paper promotes the application of the genetic algorithm for solving multi-index transportation problems. The investigated problem requires comprehensive studies, specifically, on the influence of change different parameters of the genetic algorithm (population size, the mutation, and crossover rates, etc.) on the efficiency of the algorithm in solving four-index transportation problems.

Key words: four-index transportation problem, symmetric transportation problem, genetic algorithm, program implementation.

INTRODUCTION

Under conditions of digital transformation, effective decision-making in management is possible to achieve with the use of different economic models and methods, which can be based either on classic approaches and tools or cutting-edge ones, for example, algorithms of collective intelligence, evolutionary algorithms, etc. The transportation problem as the problem of resource allocation in different domains such as manufacturing, information technologies, for example, when building communication networks or hardware and software resources sharing in cloud computing stays relevant until today.

The omnipresent usage of digital technologies is enabling the collection of large amounts of data, which can make the decision-making process more efficient. Besides, the increasing complexity of mathematical methods and models, on the one hand, is allowing using large amounts of data to make decisions more precise, and on the other hand, the number of computation increases as well and can affect the time needed to implement them. However, the evolution of computing hardware lets to solve complicated problems in an adequately short time. The problems, which

Citation: *Skitsko V., Voinikov M., 2020. Solving four-index transportation problem with the use of a genetic algorithm. LogForum 16 (3), 397-408, http://doi.org/10.17270/J.LOG.2020.493*

Received: 11.05.2020, Accepted: 09.06.2020, on-line: 30.06.2020.

were known earlier, but required numerous computations, got a second wind, one of which is the multi-index transportation problem.

LITERATURE REVIEW

Multi-index transportation problems are the extension of classic two-index transportation problems. Diverse researches have been devoted to multi-index transportation problems. One of the present complete reviews of multi-index transportation problems and their extensions is done in work [Singh et al. 2016].

The most common extensions of the multi-index transportation problem are taking into account fuzzy parameters and multiple objectives. For instance, multi-index transportation problems with fuzzy parameters are studied in [Kumar, Yadav 2012, Senapati 2018]; multi-objective multi-index transportation problems have been researched by [El-Shorbagy et al. 2020, Singh et al. 2018]; in work [Javadi et al. 2014] the research on handling several objectives in solving logistics problems is performed.

The application of a genetic algorithm in solving logistics problems, in particular, transportation and distribution ones, has been studied in the following studies [Dimov and Lukyanov 2016, El-Shorbagy et al. 2020, Indra et al. 2020, Javadi et al. 2014, Kaedure Bakhuet 2016, Karthy, Ganesan 2018, Thu Huyen et al. 2013, Yun et al. 2020].

The authors [Karthy, Ganesan 2018] suggest initializing the population with Vogel's approximation method. Additionally, the special mutation operator is introduced, which is applied after each crossover and serves a function of returning the chromosome to the feasible region. [Dimov, Lukyanov 2016, Kaedure Bakhuet 2016] propose the algorithm for initializing the initial population. In [Thu Huyen et al. 2013], described the solving of classical transportation problem with the use of a genetic algorithm.

The authors [Ritha, Vinotha 2012] propose the heuristic method for solving the triaxial transportation problem and describe the steps of the solving process.

In those works, different approaches to solving the transportation problems are proposed, in particular, with the use of a genetic algorithm. However, some aspects of solving multi-index transportation problems with the use of a genetic algorithm are not studied enough in modern literature. Additionally, to get practical results, it is essential to implement the algorithm, for example, programmatically, which can reveal new information to the researcher. The paper aims to describe the overall steps for solving four-index problems of different types with a genetic algorithm and to implement the algorithm programmatically.

FOUR-INDEX TRANSPORTATION PROBLEMS

In this paper, the following markings will be used:

$i \in I = \overline{1,n}$ is the index of the manufacturer; n is the number of manufacturers;

$j \in J = \overline{1,m}$ is the index of the good type; m is the number of types of goods;

$k \in K = \overline{1,p}$ is the index of the vehicle; p is the number of vehicles;

$l \in L = \overline{1,q}$ is the index of the consumer; q is the number of consumers;

$(ijkl) \in E = I \times J \times K \times L$ is a component part of the transportation problem;

f_{ijkl} is the cost of transportation of the good j, which is transported from the manufacturer i to the consumer l on the vehicle k;

x_{ijkl} is the quantity of the available good j, which is planned for transportation from the manufacturer i to the consumer l on the vehicle k;

a_{ijk} is the overall quantity of the good j, which is planned for transportation from the manufacturer j using the vehicle k;

b_{ikl} is the overall quantity of goods, that are planned for transportation from the manufacturer i to the consumer l using the vehicle k;

c_{ijl} is the quantity of the good *j*, which is planned for transportation from the manufacturer *i* to the consumer *l*;

d_{ikl} is the quantity of the good *j*, which is planned for transportation to the consumer *l* on the vehicle *k*;

a_{ij} is the quantity of the good *j*, which is offered by the manufacturer *i*;

b_{ik} is the quantity of goods, which are transported from the manufacturer *i* on the vehicle *k*;

c_{il} is the quantity of goods, which are transported from the manufacturer *i* to the consumer *l*;

d_{jk} is the quantity of the good *j*, which is transported on the vehicle *k*;

g_{kl} is the overall quantity of goods, which are transported on the vehicle *k* to the consumer *l*;

e_{jl} is the quantity of the good *j*, which is transported from the consumer *l*;

a_i is the overall quantity of goods, which are transported from the manufacturer *i*;

b_j is the overall quantity of good *j*;

c_k is the overall quantity of goods, which are transported on the vehicle *k*;

d_l is the overall quantity of goods, which are transported to the consumer *l*.

Objective function [Kaedure Bakhuet 2016, Raskin and Kirichenko 1982, Tuyet-Hoa and Philippe 2013]:

$$\text{Min } L(X) = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{p}\sum_{l=1}^{q} x_{ijkl} f_{ijkl} \qquad (1)$$

Depending on the real economical requirements, agreements, and contracts, the x_{ijkl} variable can be constrained differently.

The imposition of restrictions allows the researcher to add real economical requirements to the mathematical model. Depending on the type of the imposed restrictions, the transportation problems can be either symmetric or asymmetric. Among the symmetric transportation problems, the following can be highlighted [Raskin, Kirichenko, 1982]: tetraspace, hexaplanar, and tetraaxial.

The four-index tetraspace transportation problem. The tetraspace transportation problem may have the following economical interpretation: a manufacturer refers to a carrier to transport several types of goods from factories (manufacturers, in the context of the described earlier problem) to distribution places (consumers). The goods can be picked up on any factory if they are available at a particular place; the main condition is to pick up all goods from factories and to satisfy the demand for distribution places. Since there is no special requirement for vehicles, carriers can choose which vehicle to use on their own, guided by their maximal gainings.

For the described problem only the restrictions a_i, d_l, c_k and b_j are defined [Raskin and Kirichenko 1982]:

$$\sum_{j=1}^{m}\sum_{k=1}^{p}\sum_{l=1}^{q} x_{ijkl} = a_i, \forall i \in I \qquad (2)$$

$$\sum_{i=1}^{n}\sum_{k=1}^{p}\sum_{l=1}^{q} x_{ijkl} = b_j, \forall j \in J \qquad (3)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{l=1}^{q} x_{ijkl} = c_k, \forall k \in K \qquad (4)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{p} x_{ijkl} = d_l, \forall l \in L \qquad (5)$$

$$x_{ijkl} \geq 0 \qquad (6)$$

The meaning of the markings in the formulas refers the earlier described one.

Accordingly, the formalized four-index tetraspace transportation problem is presented (1)by formulas (1)-(6).

The four-index hexaplanar transportation problem. The hexaplanar transportation problem might have, in particular, the following economical interpretation: a manufacturer refers to a carrier to transfer several types of raw materials from manufacturer's suppliers (manufacturers, in the context of the described earlier problem) to the manufacturers (consumers). Additionally, the following requirements have to be satisfied [formulas (7)-(12)]:

– the quantity of the picked-up good of the particular type from the manufacturer is restricted by the availability of the good;
– the quantity of the good of the particular type is restricted by the type of vehicle;

- the quantity of goods that are transported from the particular manufacturer on the particular vehicle type is fixed;
- the overall quantity of goods is restricted, for example, by contracts, etc.;
- the quantity of transported good of the particular type to the particular consumer is restricted by the demand;
- the quantity of goods that is transported to the particular consumer on the particular vehicle type is restricted.

The mathematical formalization of the described restrictions [Raskin and Kirichenko 1982]:

$$\sum_{k=1}^{p}\sum_{l=1}^{q} x_{ijkl} = a_{ij}, \forall i \in I, \forall j \in J \quad (7)$$

$$\sum_{j=1}^{m}\sum_{l=1}^{q} x_{ijkl} = b_{ik}, \forall i \in I, \forall k \in K \quad (8)$$

$$\sum_{j=1}^{m}\sum_{k=1}^{p} x_{ijkl} = c_{il}, \forall i \in I, \forall l \in L \quad (9)$$

$$\sum_{i=1}^{n}\sum_{l=1}^{q} x_{ijkl} = d_{jk}, \forall j \in J, \forall k \in K \quad (10)$$

$$\sum_{i=1}^{n}\sum_{k=1}^{p} x_{ijkl} = e_{jl}, \forall j \in J, \forall l \in L \quad (11)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} x_{ijkl} = g_{kl}, \forall k \in K, \forall l \in L \quad (12)$$

$$x_{ijkl} \geq 0 \quad (13)$$

Thus, the formalized four-index hexaplanar transportation problem is presented by the formulas (1), (7)-(13).

The four-index tetraaxial transportation problem. The tetraaxial transportation problem has the hardest restrictions. This type of transportation problem is used in case of having transportations plans, restricted payload between warehouses, in particular, the transportation of the huge types of goods, which take all the payload of the vehicle.

In the tetraaxial transportation problem, additionally, the following requirements have to be satisfied [formulas (14)-(17)]:

- the quantity of the particular type of goods transported from the manufacturer on the particular type of vehicle is restricted;
- the quantity of goods which is planned for transportation from the manufacturer to the consumer on the particular vehicle is restricted;
- the quantity of particular type of goods from the manufacturer to the consumer is restricted;
- the quantity of the particular type of goods that is transported to the consumer on the particular type of vehicle is restricted;

The mathematical formalization of restrictions [Raskin and Kirichenko 1982]:

$$\sum_{l=1}^{q} x_{ijkl} = a_{ijk}. \forall i \in I, \forall j \in J, \forall k \in K \quad (14)$$

$$\sum_{j=1}^{m} x_{ijkl} = b_{ikl}, \forall i \in I, \forall k \in K, \forall l \in L \quad (15)$$

$$\sum_{k=1}^{p} x_{ijkl} = c_{ijl}, \forall i \in I, \forall j \in J, \forall l \in L \quad (16)$$

$$\sum_{i=1}^{n} x_{ijkl} = d_{jkl}, \forall j \in J, \forall k \in K, \forall l \in L \quad (17)$$

$$x_{ijkl} \geq 0 \quad (18)$$

Thus, the formalized four-index tetraaxial transportation problem is defined by the formulas (1), (14)-(18).

TOOLS FOR SOLVING FOUR-INDEX TRANSPORTATION PROBLEMS

The more indexed the problem is, the more time is required to get the optimal solution. The problem's non-linear increasing complexity does not allow us to solve it for a reasonable time, using classical optimization methods. Therefore, there is a need for search of such optimization methods, which let us get the suboptimal solution (or even optimal) for a reasonable time. One of those methods for solving four-index transportation problems is a genetic algorithm.

Let us outline the fundamental aspects of a genetic algorithm (based on [Goldberg 1988, Luke 2013]).

A genetic algorithm is a search evolutionary algorithm that is used for solving optimization and modeling problems by randomly creating, combining, and variation of the searched parameters with the use of the mechanisms, which resemble biological evolution.

The fundamental concepts of genetic algorithms are derived from genetics, in particular, population, chromosome, and gene. The population is the set of genotypes of the particular generation. The chromosome (or individual) is the ordered sequence of genes, which represents the decoded solution to the problem. The gene is the atomic element of the chromosome. The mating pool consists of the chromosomes, which is selected in a predefined way using selection function, to which in the future the genetic operator will be applied (for example crossover, mutation), which have the random nature.

The mechanism of genetic algorithms gives it specialness: a generic algorithm works with several potential solutions (chromosomes) on each generation. That allows getting rid of the possibility of getting into local extrema of an objective function and reducing the work time. The fitness function helps the selection function to perform a selection for the creation of a mating pool.

The classic generic algorithm consists of the following steps: 1) the initialization of the initial population; 2) calculating fitness scores of the chromosomes, based on the fitness function; 3) checking the generic algorithm's stop criteria; 4) selection of chromosomes; 5) applying the genetic operators; 6) forming the population for the next generation; 7) choosing the fittest chromosome.

The steps from step 2 to step 7 are repeated until the stop criterion is satisfied. If the stop criterion (step 3) is satisfied, the genetic algorithm executing goes to step 7; otherwise – to step 4.

SOLVING FOUR-INDEX TRANSPORTATION PROBLEMS WITH A GENETIC ALGORITHM

To solve four-index transportation problems with the use of a generic algorithm, we will define genetic algorithm concepts in the context of the transportation problem:

- a component part (x_{ijkl}) of the transportation problem is the gene of the chromosome in the genetic algorithm;
- a feasible solution is a chromosome;
- an objective function in the transportation problem is a fitness function of the chromosome.

Let us define the steps of a genetic algorithm for solving symmetric four-index transportation problems.

The four-index tetraspace transportation problem

Step 1. Initializing the initial population. The process of initializing the initial population connotes the generating of chromosomes for the initial population. For the clearness, let us make an illustrative example. Supposed, we have three manufacturers, two types of goods, two types of vehicles, and three consumers. Then, n = 3, m = 2, p = 2 and q = 3. In that case, the visualization of the chromosome can take the form of the four-index array (fig. 1). To get the value of the needed gene, the indexes of the manufacturer, type of good, type of vehicle, and the consumer should be entered.

The size of the population does not change over the generations. The researchers choose the number of chromosomes in population on their own. Nonetheless, the number of chromosomes should satisfy the diversity of genetic material, since the lack of diversity may lead to inefficiency. Not only the small size can impact the performance negatively, but also the large one. A too-large population will consume more time on calculations, consequently leading to decreased efficiency. Thus, there should be a compromise decision.

As mentioned before, for high performance, the genetic material should have high diversity. Furthermore, the genes have to satisfy the restrictions of the transportation problem (2)-(6). To initialize the chromosomes with random values of genes, which satisfies the restrictions, the approach for initializing the initial population of chromosomes for the four-index transportation problem is adapted [Dimov and Lukyanov 2016, Kaedure Bakhuet 2016, Skitsko and Voinikov 2018]:

1. the upper bound value is calculated for the x_{ijkl} variable. The upper bound equals to the lowest value among all the restrictions: $u_{ijkl} = min\,\{a_i; b_j; c_k; d_l\}$, where u_{ijkl} is the upper bound for the x_{ijkl} variable, $i \in I = \overline{1,n}$, $j \in J = \overline{1,m}$, $k \in K = \overline{1,p}$, $l \in L = \overline{1,q}$;
2. the value of the variable is assigned; the entered value is chosen randomly in the range from zero the upper bound u_{ijkl}: $x_{ijkl} = Rand(0; u_{ijkl})$;
3. the move to the subsequent variable is performed. The entered value for the current variable has to be taken into account when determining the values for the next variables. To achieve that, from the related restrictions, we subtract the ultimate value. Let us mark the subsequent consumer, vehicle, type of good and manufacturer as l^*, k^*, j^* and i^*:
$x_{ijkl^*} = min\{a_i; b_j; c_k; d_l - x_{ijkl}\}$,
$x_{ijk^*l} = min\{a_i; b_j; c_k - x_{ijkl}; d_l\}$,
$x_{ij^*kl} = min\{a_i; b_j - x_{ijkl}; c_k; d_l\}$,
$x_{i^*jkl} = min\{a_i - x_{ijkl}; b_j; c_k; d_l\}$.
If the variable i, j, k or l is the last one for the 'manufacturer', 'type of good', 'vehicle' or 'consumer' and equals to n, m, p or q, then the value for the chromosome with that index is entered as the upper bound u_{ijkl}.

The generated chromosome is checked on getting into the feasible region. If the created chromosome is in the feasible region, it is taken to the initial population; otherwise - the chromosome is destroyed and the new one is created.

Step 2. Calculating fitness scores of the chromosomes. The fitness function for the transportation problem is the objective function.

The fitness function:

$$L(X(ch_q)) = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{p}\sum_{l=1}^{q} x_{ijkl}(ch_q) f_{ijkl}, \quad (19)$$

where:

q is the index of the chromosome in population; the number of chromosomes is determined by the researcher;
ch_q is the chromosome q in population (for each generation);
$x_{ijkl}(ch_q)$ is the quantity of the good j, which is transported from the manufacturer j to the consumer l on the vehicle k; $x_{ijkl}(ch_q)$ is the gene of the chromosome ch_q;
$X(ch_q)$ is the transportation problem potential solution, which is defined by the genes of the chromosomes ch_q;

Step 3. Checking the genetic algorithm's stop criteria. The stop criteria for four-index transportation problem can be [Luke 2013]: 1) the number of generations; 2) the time of genetic algorithm functioning; 3) the reach of the approximate value for fitness function;

Step 4. The selection of the chromosomes, which used for creation of the new generation. The method of selection can be chosen from the existing ones [Luke 2013]: 1) fitness proportionate selection (or roulette-wheel selection); 2) tournament selection; 3) rank selection; 4) elitism selection, etc.

Step 5. Applying the genetic operators, such as crossover, mutation. The crossover includes combining the genetic material of two chromosomes in a predefined way. For the transportation problem, the use of multi-point crossover is efficient, in which the recombined genes have the same real-world essence.

The mutation alters one or more gene values in a particular chromosome, not relying on other chromosomes. For example, the mutation can be performed as follows:

1. choose the gene, which is to mutate. To choose the gene, the indexes are randomly generated
$i = Rand(0; n)$,
$j = Rand(0; m)$,
$k = Rand(0; p)$,
$l = Rand(0; q)$ for the variable x_{ijkl};
2. the value of the gene is changed is a particular way, for example $x_{ijkl}(ch_q) = Rand(0; min\{a_i, b_j, c_k, d_l\})$.

Because of applying the genetic operators, the created (new) chromosomes can go out of the feasible region. To return them, the procedure for returning a chromosome to the feasible region can be applied. For example, the procedure for a three-index transportation problem [Skitsko and Voinikov 2018] can be adapted for four-index.

Step 6. Forming the population for the new generation. From the chromosomes, formed as a result of applying genetic operators to the selected pairs, after the check on the subject of being in the feasible region, the population for the next generation is created.

Step 7 same as step 2.

Step 8. Choosing the fittest chromosome, which is considered the final solution. If the genetic algorithm stops, among the chromosomes of the current population, the best one is chosen by the fitness function's value. For the transportation problem, the fittest chromosome would be the one with the lowest fitness function.

In different types of transportation problems, the essence of genes may vary, as well as the restrictions applied to them may also change.

That is why all the steps of the investigated problems will be the same, except for the first one - the initializing of the initial population, which we will cover later.

The four-index hexaplanar transportation problem

Step 1. Initializing the initial population. The procedure of generating the initial population for the four-index hexaplanar problem will vary in the way of calculating the upper bound for the variable (gene). In the four-index hexaplanar transportation problem, the upper bound for the variable x_{ijkl} is calculated as:

$$u_{ijkl} = \min\{a_{ij}; b_{ik}; c_{il}; d_{jk}; e_{jl}; g_{kl}\}.$$

Moreover, all the variables, which is related to the particular restriction should be taken into account, when calculating the upper bound for the subsequent variables:

$$x_{ijkl^*} = \min\{a_{ij}; b_{ik}; c_{il} - x_{ijkl}; d_{jk}; e_{jl} - x_{ijkl}; g_{kl} - x_{ijkl};\},$$

$$x_{ijk^*l} = \min\{a_{ij}; b_{ik} - x_{ijkl}; c_{il}; d_{jk} - x_{ijkl}; e_{jl}; g_{kl} - x_{ijkl}\},$$

$$x_{ij^*kl} = \min\{a_{ij} - x_{ijkl}; b_{ik}; c_{il}; d_{jk} - x_{ijkl}; e_{jl} - x_{ijkl}; g_{kl}\},$$

$$x_{i^*jkl} = \min\{a_{ij} - x_{ijkl}; b_{ik} - x_{ijkl}; c_{il} - x_{ijkl}; d_{jk}; e_{jl}; g_{kl}\}.$$

The four-index tetraaxial transportation problem

Step 1. Initializing the initial population. In the four-index hexaplanar transportation problem, the upper bound for the variable x_{ijkl} is calculated as:

$$u_{ijkl} = \min\{a_{ijk}; b_{ikl}; c_{ijl}; d_{jkl}\}.$$

Moreover, all the variables, which is related to the particular restriction should be taken into account, when calculating the upper bound for the subsequent variables:

$$x_{ijkl^*} = min\{a_{ijk}; b_{ikl} - x_{ijkl}; c_{ijl} - x_{ijkl}; d_{jkl} - x_{ijkl}\},$$

$$x_{ijk^*l} = min\{a_{ijk} - x_{ijkl}; b_{ikl} - x_{ijkl}; c_{ijl}; d_{jkl} - x_{ijkl}\},$$

$$x_{ij^*kl} = min\{a_{ijk} - x_{ijkl}; b_{ikl}; c_{ijl} - x_{ijkl}; d_{jkl} - x_{ijkl}\},$$

$$x_{i^*jkl} = min\{a_{ijk} - x_{ijkl}; b_{ikl} - x_{ijkl}; c_{ijl} - x_{ijkl}; d_{jkl}\}.$$

THE PROGRAMMATIC IMPLEMENTATION OF THE GENERIC ALGORITHM FOR THE TRANSPORTATION PROBLEM

Based on the material, we developed program implementation for solving the transportation problem with the genetic algorithm, using the open-source programming language TypeScript [TypeScript programming language 2020]. All the methods described in this chapter are the authors' intellectual property and do not relate to any other library.

General information about the program. The program is developed using the TypeScript language in an object-oriented paradigm. The class called GeneticAlgorithm (all the class and method names have been given by authors) provides the interface to a researcher to solve the problem. To instantiate the class GeneticAlgorithm, the researcher must pass the information related to the current transportation problem to the class constructor: the payoff matrix, the restrictions, and the dimensions of the problem.

Besides the information about the current transportation problem, the researcher may also change the general settings of the program, which include the population size, the number of iterations of the genetic algorithm, the crossover rate, and the mutation rate. The default settings are as follows: population size - 100; number of iterations - 1000; crossover rate - 0.95; mutation rate - 0.05.

Let us describe the steps of the genetic algorithm for the program implementation.

Step 0. Entering data. At this step, the user enters the dimensions of the problem, fills in the pay-off matrix, and adds the restrictions.

The pay-off matrix is presented by a four-dimensional array; the property dimensions consists of four properties (*n, m, p, q*), which relate to the dimensions of the problem.

The property restrictions consist of the array of the class Restriction's instances. The class Restriction checks whether the chromosome is in the feasible region of the problem (the method isChromosomeValid), and allows calculating the upper bounds for genes' value while initializing the initial population (the method calculateAvailable Capacities).

The mechanism of those functions can differ, depending on the type of restrictions. Therefore, for the instantiation of the class, the user must pass the custom function calculateCapacityUsage as an argument for the class's constructor. That function takes a chromosome object as an argument and returns boolean value whether the chromosome is in the feasible region.

Step 1. The initialization of the initial population. For generating the initial population, the class Population is used, which has properties such as the current generation, the population size, and the number of generations (the last two taken from the configuration file, described before), and private method called initializePopulation.

The method initializePopulation starts the initialization of the initial population. That method creates a chromosome, using the algorithm described earlier in the paper: for each gene gets value is chosen randomly from zero to the calculated upper bound. If the gene is the last for one of the restrictions, the value of the gene is chosen as the current upper bound. After the creation, the chromosome is checked on getting into the feasible region; if the chromosome is not in the feasible region, the new one is created instead.

Pseudocode of the function initializePopulation:

procedure start
  for *populationSize* times
    generate: for all the genes of the chromosome
      upperBound = *min*(restrictions' available capacities)
      if the gene is the last one for any *restriction*
        then the gene equals to the *upperBound*
      else the gene equals *rand*(0, *upperBound*)

    if the chromosome is in the feasible region
      then add chromosome to the population
    else continue: generate
procedure end

Step 2. Calculating fitness scores of the chromosomes. For calculating the fitness function of a chromosome, the protected method called calculateFitness is used, which iterates all the genes, multiplying them by the corresponding value of the pay-off matrix, then sums all the multiplications.

Pseudocode of the private method calculateFitness:

procedure start
  for each chromosome
  fitness = 0
  for each gene of the chromosome
    fitness = fitness + current gene value * current pay-off matrix value
   chromosome's fitness = fitness
procedure end

Step 3. Checking the genetic algorithm's stop criteria. In the program implementation, the stop criterion is the number of generations. For checking the stop criterion, the method checkCriteria is used. If the method returns the truthy value, the execution is continued at step 8, which we will describe later.

Step 4. The selection of the chromosomes, which will be used for the creation of the new generation. For the selection function, the tournament method is chosen, where we randomly choose two chromosomes of the current generation, and the better one gets included in the mating pool. The number of 'tours' is the same as the population size.

Pseudocode of the function selectChromosomes:

input: void
output: *nextGeneration*
procedure start
 nextGeneration = empty array

 for *populationSize* times
   select1 = random chromosome from current population
   select2 = random chromosome from current population
   winner = max fitness function(*select1*, *select2*)
   push *winner* to *nextGeneration* array
 return nextGeneration
procedure end

Step 5. Applying the genetic operators, such as crossover, mutation. For the crossover, we use the function called crossoverCromosome. The probability of crossover correlates to the value in the configuration file.

Pseudocode of the function crossoverChromosome:

input: *parent1*, *parent2*
output: *child1*, *child2*
procedure start
 for all the genes
 if the gene index is odd
   child1's gene with given index = *parent1*'s corresponding gene
   child2's gene with given index = *parent2*'s corresponding gene
  else
   child2's gene with given index = *parent1*'s corresponding gene
   child1's gene with given index = *parent2*'s corresponding gene
 return array of *child1* and *child2*
procedure end

In the other case, the mutation is applied (method mutateChromosome). In the program implementation, the genes, which are going to be mutated, are chosen randomly (by generating all the indexes). The value of the gene is mutated from zero the upper bound, which is calculated as the minimum restrictions' capacity.

Pseudocode of the function mutateChromosome:

input: *chromosome*
output: *void*
procedure start
  i = rand(0, n)
  j = rand(0, m)
  k = rand(0, p)
  l = rand(0, q)
  upperBound = *min*(restrictions' capacities)
  chromosome[i][j][k][l] = *rand*(0, *upperBound*)
procedure end

Step 6. Forming the next generation's population. Applying genetic operators can cause the chromosome to go out of its feasible region. For returning it, we use the function returnToAllowableRange.

Step 7 same as step 2.

Step 8. Choosing the fittest chromosome, which is considered to be the final solution. When the specified number of iterations have been performed, for the final solution, the elite chromosome is taken. Displaying of the solution is done with the showResult function.

Described earlier functions, in particular, the function for generating the initial population (initializePopulation), the function of calculating the fitness function (calculateFitness), the function for performing selection (selectChromosomes), the function for mutation and crossover (mutate Chromosome and crossoverChromosome) are written by authors.

The program implementation of the genetic algorithm for solving four-index transportation problems allows solving four-index symmetric transportation problems with different types of restriction (passing custom Restriction instance to the genetic algorithm constructor). The code of the program can be adapted for particular use cases by method overriding.

CONCLUSIONS

The multi-index transportation problems are getting popularity since they allow taking into account more variables from the real world, compared to the classic one. Earlier, multi-index transportation problems did not get much attention because of the absence of adequate tools to solve them. The evolution of computing hardware made it possible to use such tools as a genetic algorithm.

In the paper, we elucidate the theoretical part of the four-index transportation problems problem. The solving process of the four-index transportation problems is proposed: the fundamental transportation problem concepts described in the context of the genetic algorithm; the steps of the genetic algorithm adapted for the problem.

Based on the material, we implemented the genetic algorithm for solving four-index transportation problems programmatically, using the programming language typescript. The program implementation allows solving four-index symmetric transportation problems.

Since the transportation problem can be observed as the problem of allocating resources, the material of the paper can be used for solving specific problems in the area of manufacturing, logistic systems, information technologies, etc.

For future work, we consider useful exploring the efficiency of a genetic algorithm, in particular, the influence of the population size, the dimensions, the crossover and mutation rates on the final solution; the usage of other types of selection (roulette-wheel, ranking method, etc.), crossover.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Dimov Yu.S., Lukyanov N.D., 2016. Genetic algorithm application for solving a multi-index transportation problem. Proceedings of Irkutsk State Technical University, 7, 73–79. http://doi.org/10.21285/1814-3520-2016-7-73-79

El-Shorbagy M., Mousa A., ALoraby H., Abo-Kila T., 2020. Evolutionary algorithm for multi-objective multi-index transportation problem under fuzziness. Journal of Applied Research on Industrial Engineering, 7(1), 36-56. http://doi.org/0.22105/jarie.2020.214142.1119

Goldberg D. E., 1988. Genetic Algorithms in Search, Optimization, and Machine Learning. Addison-Wesley Publishing, Inc. 432 pages.

Indra Z., Chairunisah, Refisis N.R., 2020. Application Genetic Algorithm in solving three-level supply chain distribution problems. Journal of Physics: Conference Series. 1462. 012035. http://doi.org/10.1088/1742-6596/1462/1/012035

Javadi A., Tarokh M.J., Piroozfar S., 2014. Solving a multi-objective vehicle scheduling- routing of interurban transportation fleet with the purpose of minimizing delays by Using the Differential Evolutionary Algorithm. Uncertain Supply Chain Management, 2 (3), 125-136. http://doi.org/10.5267/j.uscm.2014.5.005

Kaedure Bakhuet A.-J., 2016. Solving bi-objective 4-dimensional transportation problem by using PSO. AGK Bakhat. Sci.Int (Lahor.), 28 (3), 2403-2410. http://www.sci-int.com/pdf/636551900738439387.pdf

Karthy T., Ganesan K., 2018. Multi Objective Transportation Problem - Genetic Algorithm Approach. International Journal of Pure and Applied Mathematics. Volume 119 No. 9, 343-350. https://acadpubl.eu/jsi/2018-119-9/articles/9/33.pdf

Kumar A., Yadav S.P., 2012. A Survey of Multi-index Transportation Problems and Its Variants with Crisp and Fuzzy Parameters. K. Proceedings of the International Conference on Soft Computing for Problem Solving (SocProS 2011) December 20-22, 2011. 919–932. http://doi.org/10.1007/978-81-322-0487-9_86

Luke S., 2013. Essentials of Metaheuristics. Lulu, second edition. 242 pages., Cite this document as: Sean Luke, 2009,Essentials of Metaheuristics, available at http://cs.gmu.edu/~sean/book/metaheuristics/

Raskin, L.G., Kirichenko, I.O., 1982. Mnogoindeksnye zadachi lineinogo programmirovaniya (Multi-index Problems of Linear Programming), Moscow: Radio i Svyaz'.

Ritha W., Vinotha. M.J., 2012. Heuristic algorithm for multi-index fixed charge fuzzy transportation problem. Elixir Comp. Sci. Engg. 46, 8346-8353. https://www.elixirpublishers.com/articles/1351162502_46%20(2012)%208346-8353.pdf

Senapati. S., 2018. Multi-Index Bi-Criterion Transportation Problem: A Fuzzy Approach. International Journal of Advanced Engineering, Management and Science, 4 (7), 550-556. http://doi.org/10.22161/ijaems.4.7.8

Singh S., Chauhan S.K., Kuldeep., 2018. A Bi-Criteria Multi-Index Bulk Transportation Problem. Annals of Pure and Applied Mathematics, 16 (2), 479-485. http://doi.org/10.22457/apam.v16n2a26

Singh S., Tuli R., Sarode D., 2016. A review on fuzzy and stochastic extensions of the Multi Index transportation problem. Yugoslav Journal of Operations Research, 27 (1), 3-29. http://doi.org/10.2298/YJOR150417007S

Skitsko V.I., Voinikov M. Yu., 2018. Solving a Three-Index Transportation Problem under Risk Conditions Using a Genetic Algorithm. The Problems of Economy, 3, 246–252. https://www.problecon.com/export_pdf/problems-of-economy-2018-3_0-pages-246_252.pdf

Thu Huyen N., Luong Sy Uoc, Rosaly B. Alday, 2013. Genetic Algorithm for Solving Balanced Transportation Problem. International Journal of Innovative Technology and Exploring Engineering. (IJITEE), 3(4), 24-27. http://www.ijitee.org/wp-content/uploads/papers/v3i4/D1163093413.pdf

Tuyet-Hoa P., Philippe D., 2013. An Exact Method for Solving the Four Index Transportation Problem and Industrial Application. American Journal of Operational Research, 3(2), 28-44. http://article.sapub.org/10.5923.j.ajor.20130302.02.html

TypeScript programming language, 2020. https://www.typescriptlang.org/

Yun Y., Chuluunsukh A., Gen M., 2020. Sustainable closed-loop supply chain design problem: A hybrid genetic algorithm approach. Mathematics, 8 (1), 84. http://doi.org/10.3390/math8010084

ROZWIĄZANIA CZTEROCZYNNIKOWEGO PROBLEM TRANSPORTOWEGO PRZY POMOCY ALGORYTMU GENETYCZNEGO

STRESZCZENIE. **Wstęp:** W warunkach komputerowej transformacji, efektywny proces podejmowania decyzji powinien obejmować wykorzystania modeli metod matematycznych. Przykładem takiej sytuacji jest problem transportowy, który jest problemem alokacji zasobów, występujący w takich obszarach jak produkcji, technologie informatyczne, itp. W celu uzyskania precyzyjniejszych rozwiązań, można zastosować wieloczynnikowy problem transportowy, który umożliwia uwzględnienie wielu zmiennych.

Metody: W pracy zastosowano algorytm genetyczny dla rozwiązania czteroczynnikowych problemów transportowych.
Wyniki: Wyszczególniono kroki algorytmu genetycznego dla czteroczynnikowego problem transportowego. Udowodnione, że kroki algorytmu genetycznego są takie same dla wszystkich typów czteroczynnikowych problemów transportowych, z wyjątkiem pierwszego kroku (inicjalizacji), który został opisany osobno dla każdego z typów problemu transportowego.
W oparciu o wyniki teoretyczne, utworzono programowanie dla algorytmu genetycznego dla rozwiązywania czteroczynnikowych problemów transportowych przy użyciu opensourcowego języka typescript.
Wnioski: W pracy zaproponowano zastosowanie algorytmu genetycznego dla rozwiązywania wieloczynnikowych problemów transportowych. Analizowany problem wymaga dalszych badań, szczególnie w zakresie wpływu zmian poszczególnych parametrów algorytmu genetycznego (wielkości populacji, mutacji, współczynnika podziału, itp.) na efektywność algorytmu w rozwiązywaniu czteroczynnikowych problemów transportowych.

Słowa kluczowe: czteroczynnikowy problem transportowy, symetryczny problem transportowy, algorytm genetyczny, wdrożenie programu

Volodymyr Skitsko ORCID ID: https://orcid.org/0000-0002-6290-9194
Kyiv National Economic University named after Vadym Hetman
Institute Information Technologies in Economics
Kyiv, **Ukraine**
e-mail: skitsko@kneu.edu.ua

Mykola Voinikov ORCID ID: https://orcid.org/0000-0001-7961-5312
Kyiv National Economic University named after Vadym Hetman
Institute Information Technologies in Economics
Kyiv, **Ukraine**
e-mail: qwoxa1@gmail.com

LogForum

> Scientific Journal of Logistics <

2020, 16 (3), 409-420

http://doi.org/10.17270/J.LOG.2020.468

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

ESTONIAN LOGISTICS MARKET 2018 SURVEY: ANALYSIS AND FINDINGS

Ain Kiisler[1], Tomi Solakivi[2], Olli-Pekka Hilmola[3]

1) Tallinn University of Technology (Taltech), Tallinn, **Estonia**, 2) University of Turku, Turku, **Finland**, 3) LUT University, Kouvola, **Finland**

ABSTRACT. Background: Estonian logistics market survey has been completed three times (during years 2007, 2012 and 2018), and this research reports development from the most recent survey concerning operating conditions and logistics costs as well as performance. Survey concerns manufacturing, trading and logistics service companies.
Methods: Research data was gathered through an online survey executed during summer and early autumn of 2018. The survey received a total of 122 responses from manufacturing, trade and logistics service provision. Results of the study are compared to earlier years, and with the same approach completed Finnish logistics market survey.
Results: Survey responses showed that Estonian logistics market has been experiencing overheating and the costs of logistics activities are clearly increasing. Logistics service providers have experienced negative effects resulting thereof more than manufacturers or trading companies. Inventories and delivery times have increased, which has resulted in longer cash conversion cycles. Other than inventory and lead time related supply chain metrics have developed positively, indicating that the overall performance in Estonian logistics has remained high.
Conclusions: Increase of logistics costs and inventories remain as main future challenge for Estonian logistics. In other regards, development has been good, and quality of e.g. logistics services and customs have increased and is at high level.

Key words: logistics costs, logistics market, logistics performance, Estonia.

INTRODUCTION

Connectivity and cost of connections are critical for national economies and companies [United Nations, 2019]. For long time it has been so that not companies, but entire supply chains and networks compete with each other [Oliver, Webber, 1982; Houlihan 1985; Rice, Hoppe, 2001]. Same applies to regions and countries: Advantages are built from bunch of issues and within interaction of public-private sector. For example, in logistics it is based on interaction between private sector actors, infrastructure, superstructure, connections, legislation, demand and availability as well as quality of services. Therefore, logistics competitiveness needs to be examined from multiple angles and stakeholders. Direct logistics costs from revenues could be high in manufacturing companies, but the quality and overall performance of logistics could be so high that costs could be tolerated, and region being competitive [World Bank, 2020]. As an example could be used one of the leading countries in Logistics Performance Index (LPI), Germany [World Bank, 2020]. In addition, Sweden, Singapore, Luxemburg, Belgium and Netherlands are typically performing well within LPI, but all from own strengths, but with sure weaknesses (such as high costs). Therefore, we need to know and examine at country level factors and indicators behind logistics competitiveness.

Citation: *Kiisler A., Solakivi T., Hilmola O.P., 2020. Estonian Logistics Market 2018 Survey: Analysis and Findings. LogForum 16 (3), 409-420, http://doi.org/10.17270/J.LOG.2020.468*

Received: 25.03.2020, Accepted: 23.04.2020, on-line: 30.06.2020.

Nowadays, logistics cost estimates mostly at national level are based on surveys among private sector companies, and estimates are given as a share from company revenues [Rantasila 2014, Kiisler et al. 2017; Schwemmer, 2017]. Typically, these surveys follow the example of Heskett et al. [1973] by dividing logistics costs into sub-components like transportation costs, inventory holding / carrying costs, warehousing costs, IT and administration. For example, in Finland at national level logistics costs are followed with a biannual survey, and it is based on high amount of responses [in year 2018 amount of responses in survey were 2001, see Solakivi et al., 2018a]. However, logistics costs could also be evaluated based on macro-economic measures, and as a share of GDP [see for example Ward et al., 2019, Solakivi et al. 2018b]. Logistics cost examinations could also concern some smaller group of companies in order to understand the differences within same branch and sized actors [Shvartsburg et al., 2017]. Similar national account, and even combining private company profit and loss statement based approach, was used in national level logistics cost estimations within past [Rodrigues et al., 2005, Mckinnon, 1988].

Our purpose of this article is to give an overview of logistics market in Estonia based on recent logistics survey, simultaneously introducing some main results of this survey. Estonia is small North European country, which is among the most open countries in trade within the entire world [share of exports 73% and imports 69% from GDP in 2019; OECD, 2019]. Logistics plays a key role in this country as it has traditionally been transit transport focused, and these services have been key in balancing current and trade account deficits [Kiisler et al., 2017]. This gives high relevance and need for the survey results. The survey was carried out among Estonian manufacturing, trading and logistics companies in May-October 2018. Tallinn University of Technology (Tallinn, Estonia) and University of Turku, School of Economics (Turku, Finland) arranged and implemented the survey process. Research problem in this most recent survey could be stated through following questions: “What is the current level of logistics cost in Estonia and how it has developed from earlier surveys?”, and “What factors have accounted for logistics costs change and how competitive are Estonian supply chains?”.

This research is structured as follows: Research methodology together with survey respondent data is introduced in Section 2. Estonian logistics market and its operating conditions are analyzed in Section 3 through survey responses. Logistics costs and supply chain performance metrics and their development in Estonian companies are analyzed in Section 4. Research is concluded in Section 5, where also further research avenues are being proposed.

RESEARCH METHODOLOGY

This survey has been the third among the series of comprehensive surveys made about Estonian logistics market. The previous surveys have been completed in 2007 [see Ojala et.al. 2007] and in 2012.

The methodology of the survey is similar to biannual Finland State of Logistics, which was last arranged in 2018 [Solakivi et al., 2018a]. The survey is based on an Internet questionnaire, where a personalized link to participate was sent by email to sample companies and asking them to take part in the survey. There were three versions of questionnaires in use, focusing accordingly on manufacturing, trade and logistics service companies.

The sample consisted of 2500 Estonian manufacturing, trading and logistics companies. This sample was built up of companies belonging into TOP 100 and Turnover TOP 500 of 2012-2017 rankings of the local business newspaper "Äripäev", members of Estonian Chamber of Trade and Industry, and the members of local professional associations.

At total 122 representative responses were received, so the return rate was 4.9%. From responses 45% represented manufacturing, 26% trading (wholesale and retail) and 29% logistics services providers (see Tables 1-2).

Table 1. ESOL 2018 survey respondents base by number of employees

No of employees	Sector of economy			
	Manufacturing	Trade	LSP -s	Total
1-9	7.3%	34.4%	25.7%	19.7%
10-49	38.2%	40.6%	51.4%	42.6%
50-249	43.6%	18.8%	20.0%	30.3%
500-999	7.3%	3.1%	2.9%	4.9%
1000-1999	3.6%	3.1%	0.0%	2.5%
	100.0%	*100.0%*	*100.0%*	*100.0%*

Table 2. ESOL 2018 survey respondents base by annual turnover

Annual turnover	Sector of economy			
	Manufacturing	Trade	LSP -s	Total
0-2 MEUR	21.8%	34.4%	25.7%	26.2%
2,1-5 MEUR	20.0%	9.4%	34.3%	21.3%
5,1-10 MEUR	23.6%	21.9%	17.1%	21.3%
10,1-25 MEUR	16.4%	12.5%	8.6%	13.1%
25,1-50 MEUR	7.3%	6.3%	5.7%	6.6%
50,1-100 MEUR	7.3%	9.4%	8.6%	8.2%
100,1-500 MEUR	1.8%	6.3%	0.0%	2.5%
500-1 000 MEUR	1.8%	0.0%	0.0%	0.8%
	100.0%	*100.0%*	*100.0%*	*100.0%*

The main themes researched in the survey were the following:

- Operating conditions in the field of logistics within Estonia,
- Impact of logistics and SCM on the competitiveness and operations of local companies,
- Logistics costs and key performance indicators,
- Main disturbing factors for the supply chains,
- The extent of logistics outsourcing,
- The use of ICT in logistics/SCM operations
- The needs for further competence development in the field of logistics and SCM.

Only part of this survey themes (operating conditions, logistics costs and key performance indicators) have been tackled in this paper.

OPERATING CONDITIONS IN ESTONIAN MARKET

World Bank [2018] produces a biannual Logistics Performance Index – report, where countries are measured on six dimensions of logistics performance. The data for the report is collected from international freight forwarders and other logistics professionals outside the estimated country. In this research, the respondents in Estonia were asked to estimate the logistics performance using similar dimensions on a scale of 1-5, with 1 indicating “very poor” and 5 indicating “very good”. The respondents were also provided the option of “no response”.

On the average, Estonian firms assess the performance of local logistics market with 3.5 points out of five (see Figure 1). In comparison with previous similar survey from 2012, this rating has slightly improved (was 3.4 in 2012). The highest ratings were given to the quality of logistics services and effectiveness of customs, 3.7 points for both. The competitiveness of transport prices and shipments tracking possibilities got the lowest ratings (3.3%).

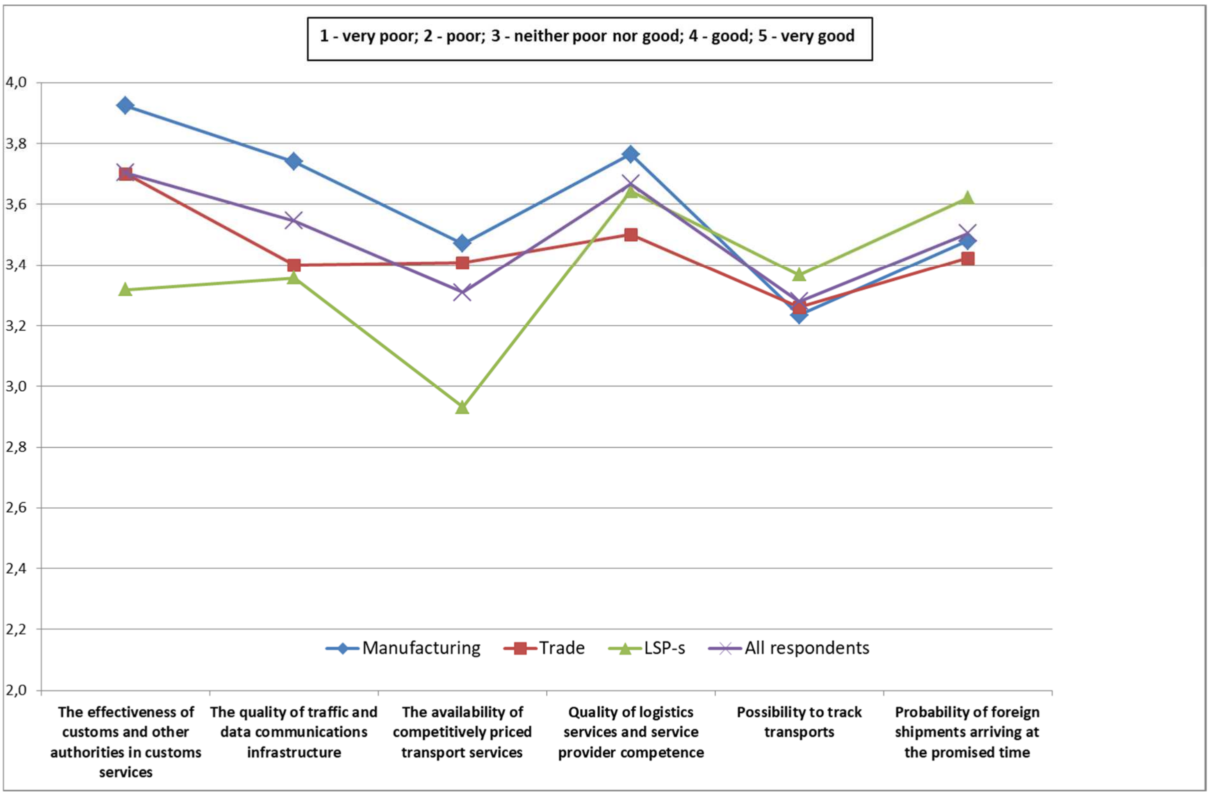


Fig. 1. Respondent estimations for the functioning of logistics in Estonia, 2018

The rankings are quite different by respondents' industries and also in comparison with the results of previous, year 2012 survey. Compared to survey made in 2012, the shippers overall estimation about Estonian logistics market performance have increased on average 0.2 points (from 3.4 to 3.6 in manufacturing and from 3.2 to 3.5 in trading sector), while LSPs estimations have fallen on average 0.35 points (from 3.7 to 3.4). While in 2012 LSP sector gave the higher ratings for Estonian logistics environment performance, in 2018 their ratings were the lowest ones.

This change has been mainly caused by the fall of LSPs average estimation for availability of competitive transport prices from 4.05 to 2.93 points and estimation for quality of transport and data communication infrastructure from 3.91 to 3.36 points.

There are significant differences between shippers and logistics services providers opinions in availability of competitively priced transport services (3.4 versus 2.9; 38% of LSPs answered either 1 or 2, 14% 3 and the remaining 48% 4 or 5.). In addition, many other survey questions show, that LSPs estimate their operating conditions and performance much lower than shippers. Probably the main reason for this is the sharp increase of the fuel excise taxes enforced in Estonia during the period of 2016-2018. Since 2010 to 2015, the diesel excise in Estonia was 39.3 eurocents per diesel liter. In 2016, this was raised by 14% and in 2017 by 10% more, resulting in 49.3 eurocents per diesel liter or 26% increase since 2015 [Ahermaa et al,. 2019]. The excise for gasoline during this period increased even more (33%), from 42.3 eurocents per liter in 2015 to 56.3 eurocents in 2018.

High fuel prices resulting thereof limit the international competitiveness of Estonian (road) transport companies and strong competition in customer markets makes it difficult to transfer these high fuel prices into service prices. Also the shortage of drivers is increasing labor cost in addition to overall salary level increases in Estonia. This is also visible in the road transport statistics. According to Statistics Estonia [2020] the total and international road transport turnovers (tonkms) of Estonian road transportation companies have both declined 28% during period of 2015-2018. The cargo amounts (in tons) transported in international road traffic by Estonian companies have fallen even 48% during this period. It should be reminded that in this period road transportation in Estonia did not experience any big changes, and overall volumes were rather stable (in transported tons volumes were slightly higher in 2018, but in tonkms they were in turn down somewhat). However, the market share of Estonian companies in road transport has considerably decreased as a result.

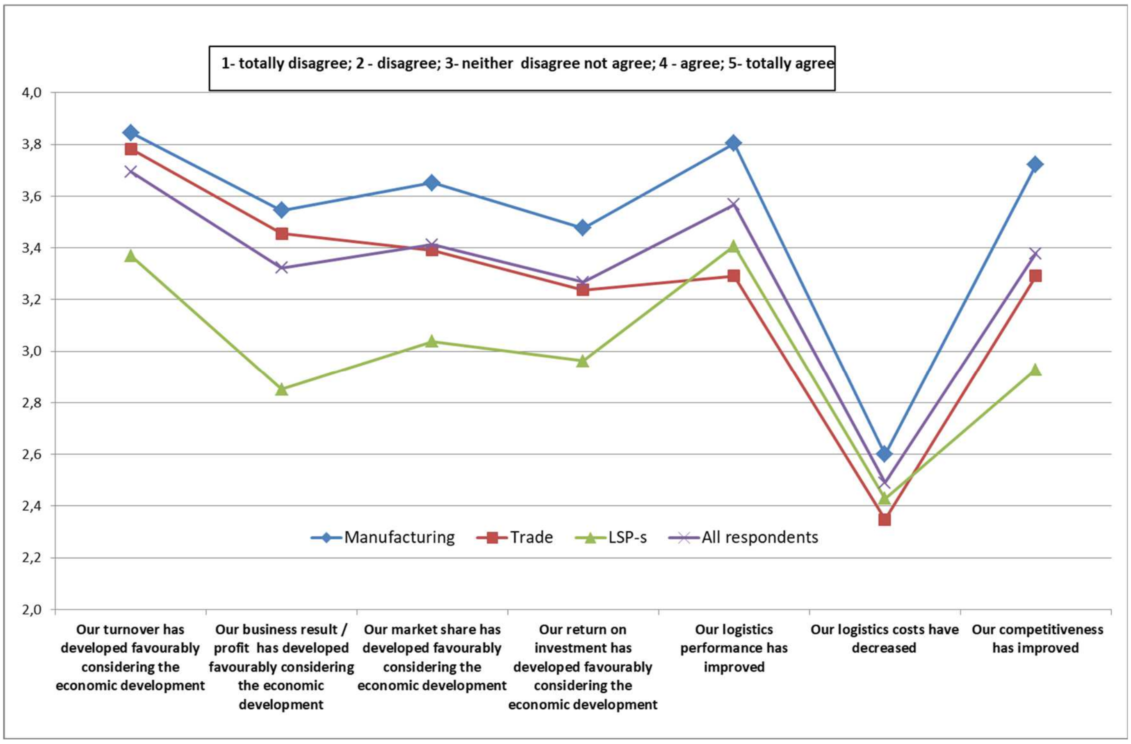


Fig. 2. Average estimations of responded companies for the developments of key performance figures during the two last years, 2018

Respondents were asked to agree or disagree with 5-point scale concerning some statements about the development of key performance indicators during the last two years (Figure 2). Overall respondents gave highest agreement rates to the following statements: "our turnover has developed favorably" and "our logistics performance has improved". Far the lowest agreement rate was with the statement: "our logistics costs have decreased". Only 17% of all answered companies were able to decrease their logistics costs during the 2016-2018. The logistics costs increased instead by 58% of all respondents and stayed stable for the rest of 25%. By the sectors, the logistics costs of 49% responded manufacturers, 70% trading companies and 64% LSPs increased during 2016-2018.

The statement about logistics costs decrease was among the manufacturers and traders single one, where the percentage of disagreeing respondents (choosing answer options 1 and 2 in Figure 2) exceeded percentage of agreeing ones (answer options 4 and 5). In logistics sector, also the statement, "Our business result / profit has developed favorably", got more disagreements than agreements (37% versus 26%). In addition, statement, "Our return on investment has developed favorably", got equal division of agreements / disagreements from LSPs (22% versus 22%). LSPs feedback to statement, "Our competitiveness has improved", divided rather equally between negative, neutral and positive opinions (32% disagreed, 32% neutral and 36% agreed).

Summing up, the manufacturing sector was clearly most and logistics sector strongly less satisfied with their business results during last two years.

LOGISTICS COSTS AND PERFORMANCE INDICATORS

The Manufacturing and trading companies were asked to estimate their logistics costs as a share of turnover in 2017. Following Solakivi et al. [2018b] they were also asked to estimate five separate logistics cost components: transportation, warehousing, inventory carrying, administration and other logistics costs. Figure 3 presents the average logistics costs of responded Estonian manufacturing and trading companies from 2017, 2011 and 2005 (latter are based on previous surveys from 2012 and 2007; cost comparison always to realized year). For comparison, the Finnish companies' similar data from similar periods originating from similar surveys has shown [Solakivi et. al. 2018].

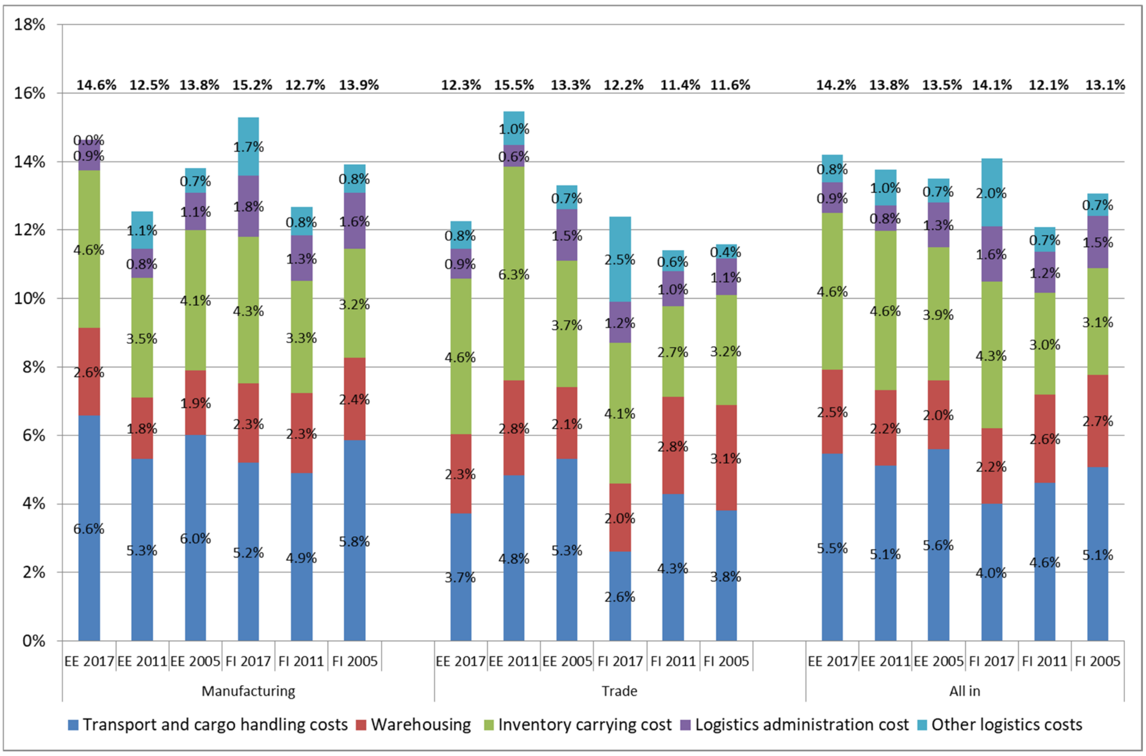


Fig. 3. Logistics cost of Estonian and Finnish manufacturing and trading companies expressed as % of turnover, 2017, 2011 and 2005

The average logistics cost of Estonian manufacturing and trading companies in 2017 were 14.2% of turnover, (14.6% in manufacturing and 12.3% in trade). These costs are at the same magnitude of Finnish enterprises (14.1%, 15.2% and 12.2% accordingly). On the average, transport costs of Estonian shippers are 5.5% of turnover (or ca 40% of total logistics costs) and inventory carrying costs 4.6% (or one third of total logistics costs). By the logistics costs structure Finnish shippers differ with lower transportation costs (on average 4.0% versus 5.5% of turnover). At the same time Finnish shipper's administration and other logistics costs are significantly higher (1.6% versus 0.8% and 2.0% versus 0.8%). The differences could be caused from the differences of logistics costs accounting practices (or sales terms) in Estonian and Finnish firms (e.g., almost all responded manufacturers declared that their other logistics costs are 0%). The second reason could be the wider use of ICT in logistics and supply chain management in Finnish companies, often such ICT solutions costs are accounted under logistics administration and other logistics costs.

The comparison of logistics costs of Estonian firms in 2017 with these ones in 2011 is quite complicated, because of differences in average size of trading companies replied in 2017 and 2011 surveys (expressed in annual turnover). In previous year 2012 survey, rather significant share of responded trading companies were micro-companies, with annual turnover up to 2 million euros, in much bigger share than in preceding and following surveys (71% of traders in 2012 answered versus 39% in 2007 and 34% in 2018). There is a direct relationship between company size expressed in financial turnover and logistics cost level expressed as percentage of financial turnover. For larger companies the economies of scale effect applies resulting in smaller percentage of total logistics costs of turnover. For example, this relationship was very clearly seen in year 2007 survey results, where the average logistics cost shares of answered micro size (annual turnover up to 2 MEUR) and large size (above 50 MEUR) differed more than twice (16.1% of micro companies versus 7.0% of large ones; Kiisler 2008). Therefore, the average logistics costs of Estonian trading companies participating in year 2012 survey were to some extent upward and not objectively comparable with results of surveys from 2017 and 2007. However, also other issues have been analyzed to potentially have caused this increase in costs within 2012 survey, like political instability and natural disasters [Kiisler et al., 2017].

Among Estonian manufacturers there is no such respondents average size variations through surveys launched. The average logistics costs of Estonian manufacturers, expressed as % of turnover has increased from 12.5% to 14.6% during 2011-2017 (growth 16.8%). Also the logistics costs of Finnish companies within the same period have increased in relative terms with nearly same amount (16.5%), from 12.7% to 15.2%. Proceeding from this data could be argued, that average logistics costs of Estonian shippers (as percentage of turnover) have increased 17%.

Table 3. Logistics indicators of Estonian manufacturing and trading companies – operational performance 2017, 2011 and 2005

Indicator	Manufacturing			Trade		
	2017	2011	2005	2017	2011	2005
Percentage of customer orders delivered correctly in relation to time, place, documentation, amount, and quality, %	94.8	89.2	80.5	95.7	86.3	85.6
Average order fulfilment cycle time (order date to delivery date), days	37.9	32.3	21.5	8.7	7.1	5.6
Percentage of correct deliveries received (correct delivery time, place, documentation, amount and quality), %	91.4	84.2	NA	84.3	85.6	NA
Supplier average delivery time (order date to delivery date), days	30.8	25.3	NA	21.8	19.1	NA
Average number of material suppliers used during the last 12 months, suppliers	59.5	43.8	NA	35.8	37.4	NA

Table 4. Logistics indicators of Estonian manufacturing and trading companies – working capital management 2017, 2011 and 2005

Indicator	Manufacturing			Trade		
	2017	2011	2005	2017	2011	2005
Average number of days of sales outstanding (DSO, i.e. average number of days between customer order delivery to receipt of customer payment), days	37.6	29.2	30.2	17.6	30.8	23.7
Average end-product inventory days of supply, days	26.6	16.6	13.9	60.2	45.4	42.1
Average number of days of payables outstanding (DPO, i.e. average number of days between supplier order receipt to order payment), days	42.3	28.8	32.7	29.0	31.2	36.5
Average cash conversion cycle (CCC), days	21.9	17.0	11.4	48.8	45.0	29.3

Tables 3 and 4 present the logistics indicators of Estonian manufacturing and trading companies in 2017, 2011, and 2007, investigated respectively in year 2018, 2012 and 2007 surveys. The investigated indicators are basing on the SCOR (supply chain operations reference model) metrics.

Based on time series showed in Tables 3 and 4, the following developments can be outlined:

- The percentages of perfect orders have been significantly improved both in manufacturing and trading sectors.
- The average order fulfillment cycles have grown both for manufacturers and traders, probably in connection with optimization of logistics / shipping costs.
- Compared with traders, manufacturers have significantly improved the percentage of correct deliveries received.
- The end product inventories have grown considerably. Since 2011, manufacturer inventory days of supply have been grown 60% and in trading correspondingly by 33%.
- The average delivery times of suppliers have increased both in manufacturing and trading sector, probably due to supplier base internationalization and logistics costs optimization.
- The average number of material suppliers has slightly decreased in trading sector since 2011 (-4%), but surprisingly there is strong growth in manufacturing sector (36%).
- The indicator describing the efficiency of using live capital in supply chain is "Cash to cash cycle" or "Cash conversion cycle" (CCC). This is the net time interval between a firm's cash expenditures for purchases and its final recovery of cash receipts from product sales [Yasdanfar and Öhman 2013] or "the average days required to turn a dollar invested in raw material into dollar collected from a customer" [Stewart, 1995]. CCC can be calculated by adding days of inventory to days of accounts receivable and subtracting days of accounts payable [Farris & Hutchison, 2003]. Calculated on the basis of Table 4 data, the average CCC of Estonian manufacturers was 11 days in 2005, 17 days in 2011 and 22 days in 2017. The corresponding figures of Estonian traders were 29, 45 and 49 days. First of all, the increase of CCC has caused by increase of firms inventories. At the same time, in comparison with the results of year 2011 survey, Estonian companies have achieved in 2017 that their average terms of payment to their clients are shorter than their own terms of payments to their own suppliers. In 2017, this average difference between the days of sales outstanding (DSO) and days of payables outstanding (DPO) was 5 days in manufacturing (37.9 versus 42.3 days) and even 11 days in trading sector (17.6 versus 29.0 days). In 2011, DSO and DPO were roughly equal.

CONCLUSIONS

Based on completed logistics survey, Estonian manufacturing, trading and logistics firms on the average assess the level of operating conditions of logistics within Estonia with 3.5 points in 5-point scale (where 3 points means "neither poor nor good" and 4 points "good"). This is slightly better estimation than by previous similar survey from 2012 (3.4). However, during this period 2012-2018, the assessments of responded shippers and logistics services providers have considerably changed in different directions. While in 2012 Estonian LSPs gave the highest ratings for local logistics environment performance, in 2018 their ratings were the lowest one, strongly fallen especially in the field of availability of competitively priced transport services. Also in 2018, LSPs estimated their business results during the last two years less satisfying than manufacturers or traders. The main reason behind this development must have been the rough gradual increase of fuel excise taxes by Estonian government (coupled together with tight labour market) during 2016-2018 (including 26% growth of diesel and 33% growth of gasoline excises). This has resulted in the increasing costs and falling competitiveness of Estonian road haulage companies, both internationally and locally. On the average, the logistics costs of Estonian manufacturing and trading companies were 14.2% of their net turnover in 2017. On the average, transportation costs make ca. 40% of total logistics costs and inventory carrying costs ca 1/3 of total costs. In comparison with similar data from 2011, logistics costs of Estonian shippers, expressed as percentage of their net turnover, have increased on the average 16.8 %. Similar growth in logistics costs could be found from other studies too, like those of Finland [Solakivi et al., 2018a], Russia and Poland [Shvartsburg et al., 2017] and within smaller extent in USA [Ward et al., 2019]. As a small open economy with an opposite trend, the logistics costs of Switzerland have been on a steady decline (see for example Solakivi et al. 2018), which might make an interesting reference to the Estonian economy. This new survey also showed that average inventories of Estonian manufacturing and trading companies have significantly increased (60% and 33% respectively). Average order fulfillment cycles and suppliers delivery times have increased everywhere, probably originating from goals of optimization delivery costs.

Overall, as Estonia has an open economy, the results of Estonian logistics survey results comply with the general logistics trends during last years identified in many regions (rapid increase of logistics costs, increasing inventories etc). The results of last Estonian logistics surveys also show, how easily and extensively governmental fiscal measures through changing excise tax rates for fuels can influence the competitiveness and economical activities of road transport sector operating in small country, in competitive international environment.

As a further research, it would be interesting to repeat this same survey for Estonian companies in 2020 or later years. Business environment has further changed as growth has slowed in Northern European economies, and we have numerous factors, which might have considerably changed logistics performance (like very low interest rates and pandemic situation of Covid-19). It is extremely interesting to follow, how companies are tackling this current difficult situation, when they a priori have increasing inventories at hand, and demand conditions are suddenly deteriorating.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Ahermaa E., Vanamölder A., Josing M., Reiman M., Hansa A., Mattheus Ü., Niklus I., 2019. The Impact of Motor Fuel Prices and Excises to the Competitiveness of Estonian Road Transport Enterprises (in Estonian). Estonian Institute of Economic Research, available at: https://www.rahandusministeerium.ee/et/uu dised/rahandusministeerium-kaalub-diislikutuse-aktsiisimaara-langetamise-voimalusi Retrieved: 2.March.2020

Farris M.T., Hutchison P.D., 2003. Measuring Cash-to-Cash Performance. The International Journal of Logistics Management, 14:2, 83-91. http://doi.org/10.1108/09574090310806611

Heskett J.L., Glaskowsky N.A., Ivie R.M., 1973. Business Logistics – Physical Distribution and Materials Management, 2nd ed., Ronald Press Co., New York, NY.

Houlihan J.B., 1985. International supply chain management. International Journal of Physical Distribution and Materials Management, 15:1, 22-38, http://doi.org/10.1002/tie.5060270308

Kiisler A., 2008. Logistics in Estonian Business Companies. Transport 23(4), 356-362, http://doi.org/10.3846/1648-4142.2008.23.356-362

Kiisler A., Hilmola O-P., Tolli A., 2017. Analysis of logistics costs drivers in Estonia. World Review of Intermodal Transportation Research, 6:2, 110-129, http://doi.org/10.1504/WRITR.2017.082731

McKinnon A.C., 1988. National expenditure on logistics in the UK. Focus on Physical Distribution and Logistics Management. Journal of the Institute of Logistics and Distribution Management, 7:8, 23-27.

OECD Data, 2019. Trade in Goods and Services. Exports / Imports, % of GDP, 2019 or latest available. OECD National Accounts Statistics: Available at: https://data.oecd.org/trade/trade-in-goods-and-services.htm. Retrieved: March 23, 2020.

Ojala L., Solakivi T., Hälinen H-M., Lorentz H., Hoffmann T.M., 2007. State of Logistics in the Baltic Sea Region, Survey results From Eight Countries, LogOnBaltic

Oliver R.K., M.D. Webber, 1982. Supply-chain management: logistics catches up with strategy. Outlook, 5:1, 42-47.

Rantasila K., 2013. Measuring Logistics Costs - Designing a Generic Model for Assessing Macro Logistics Costs in a Global Context with Empirical Evidence from the Manufacturing and Trading Industries. Publication Series A-8/2013, Dr. dissertation, University of Turku, Turku, Finland.

Rice J.B., Hoppe R.M., 2001. Supply chain vs. supply chain: The hype & the reality. Supply Chain Management Review, Sept.-Oct., 46-54.

Rodrigues A.M., Boversox D.J., Calantone R.J., 2005. Estimation of global logistics and national logistics expenditures: 2002 data update. Journal of Business Logistics, 26:2, 1-16, http://doi.org/10.1002/j.2158-1592.2005.tb00202.x

Schwemmer M., 2017. Top 100 in European Transport and Logistics Services 2017/2018. DVV Media Group.

Shvartsburg L., Zaborowski T. Cyplik P., 2017. Situation of costs in the logistics process of enterprises. LogForum, 13 (4), 9, http://doi.org/10.17270/J.LOG.2017.4.9

Solakivi T., Hofmann E., Töyli J., Ojala L., 2018. The performance of logistics service providers and the logistics costs of shippers: a comparative study of Finland and Switzerland, International Journal of Logistics Research and Applications, 21:4, 444-463. http://doi.org/10.1080/13675567.2018.1439906

Solakivi T., Ojala L., Laari S., Lorentz H., Kiiski T., Töyli J., Malmsten J., Bask A., Rintala O., Paimander A., Rintala A., 2018a. Logistiikkaselvitys 2018. Turun Kauppakorkekoulun Julkaisuja Sarja E-2:2018. available at: https://blogit.utu.fi/logistiikkaselvitys/wp-content/uploads/sites/92/2019/01/Logistiikkaselvitys-2018-FINAL.pdf

Solakivi T., Ojala L., Lorentz H., Töyli J., Laari S., 2018b. Estimating the Size of the National Logistics Market. A Method to Include Both Market-based Demand and In-house activities. International Journal of Physical Distribution & Logistics Management, 48, 5, 488-503. http://doi.org/10.1108/IJPDLM-01-2018-0032

Statistics Estonia, 2020. Statistical database: Economy. Available at URL: http://pub.stat.ee/px-web.2001/I_Databas/Economy/databasetree.asp Retrieved: 9.March.2020.

Stewart G., 1995. Logistics Supply Chain Performance Benchmarkig Study Reveals Keys to Supply Chain Excellence. Information Management, 8, 2, 38-44. http://doi.org/10.1108/09576059510085000

Swedbank, 2020. Labour market set a new record in 2019. Flash comment: Estonia, Feb 16. Available at: https://www.swedbank-research.com/english/flash_estonia/2020/20-02-16/index.csp

United Nations, 2010. Review of Maritime Transport 2019. United Nations Conference on Trade and Development (UNCTAD). United Nations, Geneva and New York.

Yasdanfar D., Öhman P., 2014. The Impact of Cash Conversion Cycle on Firm Profitability. International Journal of Managerial Finance, 10, 4, 442-452. http://doi.org/10.1108/IJMF-12-2013-0137

Ward J., Zimmerman M., Oca A., Sonthalia B., Acar K., Sun Y., 2019. 2019 State of Logistics Report, ATKearney, USA. Available at: https://www.atkearney.com/transportation-travel/state-of-logistics-report Retrieved: 5.Aug.2019.

World Bank, 2020. Country Score Card: Germany 2018. The World Bank Group. Available at URL: https://lpi.worldbank.org/international/scorecard/radar/254/C/DEU/2018 #chartarea Retrieved: 14.Feb.2020.

PRZEGLĄD ESTOŃSKIEGO RYNKU LOGISTYCZNEGO 2018: ANALIZA I WNIOSKI

STRESZCZENIE. **Wstęp:** analiza estońskiego rynku logistycznego była realizowana trzy razy (w latach 2007, 2012 oraz 2018). Poniższa praca prezentuje najświeższe wyniki dotyczące warunków operacyjnych oraz kosztów logistycznych. Badanie obejmuje przedsiębiorstwa z branży przetwórczej, handlowej i logistycznej.
Metody: Dane wejściowe zostały zebrane poprzez ankiety przeprowadzone on-line w okresie lato - wczesna jesień 2018. Uzyskana 122 odpowiedzi od przedsiębiorstw z branży przetwórczej, handlowej oraz logistycznej. Uzyskane wyniki zostały porównane z wcześniej uzyskanymi wynikami z poprzednich lat, przy zastosowaniu tej samej metodologii.
Wyniki: Wyniki wskazują, że estoński rynek logistyczny wykazuje objawy przegrzania oraz wyraźny wzrost kosztów operacji logistycznych. Dostawcy usług logistycznych doświadczają wyraźniejszych negatywnych efektów w porównaniu z przedsiębiorstwami produkcyjnymi. Zaobserwowano wzrost zapasów oraz okresów dostaw, co skutkuje dłuższymi cyklami obiegu pieniężnego.
Wnioski: Wzrost kosztów logistycznych pozostaje wyzwaniem przyszłości dla estońskich logistyków. Jednak rozwój i jakość usług logistycznych wzrasta i jest na wysokim poziomie.

Słowa kluczowe: koszty logistyczne, rynek logistyczny, działalność logistyczna, Estonia

Ain Kiisler
Tallinn University of Technology (Taltech),
Estonian Maritime Academy
Kopli 101, 11712 Tallinn, **Estonia**
email: ain.kiisler@taltech.ee

Tomi Solakivi
University of Turku, Turku School of Economics
Rehtorinpellonkatu 3, FIN-20500, Turku, **Finland**
email: tomi.solakivi@utu.fi

Prof. Olli-Pekka Hilmola
LUT University, Kouvola Unit, **Finland**
Prikaatintie 9, FIN-45100 Kouvola
email: olli-pekka.hilmola@lut.fi

LogForum

> Scientific Journal of Logistics <

2020, 16 (3), 421-429

http://doi.org/10.17270/J.LOG.2020.446

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

MULTI-CRITERIA GROUP DECISION MAKING MODEL USING SINGLE-VALUED NEUTROSOPHIC SET

Suman Das, Rakhal Das, Binod Chandra Tripathy

Tripura University, Tripura, **India**

ABSTRACT. **Background:** In this article, we introduce some approaches for decision making in the neutrosophic set. The purpose of this study is to develop a neutrosophic multi-criteria group decision-making (MCGDM) model based on hybrid score-accuracy functions for approving a tender for construction under a simplified neutrosophic environment. Five criteria have been selected from experts' opinions to be considered for the distribution of tender. In this paper, we use the score functions, the accuracy functions, and the hybrid score-accuracy functions of single-valued neutrosophic numbers (SVNNs) and ranking method for SVNNs, those will help for making a decision.

Methods: Decision making under uncertain situation is an important aspect of those days. For this, we have developed the multi-criteria decision-making model using a single-valued neutrosophic set. The main aim is to select an appropriate tender for assigning the work to be done, so that the output will be the best one, under the available resources.

Results: We have developed an algorithm for taking proper decisions for the selection of a contractor for the construction of a public/government work.

Conclusions: We have verified our algorithm with the help of an example. We have considered five criteria. However, this algorithm can be applied for multi-criteria decision making. Also, it can be applied to other case studies too.

Key words: Neutrosophic set, Indeterminacy, Fuzzy set, Decision making.

INTRODUCTION

By using multiple criteria decision making (MCDM) methods, group decision-makers can choose the best alternative given multiple criteria. For that, a strategic method needs to be implemented to this decision made in uncertainty. In MCDM difficulties, a group decision matrix is built by aggregating the individual evaluation of each decision-maker to find a group adequate solution that is most preferred by the decision-makers.

Logistics management is a component of supply chain management. It plans, implements, and manages the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of creation and the point of consumption in order to meet customers' requirements. In this connection our model is expected to be useful for the logistic practices for decision making.

The main fields within logistics are Procurement logistics, production logistics, distribution logistics, disposal logistics. Our work can help in different fields of logistics [Swierczek 2019].

Horizontal logistics collaboration allows a great opportunity for companies to diminish their distribution charges. By forming a combination, companies have the potential to become more productive. However, the selection of a coalition structure is a difficult job for decision-makers. The decision-maker needs to distinguish and choose the best workable partner(s) to carry out a joint plan

Citation: Das S., Das R., Tripathy B.Ch., 2020. Multi-criteria group decision making model using Single-valued neutrosophic set. LogForum 16 (3), 421-429, http://doi.org/10.17270/J.LOG.2020.446

Received: 24.01.2020, Accepted: 29.05.2020, on-line: 30.06.2020.

concerning many patterns. This paper aims to propose a unique combination of group decision making [Sun, 2019, Harish, 2020].

For the choice of any object to a bye, we have decided from the available object and other opportunities like home delivery and time management quality. Since logistics management is a component of supply chain management, decision-makers have to ensure the flow of work management quality.

The fuzzy sets theory proposed by Zadeh in 1965. It has been very successful in dealing with difficulties involving uncertainty. Fuzzy set theory can be used to model imprecision in MCDM problems. [Pramanik, Mukhopadhyay 2011] performed an intuitionistic fuzzy MCDM strategy for teachers selection based on the grey relational analysis.

Till now fuzzy and intuitionistic fuzzy MCDM difficulties are investigated by many researchers. Uncertainty performs a vital role in group decision-making problems. Presently multiple researchers use uncertainty in the model formulation of different MCDM problems. So neutrosophic sets should be utilized in the decision-making method. The idea of the neutrosophic set was acquainted by [Smarandache 2005].

Distribution of tender for some construction can be considered as multi-criteria group decision-making (MCGDM) problem that generally consists of selecting the most desirable alternative from all the given alternatives. Classical MCGDM approaches deal with crisp numbers i.e. the weights of criteria are measured by crisp numbers. However, it is not always possible to present the information by crisp numbers. In order to deal with such a situation, the notion of the fuzzy set was introduced by Zadeh and Atanassov extended the concept of fuzzy sets (FSs) to intuitionistic fuzzy sets (IFSs) in 1986. The distribution of tender generally involves subjective judgment of experts, which makes the accuracy of the results highly questionable. In order to tackle the problem, a new methodology is needed. Liang and Wang studied the fuzzy multi-criteria decision making (MCDM) algorithm for personnel selection. Gunor and others developed an analytical hierarchy process (AHP) for personnel selection.

Since fuzzy and intuitionistic fuzzy MCDM problems are widely studied, but indeterminacy should be incorporated in the model formulation of the problems. Indeterminacy plays an important role in the decision-making process. So neutrosophic set, the generalization of intuitionistic fuzzy sets should be incorporated in the decision making process. Neutrosophic set [Smarandache 2005] was introduced to represent the mathematical model of uncertainty, imprecision, and decision making. [Biswas et al. 2014] presented the entropy-based grey relational analysis method for multi-criteria decision making under single-valued neutrosophic assessment. [Biswas et al. 2014] also studied a new methodology to deal with neutrosophic multi-criteria decision-making problems. [Ye 2013] proposed the correlation coefficient of SVNSs for single-valued neutrosophic multi-criteria decision-making problems [Cyplik, 2011, Karaaslan, 2020].

The ranking order of alternatives plays an important role in the decision-making process. In this study, we present a multi-criteria group decision-making approach for giving a tender for the construction with known weights based on the score functions, the accuracy functions, and the hybrid score-accuracy functions proposed by [Ye 2013] under a simplified neutrosophic environment.

The rest of the paper has been divided into different sections. Section 2, is the preliminaries and the definitions. In this section, we procure the definitions and the preliminary results used in this article. Section 3 is on multi-criteria group decision-making methods based on hybrid score-accuracy function. In this section, we discuss the multi-criteria decision-making method in the single-valued neutrosophic environment. Also, we have formulated the algorithm for this. Section 4 deals with the validation of the developed model. In this section we consider an example to verify our model. In section 5 we have talked about the difference and advantage of our model. In section 6 is the conclusion on the work done in this article.

PRELIMINARIES AND DEFINITIONS

Definition 2.1: Let X be a non-empty set. A *neutrosophic set* A in X is characterized by truth-membership function T_A, indeterminacy-membership function I_A and falsity-membership function F_A. $T_A(x)$, $I_A(x)$, $F_A(x)$ are real standard or non-standard subsets of $]^-0,1^+[$. That is

$T_A: X \to]^-0,1^+[$

$I_A: X \to]^-0,1^+[$

$F_A: X \to]^-0,1^+[$

There is no restriction on the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$, so

$^-0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3^+$

Definition 2.2: Let X be a non-empty set. A single valued neutrosophic set (*SVNS*) A in X is characterized by truth-membership function T_A, falsity-membership function F_A and indeterminacy-membership function I_A. For each point x in X, $T_A(x)$, $F_A(x)$, $I_A(x) \in [0,1]$.

A SVNS A can be written as $A= \{(x, T_A(x), I_A(x), F_A(x)): x \in X, T_A(x), I_A(x), F_A(x) \in [0,1]\}$.

Definition 2.3: For a single valued neutrosophic set(*SVNS*) $A=\{(x, T_A(x), I_A(x), F_A(x)): x \in X, T_A(x), I_A(x), F_A(x) \in [0,1]\}$ in X, the triplets $(T_A(x), I_A(x), F_A(x))$ is called single valued neutrosophic number (*SVNN*),which is the fundamental element of a *SVNS* A.

Definition 2.4: The complement of a *SVNS* A is denoted by A^C and defined by

$A^C = \{(x, 1-T_A(x), 1-I_A(x), 1-F_A(x)): x \in X\}$.

Relations between two SVNSs:

1) A *SVNS* A is contained in the other *SVNS* B ($A \subseteq B$) if and only if $T_A(x) \leq T_B(x)$, $I_A(x) \geq I_B(x)$ and $F_A(x) \geq F_B(x)$, for all $x \in X$.
2) Two *SVNS*s A and B are equal ($A=B$) if and only if $A \subseteq B$ and $B \supseteq A$.

Definition 2.5: Let $\alpha = (T(\alpha), I(\alpha), F(\alpha))$ be a *SVNN*. Then the score function and the accuracy function of the *SVNN* α can be represented respectively, as follows:

$$s(\alpha)=(1+T(\alpha)-I(\alpha))/2, \text{ and } s(\alpha) \in [0,1] \quad (1)$$

$$h(\alpha)=(2+T(\alpha)-I(\alpha)-F(\alpha))/3, \text{ and } h(\alpha) \in [0,1] \quad (2)$$

For the score function of a *SVNN* α, if the truth-membership $T(\alpha)$ is bigger and the indeterminacy-membership $I(\alpha)$ are smaller, then the score value of a *SVNN* α is greater. For the accuracy function of a *SVNN* α, if the sum of $T(\alpha)$,1-$F(\alpha)$,1-$I(\alpha)$ is bigger, compared to the other SVNN, then the statement is more affirmative, i.e. the accuracy of the *SVNN* α is higher.

Proposition 2.1: Let a_1, a_2 be two *SVNNs*. Then the ranking method can be defined as follows:

1) If $s(a_1) > s(a_2)$, then $a_1 > a_2$;
2) If $s(a_1) = s(a_2)$, and $h(a_1) \geq h(a_2)$, then $a_1 \geq a_2$.

Operational definitions of the terms stated in the problem:

1. Technical approach: Technical Approach is the method of energy-saving tools that have large significance for a tender worker as well as industrial work. It gives the maximum advantage of the facility of the energy savings potential.
2. Management approach: Management or managerial system of any program is highly important because the quality of the supply and performance of work is handle by the technique of management system which is also beneficial for criteria of quick performance, technical and cost-effectiveness.

3. Quick performance: Quick performance is the main key of any work and the development of the society as well as personal. The good performance of a tender shows the degree of sincerity of the tenderer.
4. Price selection: The Price selection is the most important issue to select tender. The theory of evolution and natural selection of Price equation in such a way that the desire of the tender committee and host will have the optimum solution.
5. Credentials: This is a qualification, achievement, personal quality, or aspect of a person's background, typically when used to indicate that they are suitable for the tender or not.

MULTI-CRITERIA GROUP DECISION-MAKING METHODS BASED ON HYBRID SCORE-ACCURACY FUNCTION

In a multi-criteria group decision-making problem, let $\{A_1,A_2,A_3,\ldots\ldots.A_m\}$ be the set of alternatives and let $\{C_1,C_2,\ldots\ldots C_n\}$ be the set of all criteria. Let the committee of decision-makers assigned the weights of all criteria previously. In such a case, we develop two methods based on the hybrid score-accuracy functions for multiple-criteria group decision-making problems with known weights under single-valued neutrosophic environment and interval neutrosophic environment.

Multi-criteria group decision-making method in single valued neutrosophic environment:

In the group decision process under single valued neutrosophic environment, if a group of t decision makers is required in the evaluation process, then the k^{th} decision maker can provide the evaluation information of the alternatives A_i (i=1,2,….,m) on the criteria C_j (j=1,2,……,n), which is represented by the form of a *SVNS*

$$A_i^k = \{(C_j, T_{A_i}^k(C_j),\ I_{A_i}^k(C_j),\ F_{A_i}^k(C_j)) : C_j \in C\}.$$

Here

$0 \leq\ T_{A_i}^k(Cj) + F_{A_i}^k(Cj) + I_{A_i}^k(Cj)\ \leq\ 3$, $T_{A_i}^k(C_j)$, $I_{A_i}^k(C_j)$, $F_{A_i}^k(C_j) \in [0,1]$,

for k =1,2,…,t, j=1,2,…..,n, i =1,2,….,m.

For convenience, $(T_{ij}^k, I_{ij}^k, F_{ij}^k)$ is denoted as a *SVNN* in the *SVNS* A_i^k (k=1,2,….,t; i=1,2,…,m; j=1,2,…n). Therefore, we get the k^{th} single valued neutrosophic decision matrix $D^k=\left(A_{ij}^k\right)_{m\times n}$ (k=1,2,…,t).

Then, the group decision making algorithm is as follows

Step 1: Hybrid score-accuracy matrix

The hybrid score-accuracy matrix $Y^k=\left(Y_{ij}^k\right)_{m\times n}$ (k=1,2,….,t; i=1,2,…,m; j=1,2,….,n) is obtained from the decision matrix D^k $=\left(A_{ij}^k\right)_{m\times n}$ by the following formula:

$$Y_{ij}^k\ =\ \tfrac{1}{2}(1+T_{ij}^k-I_{ij}^k)+\ \tfrac{1}{3}(T_{ij}^k + 1 - F_{ij}^k + 1 - I_{ij}^k) \quad (3)$$

Step 2: The average matrix

From the hybrid score-accuracy matrix, the average matrix $Y^A = \left(Y_{ij}^A\right)_{m\times n}$($k$=1,2,….,$t$; i=1,2,….,m; j=1,2,…n) is calculated by

$$Y_{ij}^A = \frac{1}{t}\sum_{k=1}^{t} Y_{ij}^k \quad (4)$$

The collective correlation coefficient between Y^k (k=1,2,….,t) and Y^A is given as follows:

$$C_k = \sum_{i=1}^{m} \frac{\sum_{j=1}^{n} Y_{ij}^k Y_{ij}^A}{\sqrt{\sum_{j=1}^{n}\left(Y_{ij}^k\right)^2}\sqrt{\sum_{j=1}^{n}\left(Y_{ij}^A\right)^2}} \quad (5)$$

Step3: Decision maker's weights

In decision making problems, the decision makers may have personal biases and some individuals may give unduly high or low preference values with respect to their preferred or repugnant objects. In this case we will assign very low weights to these false or biased opinions. Since the "mean value" is the "distributing centre" of all elements in a set, the average matrix Y^A is the maximum compromise among all individual decisions of the group. It mean sense, a hybrid score-accuracy matrix Y^k is closer to the average matrix Y^A. Then, the preference value (hybrid score-accuracy value) of the k^{th} decision maker is closer to the average value and evaluation is more reasonable and more important, thus the weight of the k^{th} decision maker is bigger. Hence a weight model for decision makers can be defined as:

$$\delta_k = \frac{C_k}{\sum_{k=1}^{t} C_k} \qquad (6)$$

where $0 \le \delta_k \le 1$, $\sum_{k=1}^{t} \delta_k = 1$ for $k=1,2,\ldots,t$.

Step4: Collective hybrid score accuracy matrix

For the weight vector $\delta=(\delta_1, \delta_2, \ldots \delta_k)^T$ of decision makers obtained from equation(6), we accumulate all individual hybrid score-accuracy matrices of $Y^k=\left(Y_{ij}^k\right)_{m\times n}$ ($k=1,2,\ldots,t$; $i=1,2,\ldots.m$; $j=1,2,\ldots,n$) into a collective hybrid score-accuracy matrix $Y=\left(Y_{ij}\right)_{m\times n}$ by the following formula:

$$Y_{ij}=\sum_{k=1}^{t} \delta_k Y_{ij}^k \qquad (7)$$

Step5: Weights for criteria

The Weight of criteria for this model has to be decided by the experts or committee of decision makers according to their requirements which is denoted by w_j (j=number of criteria). The weight of criteria is based on the significance of the importance of the criteria and the total weight is always one.

Step6: Calculate weighted hybrid score-accuracy matrix

From the collective hybrid score-accuracy matrix the weighted score-accuracy matrix

$Y^W=\left(Y_{ij}^w\right)_{m\times n}$ ($w=1,2,\ldots.,t$; $i=1,2,\ldots.m$; $j=1,2,\ldots,n$)

is calculated by

$$Y_{ij}^w = w_j Y_{ij} \qquad (8)$$

Step7: Ranking the alternatives

To rank the alternatives, we can sum all values in each row of weighted hybrid score-accuracy matrix and find the overall weighted score-accuracy value of each alternative A_i ($i=1,2,\ldots.,m$):

$$M(A_i)=\sum_{j=1}^{n} Y_{ij}^w \qquad (10)$$

According to the overall weighted score-accuracy values $M(A_i)$ of each alternatives A_i ($i=1,2,\ldots,m$) we can rank the alternatives A_i ($i=1,2,\ldots,m$) in descending order and choose the best alternative.

Step8: End.

VALIDATION OF THE DEVELOPED MODEL

In this section we present an example to validate our developed model.

Example of tender distribution for construction

Suppose that the central government or any state government of our country is going to construct a national highway or any building, then they need to choose the best construction company to build that highway or building for the use of the public. Then the government gives an advertisement in some well-circulated newspaper or the particular website of the government. Some interested construction companies may submit for the tender. After initial screening, four construction companies A_1, A_2, A_3, A_4 remain for further evaluation. A committee of four decision-makers D_1, D_2, D_3, D_4 has been formed to conduct the interview and choose the better construction company. Decision-makers consider five criteria to evaluate the better alternative. The five criteria are namely, technical approach (C_1), management approach (C_2), credentials (C_3), past performance (C_4), price (C_5). If four decision-makers D_q (q=1,2,3,4) are required in the evaluation process, then the five possible alternatives A_i (i=1,2,3,4) are evaluated by the form of SVNNs under the five criteria on fuzzy concept "excellence". Thus the four single-valued neutrosophic decision matrix can be obtained from the four experts and expressed respectively as follows.

Single valued neutrosophic decision matrix for D_1:

D_1	C_1	C_2	C_3	C_4	C_5
A_1	(.8,.2,.2)	(.8,.1,.2)	(.7,.2,.1)	(.8,.3,.1)	(.7,.2,.2)
A_2	(.7,.1,.1)	(.8,.2,.1)	(.6,.3,.2)	(.7,.2,.1)	(.8,.3,.2)
A_3	(.7,.1,.2)	(.8,.3,.2)	(.6,.3,.1)	(.7,.2,.3)	(.8,.2,.2)
A_4	(.7,.2,.3)	(.8,.2,.2)	(.7,.3,.1)	(.7,.1,.2)	(.8,.3,.1)

Single valued neutrosophic decision matrix for D_2:

D_2	C_1	C_2	C_3	C_4	C_5
A_1	(.7,.2,.2)	(.8,.2,.1)	(.8,.3,.2)	(.7,.2,.2)	(.8,.2,.3)
A_2	(.7,.1,.2)	(.8,.2,.2)	(.8,.1,.2)	(.8,.2,.1)	(.8,.3,.2)
A_3	(.8,.2,.1)	(.7,.3,.1)	(.8,.3,.2)	(.7,.2,.1)	(.7,.3,.2)
A_4	(.8,.1,.1)	(.7,.2,.2)	(.7,.2,.2)	(.7,.1,.2)	(.7,.2,.1)

Single valued neutrosophic decision matrix for D_3:

D_3	C_1	C_2	C_3	C_4	C_5
A_1	(.8,.2,.2)	(.7,.2,.1)	(.8,.3,.2)	(.7,.3,.2)	(.8,.2,.2)
A_2	(.7,.2,.2)	(.7,.1,.2)	(.7,.2,.2)	(.8,.2,.3)	(.8,.2,.1)
A_3	(.8,.3,.2)	(.8,.3,.2)	(.7,.1,.2)	(.8,.3,.4)	(.7,.3,.1)
A_4	(.7,.3,.2)	(.7,.2,.3)	(.7,.2,.2)	(.7,.2,.1)	(.8,.2,.2)

Single valued neutrosophic decision matrix for D_4:

D_4	C_1	C_2	C_3	C_4	C_5
A_1	(.7,.3,.2)	(.7,.2,.1)	(.8,.1,.2)	(.8,.3,.1)	(.7,.3,.2)
A_2	(.6,.3,.2)	(.8,.2,.1)	(.8,.3,.2)	(.8,.2,.3)	(.7,.3,.2)
A_3	(.7,.2,.1)	(.8,.3,.2)	(.7,.2,.1)	(.8,.2,.1)	(.8,.2,.1)
A_4	(.7,.2,.2)	(.8,.3,.3)	(.8,.1,.1)	(.7,.4,.3)	(.8,.1,.1)

From the above four single valued neutrosophic decision matrix, the following hybrid score- accuracy matrix are obtained by using eq (3).

Hybrid score-accuracy matrix for D_1:

Y_1	C_1	C_2	C_3	C_4	C_5
A_1	1.6	1.6833	1.55	1.55	1.5167
A_2	1.6333	1.6333	1.35	1.55	1.5167
A_3	1.6	1.5167	1.3833	1.4833	1.6
A_4	1.4833	1.6	1.4667	1.6	1.55

Hybrid score-accuracy matrix for D_2:

Y_2	C_1	C_2	C_3	C_4	C_5
A_1	1.5167	1.6333	1.5167	1.5167	1.5667
A_2	1.6	1.6	1.6834	1.6333	1.5167
A_3	1.6333	1.4667	1.5167	1.55	1.4333
A_4	1.7167	1.5167	1.5167	1.6	1.55

Hybrid score-accuracy matrix for D_3:

Y_3	C_1	C_2	C_3	C_4	C_5
A_1	1.6	1.55	1.5167	1.4333	1.6
A_2	1.5167	1.6	1.5167	1.5667	1.6333
A_3	1.5167	1.5167	1.6	1.45	1.55
A_4	1.4333	1.4833	1.5167	1.55	1.6

Hybrid score-accuracy matrix for D_4:

Y_4	C_1	C_2	C_3	C_4	C_5
A_1	1.4333	1.55	1.6833	1.55	1.4333
A_2	1.35	1.6333	1.5167	1.5667	1.4333
A_3	1.55	1.5167	1.55	1.6333	1.6333
A_4	1.5167	1.4833	1.7167	1.3167	1.7167

Now we find the average matrix Y^A, from the above four hybrid score-accuracy matrix Y_1, Y_2, Y_3, Y_4 by using the equation (4).

The average matrix Y^A:

Y^A	C_1	C_2	C_3	C_4	C_5
A_1	1.5375	1.6042	1.5667	1.5125	1.5292
A_2	1.525	1.6166	1.5167	1.5791	1.5250
A_3	1.575	1.5042	1.5125	1.5292	1.5541
A_4	1.5375	1.5208	1.5542	1.5167	1.6042

Now we determine the weights of the four decision makers, by using the eq (5) and eq (6) as follows:

$$\delta_1 = 0.2498 \quad ,\delta_2 = 0.2508 \quad ,$$
$$\delta_3 = 0.2497 \quad ,\delta_4 = 0.2497$$

Therefore, by using the eq (7) the hybrid score-accuracy values of the four decision makers' evaluations are aggregated and the following collective hybrid score-accuracy matrix can be obtained as follows:

Y	C_1	C_2	C_3	C_4	C_5
A_1	1.5375	1.6042	1.5666	1.5125	1.5292
A_2	1.5251	1.6166	1.5169	1.5792	1.5250
A_3	1.5751	1.5045	1.5125	1.5292	1.5540
A_4	1.5377	1.5208	1.5542	1.5168	1.6041

Now for this multi-criteria decision making problem we assume the weights for the given criteria. We take the weight vector of the attributes as:

$W=[0.30, 0.25, 0.05, 0.15, 0.25]^T$

By using equation (8) we find the weighted hybrid score-accuracy matrix Y^W as follows

Y^W	C_1	C_2	C_3	C_4	C_5
A_1	0.46125	0.40105	0.07833	0.226875	0.3823
A_2	0.45753	0.40415	0.075845	0.23688	0.38125
A_3	0.47253	0.376125	0.075625	0.22938	0.3885
A_4	0.46131	0.3802	0.07771	0.22752	0.401025

Now we can calculate the overall weighted hybrid score-accuracy values $M(A_i)$ for each alternatives A_i, i=1, 2, 3, 4 by using the equation (10):

$M(A_1)= 1.549805$, $M(A_2)= 1.555655$, $M(A_3)= 1.54216$, $M(A_4)= 1.547765$

According to the values of $M(A_i)$, i=1, 2, 3, 4, the ranking order of the alternatives A_i , i=1, 2, 3, 4, is $A_2 > A_1 > A_4 > A_3$. Hence the alternative A_2 is the best choice to give the tender for construction.

DIFFERENCE AND ADVANTAGES OF THE DEVELOPED MODEL

In 2014, Mondal and Pramanik introduced a multi-criteria group decision-making algorithm for teacher recruitment in higher education under a simplified neutrosophic environment. In that algorithm, they used hybrid score-accuracy function, where the score function depends on the truth-membership and falsity-membership values. Again they used completely unknown weights for each criterion in the algorithm. However, for our model, we use a new score function which depends on truth and indeterminacy membership values. By using the proposed score function we get a more accurate score value for a single-valued neutrosophic number. Again we have used the completely known weights for each criterion, which is important for any decision-making problem.

In our paper, we have taken neutrosophic indeterminacy function which is very unique and interesting for the decision if the value of indeterminacy membership in score function is very less then the truth membership value then the decision will more accurate.

CONCLUSIONS

In this paper, we used some suitable criteria for decision making to a better choice of a tender among the available tenders and we use function namely score function, accuracy function and hybrid score-accuracy function of SVNNs to select the better construction company to give the tender for construction under the neutrosophic environment, where the weights of the decision-makers are completely unknown and the weights of the criteria are completely known. This method can be used for group decision making with single-valued neutrosophic information is provide simple calculations and good flexibility but also handled with the group decision-making problems with known weights by comparisons with other relative decision-making methods under single-valued neutrosophic environments.

We have established a formula for making a decision. The data used in this paper has not taken from any source. We have considered these numbers for the verification of our algorithm. However, this algorithm can apply for any real source data.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The authors thank the unanemous reviewers for their careful reading of the article and for their constructive comments, those improved the presentation of the article.

The work of the first author is financially supported by the University Grants Commission Fellowship F.No. 16-6(DEC.2018)/2019(NET/CSIR). The work of the second author is financially supported by the Council of Scientific and Industrial Research, India vide Ref. No: 17/06/2018(i) EU-V and file no. 09/714(0022)/2019-EMR-I.

REFERENCES

Biswas P., Pramanik S., Giri B.C., 2014. Entropy based grey relational analysis method for multi-attribute decision making under single valued neutrosophic assessments. Neutrosophic Sets and Systems, 2: 105-113. http://doi.org/10.5281/zenodo.22459

Biswas P., Pramanik S., Giri B.C., 2014. A new methodology for neutrosophic multi-attribute decision making with unknown weight information. Neutrosophic Sets and Systems, 3: 42-50.

Boran F.E., Genc S., Kurt M., Akay D., 2009. A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. Expert Systems with Applications, 36(8): 11363-11368. http://doi.org/10.1016/j.eswa.2009.03.039

Cyplik P., Patecki A., 2011. RTLS vs RFID-partnership or competition?. LogForum, 7(3): 1-10.

Dagdeviren M., 2010. A hybrid multi-criteria decision making model for personnel selection in manufacturing systems. Journal of Intelligent Manufacturing, 21: 451-460. http://doi.org/10.1007/s10845-008-0200-7

Harish Garg, Nancy. Algorithms for single-valued neutrosophic decision making based on TOPSIS and clustering methods with new distance measure. AIMS Mathematics, 2020, 5(3): 2671-2693. http://doi.org/10.3934/math.2020173

Karaaslan F., Hunu F., 2020. Type-2 single-valued neutrosophic sets and their applications in multi-criteria group decision making based on TOPSIS method. J Ambient Intell Human Comput. http://doi.org/10.1007/s12652-020-01686-9

Mondal K., Pramanik S., 2014. Multi-criteria group decision making approach for teacher recruitment in higher education under simplified neutrosophic environment. Neutrosophic Sets and System, 6: 27-33. http://doi.org/10.5281/zenodo.30208

Mondal K., Pramanik S., 2015. Neutrosophic decision making of school choice. Neutrosophic Sets and Systems, 7: 62-68. http://doi.org/10.5281/zenodo.22582

Pramanik S., Mukhopadhya D., 2011. Grey relational analysis based intuitionistic fuzzy multi-criteria group decision making approach for teacher selection in higher education. International journal of computer application, 34(10): 21-29.

Smarandache F., 2005. Neutrosophic Set: A generalization of intuitionistic fuzzy sets. International Journal of Pure and Applied Mathematics, 24: 287-297. http://doi.org/10.1109/GRC.2006.1635754

Sun R., Hu, J. Chen, X. Novel single-valued neutrosophic decision-making approaches based on prospect theory and their applications in physician selection. Soft Comput 23, 211–225 (2019). http://doi.org/10.1007/s00500-017-2949-0

Swierczek A., 2019. The effects of demand planning on the negative consequences of operational risk in supply chain. LogForum, 15(3): 315-329. http://doi.org/10.17270/J.LOG.2019.340

Ye J., 2013. Multi-criteria decision making method using the correlation coefficient under single valued neutrosophic environment. International Journal of General Systems, 42(4): 386-394. http://doi.org/10.1080/03081079.2012.761609

MODEL WIELOKRYTERIALNEGO GRUPOWANEGO PODEJMOWANIA DECYZJI PRZY ZASTOSOWANIU JEDNOWARTOŚCIOWYM UKŁADZIE NEUTROSOFICZNYM

STRESZCZENIE. **Wstęp:** W pracy przybliżono kilka rodzajów podejmowania decyzji w układzie neutrosoficznym. Celem pracy jest opracowanie modelu neutrosoficznego wielokryterialnego podejmowania decyzji (MCGDM) w oparciu o funkcje hybrydowej akuratności dla akceptacji ofert w uproszczonym neutrosoficznym środowisku. Wybrano pięć kryteriów na podstawie opinii ekspertów, które były użyte w trakcie budowania oferty. W trakcie badań zostały użyte funkcje oceny, akuratności, hybrydowe dla pojedynczych wartości neutrosoficznych (SVNNs) oraz metoda rankingu dla SVNNs. Służyły one jako wspomaganie do podejmowania decyzji.

Metody: Podejmowanie decyzji w niepewnym środowisku jest istotnym czynnikiem współcześnie. W tym celu opracowano wielokryterialny model podejmowania decyzji przy zastosowaniu jednowartościowego układu neutrosoficznego.

Wyniki: Opracowano algorytm podejmowania decyzji wyboru kontrahenta budowlanego dla zleceń rządowych.

Wnioski: Opracowany algorytm został przetestowany na przykładzie. W analizie uwzględniono pięć kryteriów, niemniej jednak opracowany algorytm może być użyty do wielokryterialnego podejmowania decyzji.

Słowa kluczowe: układ neutrosoficzny, nieokreśloność, układ rozmyty, podejmowanie decyzji

Suman Das
Research Scholar
Department of Mathematics,
Tripura University, Agartala,
799022, Tripura, **India**
e-mail: suman.mathematics@tripurauniv.in

Rakhal Das
Research Scholar
Department of Mathematics,
Tripura University, Agartala,
799022, Tripura, **India**
e-mail: rakhal.mathematics@tripurauniv.in

Binod Chandra Tripathy
Professor of Mathematics
Department of Mathematics,
Tripura University, Agartala,
799022, Tripura, **India**
e-mail: binodtripathy@tripurauniv.in

LogForum

> Scientific Journal of Logistics <

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

2020, 16 (3), 431-446

http://doi.org/10.17270/J.LOG.2020.458

ORIGINAL PAPER

THE RELATIONSHIP BETWEEN MANAGEMENT SUPPORT IN TRAINING PROGRAMS AND MOTIVATION TO PERFORM TASK WITH MOTIVATION TO LEARN AS MEDIATOR

Nur Izzaty Mohamad[1], Azman Ismail[1], Azmawaty Mohamad Nor[2]

1) Universiti Kebangsaan Malaysia, Bangi, **Malaysia,** 2) University of Malaya, Kuala Lumpur, **Malaysia**

ABSTRACT. **Background:** Present studies recognize that commercial organizations and public organizations have work together to set up national logistic policies for the national development requirements. In order to support this aim, leadership of public sector has planned and implemented training programs to expose latest logistic management strategies and operations to employees. Latest findings from logistic management studies circulated in the 21st century revealed that the willingness of management to support training programs has strongly invoked employees' motivation to learn creative logistic methods. As a result, this motivation may drive to an enhanced motivation to perform task. Even though this relationship is interesting, the role of motivation to learn as a significant mediating variable has largely been neglected in the logistic management literature. Thus, this situation stimulate the present study to extend the literature by examining the mediating effect of motivation to learn in the relationship between management support in training programs and motivation to perform task.

Method: Survey questionnaires were employed to gather data from employees at central government agencies under controlled by the Malaysian federal government. The SmartPLS was used to measure the psychometrics properties of instrument and test the research hypotheses.

Result: This study showed that motivation to learn did act as an important mediator of the relationship between management support in training programs and motivation to perform task.

Conclusion: The mediating effect of motivation to learn between management support in training programs and motivation to perform task also is consistent and has extended previous logistic management studies published in Western and Asian countries.

Key words: management support, motivation to learn, motivation to perform task, SmartPLS.

INTRODUCTION

Logistic management principles have widely been applied to manage the performance of commercial organizations (e.g., private companies) [Al-Minhas et al. 2020], public organizations (e.g., military, rescue and fire, as well as public enterprise organizations) [Buics 2017], and non-profit organizations (e.g., humanitarian aid organizations) [Bolsche et al. 2013]. It is often dealt with some or all of the following business functions, such as inbound transportation, outbound transportation, fleet management, warehousing, materials handling, order fulfilment, inventory management and demand planning [Buics 2017, Ristovska1 et al. 2017]. In order to handle such business functions, many organizations improve the process of planning, organizing, leading and controlling the efficient movement and storage of goods, services, and related information between the point of origin (source) and point of consumption (destination) to meet customers' needs and expectations [Council of Logistics Management 2000, Wang et al. 2018].

Citation: Mohamad N.I., Ismail A., Mohamad Nor A., 2020. The relationship between management support in training programs and motivation to perform task with motivation to learn as mediator. LogForum 16 (3), 431-446, http://doi.org/10.17270/J.LOG.2020.458

Received: 19.02.2020, Accepted: 13.05.2020, on-line: 30.06.2020.

Some important logistic methods often practiced by organizations to upgrade the efficiency of logistic operations are outsourcing critical job to logistic companies, use digital technology to monitor vendor compliance programs, business intelligent software to track transportation trends, green business practice, pay at risk and organizational flexibility practice [Al-Minhas et al. 2020, PLS Logistics Services 2020]. If such logistic methods are appropriately done they may provide many beneficial results to organizations, especially as increase revenue, improve operating cost structure, reduce overall transportation costs, and improve customer service [Kherbacha, Mocana 2016, Rivera et al. 2016].

Present studies about logistic management acknowledge that logic industry has many employees with various knowledge, skills and behavior who involve in many phases of logistic operations. Training programs is viewed as a vital function to develop highly competent and talented employees where they may remove barriers in order to enhance sustainable green logistics [Al-Minhas et al. 2020, Bombiak, Marciniuk-Kluska 2018, Iqbal et al. 2018].

At an organizational growth phase, human resource management have given more attention on the establishment of their organizations and training programs are run routinely, informally and on ad-hoc basis in order to overcome daily task deficiencies, enhance daily job performance and achieve short-term objectives [Ismail et al. 2016, Jehanzeb, Basir 2013, Slusarczyk 2018]. According to Karatzas et al. [2020] said that such training programs are applicable to upgrade organizational performance in times of stable and less market competitions. But, they have not offered sufficient help to maintain and enhance the competitive advantages of knowledge based organization in an era global economic turbulence [Schwab 2017, Ismail et al. 2016, Howard, Lee 2019].

In consistent with economic, social and political changes, many commercial and commercial organizations have changed their management paradigms, that is from an internal job based to external competitiveness based management in order to meet the requirements of various management segments, particularly training management [Roblek et al. 2018, Schwab 2017, Howard, Lee 2019]. Under this new paradigm, human resource management will establish a department training committees which involve line management and consultants to prepare a training master plan for its organization. This committee will hold a training need analysis to clearly identify the requirements of organization, job and personnel. Further, information gathered from the analysis will help them to set up realistic learning objectives, relevant training content and determine attractive and interactive learning methods [Jehanzeb, Basir 2013, Slusarczyk 2018, Karatzas et al. 2020]. Implementation of the training design may impart employee competencies in coping with uncertain environments, and grabbing open market opportunities to rebuild organizations, as well as respond and adapt to external and internal organizational changes timely [Ospina et al. 2011, Reinhold et al. 2018].

Many research and practice support the significance of management support in training programs in fulfilling organization and employee objectives [Forbes 2019, Hajjar, Alkhanaizi, 2018]. For instance, results from a study by the Association for Talent Development [Forbes 2019] in many European countries reported that management support had played very important roles in designing and administering job based training, as well as creating a positive learning culture that enhance daily work performance and responsive to external and internal organizational challenges. Hence, this support practice had improved 70% employees' productivity and this could assist in enhancing the organizational competitiveness in a global economy.

A careful examination of the present literature which related to logistics management shows that how well training programs are designed they will not be able to accomplish their objectives if management does not provide effective support in organizations [Al-Minhas et al. 2020, Jabbour, de Sousa Jabbour 2016]. In a logistic management standpoint, effective management support is often done into two major forms, namely emotional support (e.g., making someone feel valued, loved and cared for) and instrumental support (e.g., helping, appreciate, understanding, and breaking) [Issah 2018, Morelli et al. 2015]. Undeniably, management support has been recognized as a crucial management behaviour in commercial and non-commercial organizations [Al-Minhas et al. 2020, Issah 2018]. Most findings from organizational training studies published in an era of globalization disclosed that effect of management support on motivation to perform a task is indirectly affected by motivation to learn [Olumuyiwa et al. 2012, Al-Minhas et al. 2020]. Although the relationship has extensively been examined, the role of motivation to learn as a significant mediating variable has been largely ignored in the logistic management research literature [Al-Minhas et al. 2020, Iqbal et al. 2018].

Most researchers discuss that this situation may be caused by several factors: First, many previous studies have used a descriptive approach to elaborate the internal properties of motivation to learn, such as conceptual discussion about definitions, dimensions and advantages of the construct in logistics management [Iqbal et al. 2018, Nadeem, Ahmad 2017, Lee et al. 2017]. Second, abundant past studies have used a simple direct relationship model to examine the association between two variables: (a) employees' perceptions toward management support in training programs; (b) association between management support in training programs on employees' motivation to learn; and (c) association between employees' motivation to learn and employees' motivation to perform task [Abdulkarim et al. 2009, Park et al. 2018, Ristovska1 et al. 2017]. These models have not been assessed using advanced statistical analyses (such as, descriptive statistics and bivariate statistics) and outcomes of this analysis have only able to display the magnitude of association between such variables. Conversely, the statistical results have not sufficient to determine the effect size and nature of motivation to learn as a crucial mediating variable in the hypothetical models [Abdulkarim et al. 2009, Karatzas et al. 2020, Nadeem, Ahmad 2017]. Consequently, the study approach has only able to produce general recommendations and may not sufficient to offer a clear road maps to be used by practitioners in understanding the complexity of motivation to learn construct and designing appropriate instructional strategies to maintaining and achieving organizational strategy and objectives in an era of global economic turbulence.

This study setting is central government agencies of the federal government of Malaysia. These agencies consist of four regulatory bodies, namely Malaysian Administrative Modernization and Management Planning Unit, Implementation Coordination Unit, Economic Planning Unit, Treasury, Public Service Department and Socio-Economic Research Unit. These agencies have often cooperated to perform their critical functions, namely a) to formulate the national financial and economic policies, public sector human resource policies and monitor the implementation of these policies, b) to assist, coordinate and control the running operating agencies (i.e., ministries, government departments and public bodies), and c) to provide several requirements to operating agencies in implementing government project and programs for citizens [Hai, Nawi, 2007].

In order to support the functions of central agencies, they have adopted positive business management values and applied logistic management solutions to accomplish the grand national agenda, namely Vision 2020 inspired by the 4th Prime Minister of Malaysia Mahathir Mohamad to become Malaysia as a fully developed country by the year 2020 [Mahathir, 1991, 1997], and Government Transformation Programme created by the 6th Prime Minister of Malaysia Najib Abdul Razak to make Malaysia as a developed and high-income nation [Prime Minister Office 2020].

The central agencies have adopted logistic methods to enhance the competency of public sector in two major fields: First, apply logistical methods to improve the bureaucratic systems in order to increase customer satisfaction. For example, the regulatory bodies have introduced some institutional reforms, such as implement innovator and cost saving strategies, decrease hierarchical levels in the administration, promote decentralization of decision making to lower levels, introduce job flexibilities, simplify job procedures, upgrade mobile commerce technologies, deregulate the complicated legal system, allow citizen participations and practice customer-friendly administration have helped operating agencies (e.g., ministries) to get brilliant input, useful message and information sharing, make faster decisions in obtaining funds, buying and distributing products (goods or service) to other government agencies (e.g., military, rescue and fire organizations, hospital, educational institutions, as well as government linked company), enhancing integrity and honesty in doing daily job operations (e.g., decrease corruptions and malpractices), and helping citizens to get better services (e.g., discount for paying utility bills, efficient public transport, good health treatments for dangerous diseases, tax deductions for corporate social responsibility and innovation companies). This reform may lead to deliver better services in terms of quality, speed, efficiency, convenience and fairness to citizens [Rosena et al. 2008, Zuraimi et al. 2013].

Second, the central and operational government agencies have collaborated with business companies to design strategic plans for creating condusive ecosystem that may motivate logistic industry to succeed in domestic and international market [The Ministry of Transport Malaysia 2016]. The Ministry of transport Malaysia has taken a proactive action by establishing the National Logistics Task Force comprising inter-agency and private sector representatives to design the logistics and trade facilitation masterplan. The main objective of this plan is to become logistics industry as the backbone of the Malaysian economy through overcoming debottlenecking, enhancing domestic growth and creating regional footprint. This effort is very useful to support all sectors of the economy, facilitates trade and reduces cost of doing business, besides improving productivity and efficiency of the economy [The Ministry of Transport Malaysia 2016]. To strengthen the masterplan, East Coast Economic Region of Peninsular Malaysia project, for example, was launched in 2007 to transform the region into a major international and local tourism destination, an exporter of resource based and manufactured products, a vibrant trading centre, and an infrastructure and logistics hub to become the main gateway for trade and industry within the Asia Pacific region. This mega project involves high expenditures for business infrastructures, but returns from their activities may enhance the flow of economic transactions and sustain national economic growth for long term [Zuraimi et al. 2013]

Designing and implementing a systematic training programs in atrracting, maintaining and motivating civil servants to support the implementation of grand national agenda and mega projects are pivotal in Malaysian public sector. Training methods and content which related to logistic operations implemented in the central agencies and operating agencies are done according to the national human resource development guidelines as set up by the Public Service Departments [Syed Ibrahim 2007, Tajuddin Hussein 2009]. In the central agencies, various types of on the job and off the job training programs have been implemented to emphasize on four major areas, namely a) providing competencies, knowledge and responsibility of the job, b) applying wholesome values and fostering team spirit, c) creating a quality pool of talents, multi-skills and d) inculcating the ability to cope with current and future challenges. For example, The Public Service Department [2019] reported the willingness of management to offer satisfactory support through instrumental aids (e.g., providing training and budgeting) and emotional aids (e.g., advice and guidance) in performing daily job have enhanced motivation of employees to learn new knowledge, latest skills, up-to-date cognitive and emotion abilities, improve positive attitudes and master current capabilities that suit with the current logistic operations. [The Public Service Department 2019]. As a result, this motivation may stimulate employees to perform daily job operations efficiently and effectively [The Public Services Department 2019]. Although this relationship is important, the mediating effect of motivation to learn has not been empirically evaluated in the organizations. With the scarcity of empirical evidence, there is a vital need to enrich the existing literature by evaluating the role of motivation to learn as a mediating variable between management support and motivation to perform task. Hence, the structure of this paper discusses five major issues: literature review, methodology, findings, discussions and implications and conclusion.

LITERATURE REVIEW

Management support in training programs

Management support is an important feature of Locke and Lathman's [1991] Goal Setting Theory and Dansereau's et al. (1965) Leader-Member Exchange Theory. It consists of two major facets, namely emotional support and instrumental support [Morelli et al. 2015, Issah 2018]. Emotional support is usually related to the ability of management to understand diverse employees' needs, provide training types that suit with employees' job, maintain social relationship to attract employees enrolling training programs, making someone feel valued, cared for and lengthening positive effect on others [Morelli et al. 2015, Issah 2018]. Next, instrumental support is often referred to as the management giving high commitment and assistance to the employee such as allocating training budgets, creating conducive working climate, providing adequate physical facilities, harmonizing procedures and techniques, designing instructional training programs and coordinating all kinds of instrumental support with the organizational strategies [Schindler, Bukholder 2014, Issah 2018]. Numerous organizational training studies prove that the readiness of management to appropriately provide various types of emotional and instrumental aids in managing training programs may lead to a higher positive trainees' outcomes, particularly motivation to perform a task and trainees' motivation to learn [Ismail et al. 2016, Nadeem, Ahmad 2017].

Motivation to learn

Motivation to learn is a critical component of Knowles's [1984] Adult Learning Theory. It is broadly interpreted as employees' desire and willingness to acquire and master new knowledge, up-to-date skills, latest emotional and cognitive abilities, positive attitudes and present capabilities in order to fulfill their organizational objectives [Lee et al. 2017, Govaerts et al. 2017]. According to a training management perspective, motivation to learn consists of two salient features, that is, high motivation to learn and low motivation to learn. High motivation to learn is often referred to employees' willingness to learn training content, such as latest knowledge, new talents and progressive job-related skills. Ability to master the training content may lead to a higher performance in organizations [Abdulkarim et al. 2009, Ismail et al. 2016]. While, low motivation to learn is normally related to employees' failures in understanding the training content and this situation may not help them to improve their job performance in organizations [Abdulkarim et al. 2009]. Many recent studies have found that employees with high motivation to learn is an important outcome of management support and also can act as an effective mediating variable between management support and motivation to perform task in different organizational settings [Ismail et al. 2016, Nadeem, Ahmad 2017, Abdul Aziz 2016, Park et al. 2017].

Motivation to perform task

Motivation to perform task is a critical element of Amabile's (1983) componential model of creativity. It is often discussed from an intrinsic motivation perspective where individuals have high desire and passion to perform creativity and innovation in organizations [Olumuyiwa et al. 2012]. According to a training management viewpoint, motivation to perform task consists of two important characteristics, namely high motivation to perform tasks and low motivation to perform task [Diamantidis, Chatzoglou 2018, Amos, Natamba 2015]. For example, employees with high motivation to perform task will have high desire in carrying out daily tasks to achieve their job objectives [Diamantidis, Chatzoglou 2018, Amos, Natamba 2015]. While, employees with low motivation to perform task will have low inspiration in doing daily task to meet their job targets [Diamantidis, Chatzoglou 2018]. Further, extant organizational training studies advocate that motivation to perform task is a significant result of the relationship between management support and motivation to learn [Park et al. 2017, Abdul Aziz 2016].

THEORETICAL BACKGROUND AND HYPOTHESIS DEVELOPMENT

Relationship between management support and motivation to perform task

Influence of management support in motivating individuals to perform task is consistent with the essence of Dansereau et al.'s (1965) Leader-Member Exchange Theory. It explains two major types of relationship in organizations, namely high quality of the relationship between leaders and members and low quality of the relationship between leaders and members. In the context of high quality relationships define the leader's willingness to practice a high physical and emotional effort on employees such as providing information, providing feedback, openness and caring can enhance a positive employees' behaviour. Conversely, in a low quality relationship condition define the leaders' inability to provide a high physical and emotional support to employees' can enhance a negative outcome. The application of this theory in a training management shows that essence of high quality relationship is frequent translated as management support. This essence of this theory has received strong support from the research papers in workplace training management.

Previous studies have not supported the role of management support in enhancing motivation to perform task. For example, results from surveys by McCoy and Evans [2005] and Haris et al. [2000] had only focused on a component instrumental support, namely material aids and neglected emotional support as determinants of motivation to perform task. This finding may be due by the majority employee's perceived material aids such as values of training, physical aids as the bread winner that may help them to decrease current work problems and improve their daily work performance in the organizations.

Recent studies advocate that management support is an important determinant of motivation to perform task. For example, results from surveys by Ismail et al. [2016] and Nadeem and Ahmad [2017] displayed that the ability of management to appropriately provide emotional aid (e.g., encouraging employees to attend training programs, practicing open communication, delivering training programs information and caring for employee needs) and instrumental aid (e.g., providing convenient training facilities, provide feedback on training applications and allocate financial for training programs) in executing on the job and off the job training programs had been an important determinant of motivation to perform task in the respective organizations. Thus, the hypothesis is formulated as below:

H1: Management support has a positive relationship with motivation to perform task

Relationship between management support and motivation to learn

Influence of management support in affecting motivation to learn has supported the principal meaning of Locke and Lathman's [1991] Goal Setting Theory. It suggests that clear and challenging goals provide road map to enable employees fulfill their intended outcomes. The use of this theory in a training management displays that the principal meaning of goal is usually interpreted as management support. This principal meaning is consistent with the research articles in organizational training management.

Past studies uncover that management support is not an important predictor of motivation to learn. For example, outcomes of surveys by Huchin [2009] and Sarks and Belcourt [2006] had only highlighted an element of instrumental aid, namely technical support and ignored emotional support as predictors of motivation to learn. This outcome may be affected by the majority employee's view that training equipment, additional information and technical assistance are specific factors that can help them in achieving job targets in the organizations.

Further, extant studies recognized that management support is a significant predictor of motivation to learn. For example, results from surveys by Govaerts et al. [2017] and Park et al. [2017] disclosed that the capabilities of management to provide emotional aid (e.g., disseminate a complete training information and adopt an open mind in introducing new ideas and skills) and instrumental aids (e.g., high incentives for employees) in training management had enhanced trainees' motivation to learn in the different organizational settings. Thus, the hypothesis is established as below:

H2: Management support has a positive relationship with motivation to learn

Relationship between management support, motivation to learn and motivation to perform task

Mediating effects of motivation to learn in training programs is consistent with the spirit of Adult Learning Theory [Knowles 1984]. It posits that learning by observing a role model may inspire individuals to learn. Application of this theory in a training management shows that the ability of management to adequately provide emotional aid (e.g., arrangement training activities, give encouragement) and instrumental aid (e.g., instructional strategy, training environment, technology support) can enhance employees' motivation to learn in organizations. The spirit of this theory has received strong support from the research papers in training management.

Past studies have not supported the role of motivation to learn as an important intermediary between management support and motivation to perform task. For example, a survey by Meyer and Tuner [2002] found that a dimension of instrumental support, namely psychological problem-solving technique and neglected emotional support was seen as an important antecedent of motivation to learn. This finding may be caused by the majority employees believe that psychological problem solving is sufficient to achieve employees' needs and expectations in the organizations.

More recent studies advocate that effect of management support on motivation perform a tasks is indirectly affected by motivation to learn. For example, outcomes of surveys by Abdul Aziz [2016] and Abdulkarim et al. [2009] reported that the ability of management to appropriately provide emotional aid (e.g., relevant to the job, provide the latest training) and instrumental aid (e.g., training reputation, cultural support) in the design and administration of training programs had strongly invoked trainees' motivation to learn (e.g., spirit to learn the content of training, focus and committed in training programs). As a result, this motivation could lead to greater motivation to perform task in the organizational samples. Thus, hypothesis is developed as below:

H3: Effect of management support on motivation to perform task is mediated by motivation to learn.

METHODOLODY

Research design

A survey method is used as the research strategy to assist the researchers to gather accurate, unbiased and high quality of data [Lomand 2016, Sekaran and Bougie 2016]. This study was conducted at central agencies of the Malaysian federal government. Due to the confidentiality, the real name of this organization is not stated. At the early stage of this study, a survey questionnaire was drafted based on the training management literature.

Further, a back translation technique was used to translate the questionnaire in English and Malay languages in order to enhance the quality of research findings [Lomand 2016, Sekaran, Bougie 2016].

Measurement tools

The survey questionnaire has five major parts. First, management support had 7 items adapted from the training related management support literature [Madagamage et al. 2014, Dermol, Cater 2013]. Second, motivation to learn had 7 items adapted from the training related motivation to learn literature [Abdul Aziz, Selamat 2016, Soon, Ahmad 2012]. Third, motivation to perform task had 8 items adapted from the training related job motivation literature [Madagamage et al. 2014, Podsakoff et al. 1997]. All items were evaluated based on the 7-item Likert scale, starting from "very disagreeable/ very dissatisfied" (1) to very agree/ very satisfied (7). The respondent characteristics are used as controlling variables because this study focuses on employee attitudes.

Sample of study

The unit of analysis is employees who serve at the studied organizations. A purposive sampling technique was used to distribute 200 questionnaires to different categories of employees who work at various departments/divisions within the organizations. For the specific purpose, the sampling technique was chosen because the organization heads could not provide a detail employee record to the researchers due to the confidentiality factor. This constraint did not permit the researchers to select participants using a random technique. From the total of number, only 115 (38.3%) participants answered the questionnaires with consent, voluntary and secrecy. Harman's single factor test is used as recommended by Eichhorn [2014] and Podsakoff et al. [2003] to detect bias caused by the survey method. Results from this test indicated that the variance percentage was 45 percent and this value was lower than 50 percent of the variance [Eichhorn 2014, Podsakoff et al. 2003], indicating that bias is not present in the survey questionnaire data.

FINDINGS

Respondent characteristics and sample profile

Most respondents aged 34 to 39 years old (41.7%), female (67.0%), Malay (94.8%), Malaysian higher education certificate holders (43.5%), supporting staff (59.1%), position grades 19 to 26 (40.9%), monthly salaries RM1000 and RM2499 (41.7%), length of service less than 5 years (33%) and married (75.7%).

Validity and reliability analysis

Table 1 shows the results of convergent validity analysis. Outer loading values for the correlation between items and constructs were greater than 0.70 [Hair et al. 2017], and he values of the average variance extracted (AVE) for each construct were greater than 0.50 [Hair et al. 2017], confirming that the constructs have met the convergent analysis standard. Meanwhile, the values of composite reliability for each construct were greater than 0.80 [Hair, et al. 2017], indicating that the constructs have high internal consistency.

Table 2 shows the results of discriminant validity. The values of Heterotrait-Monotrait Ratio (HTMT) for each construct were less than 0.85 [Hair et al. 2017], and the confidence interval values in the bracket for each construct were greater than 1.0 [Hair et al. 2017], indicating that the constructs have fulfilled the discriminant validity criteria.

Table 1. Convergent Validity Analysis and AVE Values

Constructs/ Variables	Outer Loading			Composite Reliabilty	AVE Values
	Management Support	Motivation to Learn	Motivation to Perform Task		
Management Support					
A1. encouragement to attend training	0.877			0.950	0.733
A2.caring for the needs of skills in the task	0.867				
A3.encouraging to acquire new skills	0.868				
A4. open to discussing training problems	0.863				
A5.clearly explain the objective of the training programs	0.833				
A6.provide feedback on the training programs applied	0.851				
A7. suggest an exciting training program	0.830				
Motivation to Learn					
B1.the spirit to learn the training content		0.768		0.913	0.600
B2. interested in attending training programs		0.753			
B3. focuses on the training content		0.858			
B4.increase motivation to carry out		0.770			
B5.improve skill level		0.788			
B6. resulting in quality job performance		0.761			
B7. increase the level of current knowledge		0.747			
Motivation to Perform Tasks					
C1. Ready to assist colleagues in performing duties			0.820	0.951	0.710
C2. encouraged to help co-workers to solve task problems			0.877		
C3. take part in the meeting to improve organizational performance			0.795		
C4. share job expertise with co-workers			0.831		
C5. confident of higher quality work			0.860		
C6. sure to develop the skills learned in the task			0.875		
C7. believe it can overcome the task barriers when using new knowledge			0.853		
C8. trying to solve job-related problems			0.824		

Table 2. Discriminant Validity HTMT Analysis and HTMT Confidence Interval

Constructs/ Variables	Management Support	Motivation to Learn
Management Support		
Motivation to Learn	0.468 (0.222, 0.569)	
Motivation to Perform Task	0.445 (0.221, 0.588)	0.842 (0.756, 0.562)

Note: In the bracket is the confidence interval of 5% and 95%

Construct analysis

Table 3 shows the results of descriptive statistics and variance inflation factor. The mean values for each construct between 5.523 and 5.879, indicating that the levels of management support, motivation to learn and motivation to perform task range from high level (4) to very high level (7). The correlation coefficients for the relationships a) between the independent variable (management support) and the mediating variable (motivation to learn), and b) the mediating variable (motivation to learn) and the dependent variable (motivation to perform tasks) have values of variance inflation factor less than 5.0 [Hair et al. 2017], confirming that all constructs are free from serious collinearity problems. Overall, the result further confirms that all constructs have met the validity and reliability criteria.

Table 3. Descriptive statistics and Variance Inflation Factor Analysis (VIF)

Constructs/ Variables	Mean	Standard Deviation	Variance Inflation Factor (VIF)
Management Support	5.523	0.774	1.232
Motivation to Learn	5.879	0.636	1.000
Motivation to Perform Task	5.874	0.702	1.232

Outcomes of testing H1 and H2

Table 4 shows the results of testing research hypotheses for the direct effects model. First, management support had a significant relationship with motivation to perform task (β =0.447; t=4.856), hence H1 was supported. Second, management support had a significant relationship with motivation to learn (β =0.452; t=5.565), hence H2 is supported. This result indicates that management support is an important determinant of motivation to perform tasks and motivation to learn.

In terms of explanatory power, the entry of management support into the analysis has contributed 23% of the variance in motivation to perform task and 20% of the variance in motivation to learn. The result shows that the value of R2 is greater than 0.13, meaning that this research model has moderate impact [Cohen 1992].

Table 4. Hypothesis Testing Result H1 and H2

Hypothesis	Relationship	β Values	t Value	R^2 (%)	Result
H1	Management Support→ Motivation to Perform Task	0.447	4.856	0.23	Supported
H2	Management Support→ Motivation to Learn	0.452	5.565	0.20	Supported

Note: Significant level t >1.65 (10%)

Further, the effect size (f2) and predictive relevant (Q2) were assessed. The finding of the PLS algorithm test showed that the value of f2 in the relationship between management support and motivation to perform task was 0.232, which was greater than 0.15, indicating a medium effect on motivation to perform task [Hair et al. 2017]. While, the value of f2 for the relationship between management support and motivation to learn was 0.025, which was greater than 0.02, indicating a weak effect on motivation to learn [Hair et. al 2017]. Furthermore, the result of the PLS blindfolding test displayed that management support had Q2 value of 0.118, which was greater than zero [Hair et al. 2017], indicating that the model has predictive relevance.

Outcomes of testing H3

Table 5 shows the results of testing research hypotheses for the indirect effects model. The relationship between management support and motivation to learn was significantly related to motivation to perform task, (β =0.439; t=5.716), hence H3 was supported. This result confirms that motivation to learn acts as an important mediating variable between management support and motivation to perform task.

The entry of management support and motivation to learn into the analysis has contributed 68% to motivation to perform task. The result shows that the value of R2 is greater than 0.67 meaning that this research model has a substantial impact [Cohen 1992].

Table 5. Hypothesis Testing Result H3

Hypothesis	Relationship	β Values	t Value	R^2 (%)	Result
H3	Management Support→ Motivation to Learn→ Motivation to Perform Task	0.439	5.716	0.68	Supported

Note: Significant level t >1.65 (10%)

Hence, the effect size (f2) and predictive relevant (Q2) were evaluated. The results of effect size tests revealed that the value of f2 for management support was 0.102, which was greater than 0.02, signifying that it has a small effect on motivation to learn [Hair et al. 2017]. The value of f2 for motivation to learn was 0.398, which was higher than 0.35, signifying that is has a large effect on motivation to perform task [Hair et al. 2017]. The result of the predictive relevant test showed that the value of Q2 of motivation to learn was 0.308 and for motivation to perform a task is 0.433, which were greater than zero [Hair et al. 2017], signifying that the model has predictive relevance.

DISCUSSION AND IMPLICATIONS

The findings of this study show that motivation to learn acts as an effective mediating variable between management support and motivation to perform task. In the context of this study, leadership of the central government agencies have given more attention to implement training programs that expose current logistic business solutions (e.g., job implication, deregulation of unnecessary laws and use mobile-commerce in managing inventory and transportation) to upgrade the competencies of management and supporting staff in fulfilling citizen needs and assist logistic industry to enhance their performance in domestic and international trade. This achievement may lead to meet the grand national agenda, namely Vision 2020 [Mahathir 1991, 1997], and Government Transformation Program [Prime Minister Office].

In this study, the majority of respondents viewed that the levels of management support, motivation to learn and motivation to perform tasks as high. This situation explains that the capability of management to adequately provide emotional support and instrumental support in improving daily job operations will strongly invoke employees' motivation to learn. As a result, this motivation may lead to a greater motivation to perform task in the training models of the organizational sample. The study provides three important implications, namely theoretical contribution, robustness of research methodology and practical contribution. In term of theoretical contribution, the findings of this study are consistent with the principal meaning of Knowles's [1984] Adult Learning Theory, which reveal that the ability of management to provide adequate emotional aids (e.g., encouragement, concern, openness, motivation and care) and instrumental aids (e.g., delivery of information and opportunities, coordinate training process, allocate budgets, selection of location and physical convenience) will strongly invoke employees' motivation to learn new competencies (e.g., logistic methods and solutions). Consequently, this motivation may enhance employees' motivation to perform task (e.g., active in group works, facilitate co-workers to perform key performance indicators, provide aids to citizen and logistic industry). The principal meaning of the theory has received strong support from the research articles in training management research literature. For example, results from surveys by Ismail et al. [2016], Abdul Aziz [2016], Nadeem and Ahmad [2017] and Park et al. [2017] found that high level of management support (i.e., emotional and instrumental support) has increased trainees' motivation to learn in training programs. As a result, this situation may lead to a higher motivation to learn in the respective organizational settings.

With respect to the robustness of research methodology, the survey questionnaire used in this study has met the acceptable standards of validity and reliability analyses. This situation may assist in enhancing the accuracy and reliability of research outcomes.

Further, in terms of practical contribution, this study can be used as important guidelines by employers to improve training management in organizations. In order to support this aim, the organization needs to give more attention to this issue to ensure this goal can be achieved: First, training assessments should be done before, during and/or after training programs to identify the ability of employees in applying competencies in solving daily job operations. Second, training methods and content should be updated in line with the organizational strategic business vision and missions. Third, adequate financial, emotional and physical assistance should be provided to employees. Lastly, implementing content updates and training program delivery methods (for example, digital editing and attractive graphical displays) to enhance employee learning focus. If these suggestions are given more attention this may lead to accomplish the organizational strategies and goals.

CONCLUSION

This study evaluated the theoretical framework formulated based on logistic management literature. The measurement scale fulfilled the required criteria of validity and reliability analyses. The outcomes of

SmartPLS path analysis model indicate that motivation to learn does act as an important mediating variable between management support and motivation to perform task. This finding also has supported and broadened the role of motivation to learn in logistic management published in Western and Asian countries. The current research and practice need to incorporate motivation to learn as an essential factor in logistic training program domain. This study further suggests that the capability of management to adequately provide emotional support (i.e., supportive, guidance) and instrument support (i.e., financial, location, equipment) in the operation of logistic training programs will strongly inspire positive employee outcomes (e.g., satisfaction, commitment and ethical behaviour). Hence, this positive outcome may lead organizations to become a market winner based organization in times of globalization and unpredictable economic conditions.

LIMITATIONS AND FUTURE RESEARCH

Despite the contributions made, this study has several conceptual and methodological limitations. First, a cross section method restricts the researchers in assessing detailed causal relationship between intended variables in the sample data. Second, the relationship among the specific elements of independent variable, the mediating variable and the dependent variable are not assessed and this may restrict possible exploration on the issues under study. Third, a specific agencies in Malaysia was chosen for this study and the finding may be specific to this organization. Fourth, a purposive sampling technique used in this study is not able to control response bias in the sample data. The above limitations restrict the findings from being generalized to the other settings.

Despite the limitations as mentioned above, they should be used to guide improvement in future research. First, several important characteristics of the organization (e.g., types of services group, categories) and employees (e.g., age, education, position) should be explored as they may indirectly affect respondent's attitudes on the mediating effect of training programs in the hypothesized model. Second, a longitudinal study should be considered because it will show the effectiveness of a hypothesized model between subsamples with the sample data. This approach may explain in detail the patterns of change and the magnitude of causal relationship among the intended variables. Third, a comparison technique should be used to evaluate the effectiveness of mediating effect of training programs in the private sector to get better findings. Fourth, a larger sample size should be used to decrease response bias which may characterize the population under study. Fifth, other specific theoretical constructs of motivation, such as orientation to learn and intention training transfer should be considered because they have been widely recognized as important connections between management support and employee outcomes. Lastly, another dimension of management support such as respect and trust should be considered because their roles have been extensively acknowledged in training program literature. The significance of these factors needs to be further elaborated in future study.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

Research fund of the Faculty of Economics & Management, Universiti Kebangsaan Malaysia (FEP2020-001).

REFERENCES

Abdul Aziz S.F., 2016. Evaluating training effectiveness using the Malaysian sample: Tracing the mediation effect of training motivation using SEM-AMOS, International Journal of Economics and Financial, 6 (6): 94 -100.

Abdul Aziz S.F., Selamat M.N., 2016. Stimulating workplace learning through training characteristics and motivation to learn. Jurnal Pengurusan, 49: 173-185.

Abdulkarim S., Al-Eisa Musaed A., Furayyan Abdulla M., Alhemoud, 2009. An empirical examination of the effects of self-efficacy, supervisor support and motivation to learn on transfer intention, Management Decision, 47 (8): 1221-1244.

Al-Minhas U., Ndubisi N.O., Barrane F.Z., 2020. Corporate environmental management: A review and integration of green human resource management and green logistics. Management of Environmental Quality: An International Journal, 31 (2): 431-450

Amos K.J., Natamba B., 2015. The impact of training and development on job performance in Ugandan banking sector, Journal on Innovation and Sustainability 6 (2): 65-71.

Amabile T.M., 1983. Social psychology of creativity: a componential conceptualization. Journal of Personality and Social Psychology, 45: 997-101

Bolsche D., Klumpp M., Abidi H., 2013. Specific competencies in humanitarian logistics education. Journal of Humanitarian Logistics and Supply Chain Management, 3 (2): 99-128. http://doi.org/10.1108/JHLSCM-08-2012-0019

Bombiak E., Marciniuk-Kluska A., 2018. Green human resource management as a tool for the sustainable development of enterprises: polish young company experience. Sustainability, 10 (6): 1739. http://doi.org/10.3390/su10061739

Buics L., 2017. The role of logistics management in public services –research plan. International Journal of Engineering and Management Sciences, 2 (3): 33-43. http://doi.org/10.21791/IJEMS.2017.3.4.

Cohen J., 1992. A Power Primer, Psychological Bulletin, 112: 155-159. http://doi.org/10.1037//0033-2909.112.1.155

Council of Logistics Management, 2000. In: Swamidass P.M. (eds) Encyclopedia of Production and Manufacturing Management. Springer, Boston, MA.

Dansereau F.Jr., Graen G., Haga W.J., 1975. A vertical dyad linkage approach to leadership within formal organizations: A longitudinal investigation of the role making process. Organizational Behaviour and Human Performance, 13: 46 - 78. http://doi.org/10.1016/0030-5073(75)90005-7

Dermol V., Cater T., 2013. The influence of training and training transfer factors on organisational learning and performance. Personnel Review 42 (3): 324 - 348. http://doi.org/10.1108/00483481311320435

Diamantidis D. A., Chatzoglou P. D., 2014. Employee post-training behavior and performance: evaluating the results of the training process. International Journal of Training and Development, 18 (3):149-170. http://doi.org/10.1111/ijtd.12034

Eichhorn B. R., 2014. Common Method Variance Techniques. Paper AA11.

Forbes, 2019. [Online]. Available at: https://www.forbes.com/sites/tomtaulli/2018/06/09/how-to-create-an-effective-company-training-program/#4944be42224a. [Accessed 20 04 2010]

Govaerts N., Kyndt E., Dochy F., 2017. The influence of specific supervisor support types on transfer of training: examining the mediating effect of training retention. Vocations and Learning, 11(2): 265-288. http://doi.org/10.1007/s12186-017-9190-y

Hajjar S. T., Alkhanaizi M. S., 2018. Exploring the factors that affect employee training effectiveness: A Case Study in Bahrain, SAGE Open, 8(2). http://doi.org/10.1177/2158244018783033

Hai J.C., Nawi N.F., 2007. Principles of public administration: an introduction. Shah Alam, Selangor: Karisma Publications.

Hair J.F., Hult G.T.M., Ringle C.M., Sarstedt M., 2017. A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM), (2nd Ed.), Los Angeles: SAGE Publications Inc.

Harris R., Simons M., Bone J., 2000. More than meets the eye? Rethinking the role of workplace trainer, NCVER, Adelaide.

Howard M.C., Lee J., 2019. Pre-training interventions to counteract seductive details in virtual reality training programs. Human

Resource Development Quarterly, 1-17 http://doi.org/10.1002/hrdq.21378

Huchin T., 2001. Enterprise-Focused Management: Changing the Face of Project Management, London: Thomas Telford Publishing.

Iqbal Q., Hassan S.H., Akhtar S., Khan S., 2018. Employee's green behaviour for environmental sustainability: a case of banking sector in Pakistan. World Journal of Science, Technology and Sustainable Development, 15 (2): 118-130. http://doi.org/10.1108/WJSTSD-08-2017-0025

Issah M., 2018. Change Leadership: The role of emotional intelligence. SAGE Open, 8(3):1-6. http://doi:10.1177/2158244018800910

Ismail A., Mohd Zainol N. A., Ahmad N. N., 2016. Program pembangunan kepimpinan meningkatkan pemindahan latihan dalam tentera darat Malaysia: Kajian empirical. Jurnal Pengurusan, 46: 149 -161.

Jabbour C.J.C., de Sousa Jabbour A.B.L., 2016. Green human resource management and green supply chain management: linking two emerging agendas. Journal of Cleaner Production, 112: 1824-1833. http://doi.org/10.1016/j.jclepro.2015.01.052

Jehanzeb K., Basir N.A., 2013. Training and development program and its benefits to employee and organization: A conceptual study. European Journal of Business and Management, 5(2).

Karatza A., Papadopoulos G., Godsell J., 2020. Servitization and The Effect of Training on Service Delivery System Performance. Production and Operations Management.

Kherbacha O., Mocana M.L., 2016. The importance of logistics and supply chain management in the enhancement of Romanian SMEs. Procedia - Social and Behavioral Sciences, 221: 405-413.

Knowles M., 1984, Andragogy in Action, San Francisco: Jessey-Bass Publishers. http://doi.org/10.1111/poms.13165

Lee J.Y., Park S., Baker R., 2017. The moderating role of top management support on employees' attitudes in response to human resource development efforts. Journal of Management & Organization, 24: 369-387. http://doi.org/10.1017/jmo.2017.37

Locke E. A., Latham G. P., 1991. A Theory of Goal Setting and Task Performance, Englewood Cliffs, NJ: Prentice Hall.

Lomand T. C., 2016. Social Science Research: A Cross Section of Journal Articles for Discussion and Evaluation, 7th Ed, New York:Routledge. http://doi.org/10.4324/9781315265841

Madagamage G. T., Warnakulasooriya B. N. F., Wickramasuriya H. V. A., 2014. Factors influencing motivation to transfer training: an empirical study of a government sector training program in Sri Lanka. Tropical Agricultural Research, 26(1):12-25. http://doi.org/10.4038/tar.v26i1.8068

Mahathir M., 1991. The way forward, working paper presented at the Ingaural Meeting of the Malaysian Business Council. Kuala Lumpur: Malaysian Business Council.

Mahathir M., 1997. Vision 2020: The way forward, keynote address at the Vision 2020 National Congress, Petaling Jaya, Kuala Lumpur. Prime Minister's Department.

Meyer D. K., Turner J. C., 2002. Discovering emotion in classroom motivation research, Educational Psychologist, 37, 107-114. http://doi.org/10.1207/S15326985EP3702_5

McCoy J. M., Evans G. W., 2005. Physical work environment. In: J. Barling, E., K,

Morelli S.A., Lee I.A., Arnn M.E., Zaki J., 2015. Emotional and instrumental support provision interact to predict well-being. Emotion, 15(4): 484–493. http://doi.org/10.1037/emo0000084

Nadeem K., Ahmad A. 2017. Impact of work environment factors on employee performance; Empirical evidence from manufacturing industry of Lahore. Journal of Managerial Science, 11: 422-436.

Olumuyiwa O.S., Adelaja A.S., Oluwatosin O.A., 2012. Motivation an engine for organizational performance, A case study of Lagos State University. Journal of Business and Management, 6(2): 30-41.

Ospina S., El Hadidy W., Caicedo G., 2011. Advancing Diversity and Inclusion in Public Service: A Review of Leadership Development Programs in the US.

Park S., Kang H.S., Kim E.J., 2018. Does supervisor support make a difference in employees' training and job performance? An empirical study of a professional development program. European Journal of Training and Development, 1-29. http://doi.org/10.1108/EJTD-06-2017-0054

PLS Logistics Services, 2020. Logistics management best practices all for superior customer service, 1-15. https://www.logisticsmgmt.com/wp_content/pls_wp_best_practices_092915.pdf [Accessed 03 05 2020]

Podsakoff P.M., Ahearne M., MacKenzie S.B., 1997. Organizational citizenship behavior and the quantity and quality of work group performance. Journal of Applied Psychology, 82(2): 262-270. http://doi.org/10.1037/0021-9010.82.2.262

Podsakoff P.M., Mackenzie S.B., Lee J.Y., Podsakoff N.P., 2003. Common Method Biases in Behavioral Research. A Critical Review of the Literature and Recommended Remedies. Journal of Applied Psychology, 88(5): 879-903. http://doi.org/10.1037/0021-9010.88.5.879

Prime Minister Office. "GTP". Prime Minister Office of Malaysia. [Retrieved 06 04 2020].

Reinhold S., Gegenfurtner A., Lewalter D., 2018. Social support and motivation to transfer as predictors of training transfer: Testing full and partial mediation using meta-analytic structural equation modelling. International Journal of Training and Development, 22(1):1-14. http://doi.org/10.1111/ijtd.12115

Ristovska1 N., Kozuharov S., Petkovski V., 2017. The Impact of Logistics Management Practices on Company's Performance. International Journal of Academic Research in Accounting, Finance and Management Sciences, 7 (1): 245–252.

Rivera L., Gligor D., Sheffi Y., 2016. The benefits of logistics clustering. International Journal of Physical Distribution & Logistics Management, 46 (3): 242-268.

Roblek V., Erenda I., Meško M., 2018. The Challenges of Sustainable Business Development, In Thepost-Industrial Society in the First Half of the 21st Century. In Managerial Strategies for Business Sustainability during Turbulent Times, IGI Global, 1-194. http://doi.org/10.4018/978-1-5225-2716-9.ch001

Rosena M.A., Harlina Suzana J., Sabariah M., 2008. Logistics and Supply Chain in Malaysia: Issues and Challenges. EASTS International Symposium on Sustainable Transportation incorporating Malaysian Universities Transport Research Forum Conference 2008 (MUTRFC08). Universiti Teknologi Malaysia. 12-13 August 2008.

Saks A.M., Belcourt M., 2006. An investigation of training activities and transfer of training in organizations. Human Resource Management, 45(4): 629–648. http://doi.org/10.1002/hrm.20135

Schindler L.A, Bukholders G.J., 2014. A mixed methods examination of the influence of dimensions of support on training transfer. Journal of Mixed Methods Research, 10(3): 1-19. http://doi.org/10.1177/1558689814557132

Schwab K., 2017. The Fourth Industrial Revolution, New York: Crown Business.

Sekaran U., Bougie R., 2016. Research Methods for Business: A Skill Building Approach (7th ed), United Kingdom: John Wiley & Sons, Inc.

Ślusarczyk B., 2018. Industry 4.0- Are We Ready?. Polish Journal of Management Studies, 17(1): 232-248.

Soon N.K., Ahmad N., 2012. Impact of motivation to learn on perceived training transfer: Empirical evidence from a bank. Proceedings International Conference of Technology Management, Business and Entrepreneurship.

Syed Ibrahim, 2007. Malaysia Kita. Panduan dan Rujukan untuk Peperiksaan Am Kerajaan. International Law Book Services.

Tajuddin Hussien, 2009. Malaysia negara kita. Kuala Lumpu, Malaysia: MDC Publishers.

The Ministry of Transport Malaysia, 2016. Logistics and trade facilitation masterplan: Performance report 2016. http://www.mot.gov.my/SiteCollectionDocuments/logistik/Logistics%20and%20Trade%20Facilitation%20Masterplan%20Performance%20Report%202016.pdf [Accessed 07 05 2020].

The Public Service Department, 2019. [Online] Available at: https://www.jpa.gov.my/ [Accessed at 20 04 2019]

Wang D.F., Dong Q.L., Peng Z.M., Khan S.A.R., Tarasov A., 2018. The green logistics impact on international trade: evidence from developed and developing countries. Sustainability, 10: 2235. http://doi.org/10.3390/su10072235

Zuraimi A. A., Mohd Rafi Y., Dahlan M., 2013. An Initial Study of Logistics Development in Malaysia East Coast Region. World Review of Business Research, 3 (3): 81 – 95.

ZALEŻNOŚĆ POMIĘDZY WSPOMAGANIEM ZARZĄDZANIA W PROGRAMCH SZKOLENIOWYCH I MOTYWACJĄ REALIZACJI ZADAŃ Z MOTYWACJĄ DO NAUKI JAKO MEDIATOREM

STRESZCZENIE. **Wstęp:** Aktualnie publikowane prace wskazują na współpracę organizacji komercyjnych i publicznych w obszarze ustalenia narodowej polityki wymagań dla rozwoju narodowego. W tym celu, przywódcy sektora publicznego zaplanowano wali i wdrożyli programy szkoleniowe dotyczące strategii zarządzania logistycznego oraz operacyjnego dl pracodawców. Ostatnie badania naukowe dotyczące zarządzania logistycznego pokazują, że wśród pracodawców powstała silna motywacja nauki kreatywnych metod logistycznych. W rezultacie tej motywacji, wzrosła też motywacja do realizacji zadań. Jest to ciekawa zależność, aczkolwiek rola motywacji w nauce, jako istotnej zmiennej mediującej jest najczęściej pomijana w literaturze dotyczącej zarządzania logistycznego. Sytuacja ta spowodowała potrzebę zbadania efektu mediacyjnego motywacji do nauki w relacji pomiędzy wspomaganiem zarządzania w programach szkoleniowych i motywacją do realizacji zadań.

Metody: Dane zebrano na podstawie przeprowadzonej ankiety wśród pracodawców w centralnych agencjach rządowych będących pod kontrolą malezyjskiego rządu federalnego. SmartPLS został użyty do mierzenia właściwości psychometrycznych oraz do testowania postawionych hipotez.

Wyniki: Uzyskane wyniki wskazują, że motywacja do nauki jest istotnych mediatorem zależności pomiędzy wspomaganiem zarządzania w programach szkoleniowych i motywacją do realizacji zadań.

Wnioski: Efekt mediacyjny motywacji do nauki pomiędzy wspomaganiem zarządzania w programach szkoleniowych i motywacją do realizacji zadań jest spójny i wzbogaca wcześniejsze badania dotyczące zarządzania logistycznego publikowane w krajach zachodnich i azjatyckich.

Słowa kluczowe: wspomaganie zarządzaniem, motywacja do nauki, motywacja do realizacji zadań, SmartPLS

Nur Izzaty Mohamad
Institute of Islam Hadhari
Universiti Kebangsaan Malaysia, Bangi,, **Malaysia**
e-mail: nurizzaty_mohamad@yahoo.com

Azman Ismail, ORCID ID: https://orcid.org/0000-0003-2802-711X
Faculty of Economics & Management
Universiti Kebangsaan Malaysia, Bangi, **Malaysia**
e-mail: azisma12@ukm.edu.my

Azmawaty Mohamad Nor
Faculty of Education
University of Malaya, Kuala Lumpur, **Malaysia**
e-mail: azy_mn@um.edu.my

LogForum

> Scientific Journal of Logistics <

2020, 16 (3), 447-463

http://doi.org/10.17270/J.LOG.2020.473

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

COMPILING THE STRATEGIES OF ALFA MINING COMPANY AND PRIORITIZING THEM BY WASPAS METHOD

Seyed Moslem Seyed Mirzaee, Seyed Heydar Mirfakhredini, Alireza Nasser Sadrabadi, Ali Morovati Sharifabadi

Yazd University, Yazd, **Iran**

ABSTRACT. **Background:** Nowadays mining companies, as non-profit organizations like other organizations, face a complex and turbulent environment. The proper guidance of the organizations depends on understanding the internal and external environment and making smart strategic decisions. Therefore, to deal effectively with all the factors that affect the ability of the company in its profitable growth, because organizations need compiling strategic planning to increase their capabilities, long-term growth and survival and to reduce operational risk, organizations have turned to strategic planning in particular. After compiling strategies, determining the priority of strategies is very important. The statistical population of this research has consisted of 50 heads of operational and support affairs units [to determine internal factors] along with 10 managers and deputies [to determine external factors]. In this research, strategies were first identified via the Strengths, Weaknesses, Opportunities, and Threats [SWOT] matrix and then ranked by the Weighted Aggregates Sum Product Assessment [WASPAS] method.

Materials and methods: In addition to the QSPM approach, multi-indicator decision-making models can also be used to prioritize strategies. Nowadays, as multi-indicator decision-making related topics are intensified and on the other hand, the increasing tendency towards interdisciplinary sciences and the use of theories of various groups and specialties in solving complex problems, the necessity to pay attention to decision-making analysis techniques and exploiting them in solving existing complex problems is of great importance. In these models, selecting one option among the available options is considered. In a general definition, multi-indicator decision making refers to specific [preferential type] decisions, such as evaluating, prioritizing, or selecting among the available options [which sometimes should be done among several contrasting indicators]. Some multi-indicator decision-making models are: AHP, ANP, ELECTRE, VICTOR, TOPSIS, SAW, GRA, SIR, PROMETHEE and WASPAS. In this article, the WASPAS method has been used to determine the prioritization of strategies.

Results: In this research, strategies were first identified via the Strengths, Weaknesses, Opportunities, and Threats [SWOT] matrix and then ranked by the Weighted Aggregates Sum Product Assessment [WASPAS] method. Ultimately, the strategies of "assigning a part of the sale to individuals or qualified private companies", "creating the Technology Transfer Office [TTO] in order to move towards self-sufficiency", and "comprehensive planning in the field of human resources in order to create an effective and efficient culture" were selected as strategic priorities for the Alpha Mining Company.

Conclusions: Various approaches have already been proposed to prioritize strategies; in this research, the criteria have been specified using the ACCEPT approach and finally by the WASPAS method, the strategies have been prioritized. The ACCEPT method unlike the QSPM method, which prioritized strategies by taking into account strengths and weaknesses, opportunities and threats, regardless of environmental conditions and existing organizational status and externally by considering 6 main parameters of strategy evaluation including cost, time, popularity, effective, and so on, helps to prioritize strategies. In this research, it was tried to use one of the techniques of MADM according to relevant and important criteria to enhance the assurance coefficient of managers' decision making. Multi-criteria decision-making techniques have this advantage that they evaluate various options according to various criteria that do not have equal units. Another important advantage of multi-criteria decision-making techniques is that they are capable of analyzing quantitative and qualitative criteria simultaneously.

Key words: SWOT Matrix, Strategic Planning, WASPAS, ACCEPT.

Citation: *Seyed Mirzaee S.M., Mirfakhredini S.H., Nasser Sadrabadi A., Morovati Sharifabadi A., 2020. Compiling the Strategies of Alfa Mining Company and Prioritizing them by WASPAS Method. LogForum 16 (3), 447-463, http://doi.org/10.17270/J.LOG.2020.473*

Received: 06.04.2020, Accepted: 28.05.2020, on-line: 30.06.2020.

INTRODUCTION

Nowadays, strategic planning, as one of the most efficient management approaches in organizations, has been considered by experts and planners. In today's complex and varied world, strategic planning and management is a way to help organizations and communities to face with rapid environmental changes. In fact, comprehensive planning is an effective measure against the competitive and changing world because it considers the internal and external facilities and constraints of the organization and makes its forecasts according to them. Strategic planning is a structured effort to take fundamental decisions and to perform actions that shape and enable the nature of the organization, the type of activities, and the reasons for doing those activities by the organization. In general, strategic planning provides this possibility for the organization to know where it will go in the next one to three years and how it can get there [Movahedi et al., 2012]. Strategic planning has always been promising transformation and success since its inception in the 1960s to the present. During this period, prominent thinkers and philosophers have developed the concepts and foundations of this field; and as a result of their efforts, the concepts and tools of strategic planning have greatly been evolved. By analyzing an organization's capabilities, weaknesses, opportunities, and threats, factors that may affect the future outcomes of the organization or institution are identified. The patterns of capabilities, weaknesses, opportunities, and threats to identify the unique competencies of the organization are considered as the fundamental factors of the success of the organization, and the purpose of analyzing these factors is to provide strategies that guarantee a balance between the external environment and the internal status [Lerner, 1999].

Managers are turning to strategic planning in order to deal effectively with all the factors that affect the company's ability in its profitable growth. Many quantitative tools and techniques have already been used in the field of strategic management, that since the major component in this field is decision-making regarding the concurrent multiple considerations, so multi-criteria decision-making techniques have allocated the highest ratio of use to themselves. In this respect SWOT analysis is one of the tools used in the strategy compilation stage to analyze internal and external strategic cases that can summarize the most important internal and external factors that can influence an organization's future. This matrix is one of the important tools whereby the managers compare information and using it can present four types of strategies: SO or offensive strategies, WO or conservative strategies, ST or competitive strategies, and WT or defensive strategies [David, 2009]. In fact, strategic planning is the process of determining the organization goals and taking a decision about comprehensive operational and executive plans to realize those goals. Strategic planning in organizations typically includes the stages such as: assessing the current environment, defining the mission of the organization, determining the organization's vision, recognizing the capabilities, weaknesses, opportunities, and threats of the organization and planning to move the organization or institution from current situation to desirable status periodically [Policastro, 2000].

SWOT analysis is to find a strategy or strategic balance between opportunities [external] and strengths [internal] with respect to threats [external] and weaknesses [internal], in order to remove them; the following factors summarize the strategic factors of a company: Strengths, Weaknesses, Opportunities, and Threats [Arabi, Parsaian, 2019]. The first step in the strategic planning is to determine the mission, goals, and assignments of the organization, then, a strategy can be designed for the organization that is appropriate to its environment through SWOT analysis, that is one of the strategy compilation tools [Pierce and Robinson, 2000]. This matrix shows how to create a balance between external and internal factors. In fact, by shaping a quadratic matrix, it compiles four different types of strategies depending on a pair of internal and external factors [Hanger, Violin 2002].

Generally, this matrix links internal and external factors together and uses it as a basis for possible strategies [Movahedi et al., 2012]. In the Alpha Mining Company, considered as the case study in this research, it can be hoped that strategic planning, by determining the strategic and overall goals of the organization is identified, and by the optimized use of organizational resources enhances the objectives. Strategic planning will lead to the recognition of the strategic position of the organization, the identification of strategies and the selection of proper strategies based on priorities. Therefore, the main purpose of this research is to compile strategies and prioritize them by the WASPAS method for the Alpha Mining Company. In Table 1 some of the important conducted domestic and foreign researches have been presented.

Table 1. Previous Domestic and Foreign Researches

Research Title	Year	Authors
Exploring competitive priorities in the service sector: evidence from India	2019	Idris, F. and Naqshbandi, M.M.
Using the ANP Method to Prioritize Rural Development Strategies with the LEADER Approach in Protected Areas	2019	Fernandez Portillo et al.
Selection of effective risk mitigation strategies in container shipping operations	2019	Chang, C.H., Xu, J., Dong, J. and Yang, Z.
Prioritizing E-Government Strategies Using the Ranked Voting of SWOT Analysis Technique: Case study: Jordan	2017	Yousef Elsheikh, Mohammad Azzeh
Prioritizing Strategies in EMS Systems	2017	Bandara et al.
Application of TOPSIS and Fuzzy Intuitive Set Approaches to Rank Lifecycle Sustainability Efficiency in Alternative Vehicles Technology	2016	Onat et al.
Hydrogen Economy In China: Strengths, Weaknesses, Opportunities, and Threats Analysis and Prioritizing Strategies; Scipers	2015	Ren et al.
Environmental and Social Sustainability Priorities: Integrating Them into Operational Strategies	2015	Annachiara Longoni, Raffaella Cagliano
Prioritizing Stakeholders, Corporate Strategic Social Responsibility and Corporate Performance: Further Evidences	2014	Giacomo Boesso, Francesco Favotto, Giovanna Michelon
Direct shipping across the Taiwan strait: flag selections and policy issues	2013	Yang, S.H. and Chung, C.C.
Operations strategy and business strategy alignment model (case of Iranian industries)	2013	Khalili Shavarini, S., Salimian, H., Nazemi, J. and Alborzi, M.

By examining the above research, and by examining the research literature, it is possible to clearly accept the use of the QSPM method as the dominant and superior method for prioritizing strategies. But using this method, like other MCDM methods, has its drawbacks. For example, in the QSPM method, when weighing strategies according to SWOTs, the quality of the results can be reduced by the accuracy of the experts due to the multiplicity of SWOTs. On the other hand, in this method, only strategies based on SWOTs are prioritized. While other factors of strategy prioritization, including factors: cost, time, complexity, etc. are not considered. Therefore, in this study, one of the new methods of MCDM called WASPAS for prioritization of strategies has been studied.

RESEARCH METHODOLOGY

The orientation of this research is among applied researches as it is used for all large companies that it is in respect of applying its results to solve the problem ahead, namely compiling strategies along with prioritizing them. The present research is done by the inductive approach. In a way that, in investigating the existing research literature and models, the identification of the internal and external factors classes has been done by the inductive approach of the previous models, that are referred below. This research is qualitative in respect of type. Therefore, in the first stage of the research, by the qualitative research method such as meeting, interview and completing forms by internal and external experts, it is necessary to specify external and internal factors. In conducting this research to compile the strategies of the Alpha Mining

Company using SWOT, at first the strengths and weaknesses of the company were determined by interviewing with the heads of affairs and then the threats and opportunities were extracted by interviewing the manager and the deputies. Then, in the article, the heads of units are called internal experts, and the managers and deputies of the company are called external experts. The internal and external factors are identified in a single internal form by internal experts and in a single external form by external experts of the company, and those factors were scored and the internal and external factors evaluation matrix was prepared. The SWOT matrix was then drawn and with the help of this matrix, appropriate strategies for the Alpha Mining Company were obtained. The criteria of the ACCEPT method were used as the criteria of the WASPAS method. The criteria were weighted using the Shannon Entropy method. Finally, prioritizing the selected strategies was done using the Weighted Aggregates Sum Product Assessment [WASPAS] method. The statistical population of this research has been 60 persons including 50 heads of operational and support units [for determining internal factors] along with 10 managers and deputies [for determining external factors].

Methods for Prioritizing Strategies

In addition to the QSPM approach, multi-indicator decision-making models can also be used to prioritize strategies. Nowadays, as multi-indicator decision-making related topics are intensified and on the other hand, the increasing tendency towards interdisciplinary sciences and the use of theories of various groups and specialties in solving complex problems, the necessity to pay attention to decision-making analysis techniques and exploiting them in solving existing complex problems is of great importance [Moradi, Akhtarkavan, 2009]. In these models, selecting one option among the available options is considered. In a general definition, multi-indicator decision making refers to specific [preferential type] decisions, such as evaluating, prioritizing, or selecting among the available options [which sometimes should be done among several contrasting indicators]. Some multi-indicator decision-making models are: AHP (Analytic Hierarchy Process), ANP (Analytic Network Process), ELECTRE (Elimination et Choice in Translating to Reality), VICTOR (VIsekriterijumsko KOmpromisno Rangiranje), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), SAW (Simple Additive Weighted), GRA (Grey Relational Analysis), SIR (Superiority and Inferiority Ranking), PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations), WASPAS.

In this article, the WASPAS method has been used to determine the prioritization of strategies.

Weighted Aggregates Sum Product Assessment [WASPAS] Method

The world around us is full of multi-criteria decision-making issues, and humans are always forced to make decisions in these areas; macro decision makings in which various goals are pursued and we wish these goals to be optimal. In some cases, the decision-making result is so important that the emergence of error may impose irreparable losses, hence using the proper method for optimal selection and accurate decision-making is essential.

WASPAS is one of the new decision-making techniques. This model was introduced by Zavadskas in 2012, and it is recognized as one of the MCDM methods. This method is a combination of the Weighted Sum Model [WSM] and the Weighted Product Model [WPM]. Each MCDM problem starts with a decision matrix, in which m is the number of candidate options and n is the number of evaluation indicators.

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}$$

At this stage, regarding the index type [positive or negative] the following formulas [linear soft] are used for normalization:

For positive and negative indices the following formulas are used:

[Positive index] $\overline{x_{ij}} = \frac{x_{ij}}{Max_i x_{ij}}$ [1]

[Negative index] $\overline{x_{ij}} = \frac{Min_i x_{ij}}{x_{ij}}$ [2]

In the WASPAS method, a common optimization index based on the two optimization indices is used. The first optimization index like weight success mean is similar to the WSM method. Based on the WSM method, the relative importance of the whole option-i is calculated according to the following formula:

$$Q_i^{[1]} = \sum_{j=1}^{n} \bar{x}_{ij} w_j \quad [3]$$

On the other hand, according to the WPM method, the relative importance of the whole option i is calculated based on the following formula:

$$Q_i^{[2]} = \prod_{j=1}^{n} [\bar{x}_{ij}]^{w_j} \quad [4]$$

In which w_j is the relative importance of the index j.

The common index created by the integration of weighting mass and multiplication methods is suggested as follows:

$$Q_i = 0.5Q_i^{[1]} + 0.5Q_i^{[2]} = 0.5\left[\sum_{j=1}^{n} \bar{x}_{ij} w_j + \prod_{j=1}^{n} [\bar{x}_{ij}]^{w_j}\right] \quad [5]$$

In order to increase the accuracy and effectiveness of the decision-making process in the WASPAS method, a general equation to determine the relative importance of the whole option i has been expanded as follows:

$$Q_i = \lambda Q_i^{[1]} + (1-\lambda) Q_i^{(2)} = \lambda \sum_{j=1}^{n} \bar{x}_{ij} w_j + (1-\lambda) \prod_{j=1}^{n} [\bar{x}_{ij}]^{w_j} \ ; \ \lambda = 0, 0.1, \dots, 1 \quad [6]$$

When the value of λ is zero, the WASPAS technique will be converted to the WPM technique, and when it is equal to 1, we will have the WSM technique. If there is no particular idea for λ, λ = 0.5 will be considered. In this article based on λ = 0.5, the corresponding calculations have been performed.

Shannon Entropy Weighting Method

The Entropy method is one of the multi-criteria decision-making methods for calculating the weight of the criteria. In this method, the criteria-option matrix is required. This method was proposed by Shannon and Weaver in 1974. The Entropy expresses the value of uncertainty in a continuous probability distribution. The main idea of this method is that the higher the dispersion in the values of an index is, that index has more importance. Shannon showed that events with a high probability of occurrence provide less information, and on the contrary, the lower the occurrence probability of an event is, the information obtained from it will be higher. By acquiring new information, uncertainties actually decrease and the value of new information equals the value that has been reduced from uncertainty. Consequently, uncertainty and information are interdependent parameters. Entropy is a very important concept in the social, physical sciences and information theory. The idea of the above method is that the higher the dispersion in the values of an index is, that index is more important [Soleimani Damaneh et al., 2011]. Entropy in information theory is a criterion of uncertainty expressed by the specified probability distribution. Shannon entropy method has been used in this article to weight the criteria. Entropy in information theory is a criterion of uncertainty expressed by the specified probability distribution P_i. Measurement of this uncertainty [E_i] by Shannon has been expressed as follows:

$$E_i = S(P_1, P_2, \dots, P_n) = -k \sum_{i=1}^{n} [P_i - Ln \ p_i] \quad [7]$$

k is a constant value and is applied in the order that the E_i is between zero and one. E is calculated from the probability distribution of P_i based on the statistical mechanism, and its value in case of equality of P_i with each other [that is $P_i = \frac{1}{n}$], will be the maximum possible value that is calculated as follows:

$$-k\sum_{i=1}^{n} P_i - Ln P_i = -k\left\{\frac{1}{n}Ln\frac{1}{n} + \frac{1}{n}Ln\frac{1}{n} + \dots + \frac{1}{n}Ln\frac{1}{n}\right\} = -k\left\{Ln\frac{1}{n}\left(\frac{n}{n}\right)\right\} = -k \times Ln\frac{1}{n} \quad [8]$$

k as a constant value is calculated as follows:

$$k = \frac{1}{Ln(m)} \quad [9]$$

The "Decision-Making Matrix" contains information that entropy can be used as a criterion for evaluating it. Suppose that the decision making-matrix is as follows.

Table 2. Decision-Making Matrix

Index / Options	C_1	C_2	……	C_n
N_1	a_{11}	a_{21}	….	a_{1n}
N_2	a_{21}	a_{22}	….	a_{2n}
…	…	…	…	…
N_m	a_{m1}	am2		amn
W_j	W_1	W_2	…..	W_n

Using this matrix, P_{ij} is calculated as follows:

$$P_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}} \; ; \forall_{i,j} \quad [10]$$

And the Entropy of the j-index $[E_j]$ is calculated as follows:

$$E_j = -k \sum_{i=1}^{m} [P_{ij} \; Ln \; P_{ij}] \; ; \forall_j \quad [11]$$

The uncertainty or degree of deviation $[d_j]$ from the information obtained for the index j indicates how much useful information the relevant index [j] provides to the decision-maker for decision-making. The value $[d_j[$ is obtained as follows:

$$d_j = 1 - E_j \quad ; \quad \forall_j \quad [12]$$

Then the weight value w_j is obtained as follows:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad ; \quad \forall_j \quad [13]$$

RESEARCH FINDINGS

In this section, the research findings and results have been investigated briefly. Since the main purpose of this research is to prioritize strategies and compare prioritization methods; therefore, in order to avoid content prolongation, no description of strategic planning is stated and only the SWOT matrix has been presented and then the priority of using strategies by the WASPAS technique has been specified.

Matrix of Strengths and Weaknesses, Opportunities and Threats of the Alpha Mining Company

To prepare the SWOT matrix, the strengths, weaknesses, opportunities, and threats of the company should be mentioned in the SWOT matrix houses, and then by comparing these factors with each other, the strategies of WT, ST, WO, SO should be stated.

First Step: Identifying Internal Factors by Internal Experts

For a detailed analysis of SWOT, the raw form of strength and weakness was sent to the head of affairs [Internal Experts] of the Alpha Mining Company. The heads of affairs include middle managers of the company who have an acceptable dominance on internal organizational issues. To prevent the dispersion of opinions, the raw form is set into eight categories of "Manpower", "Equipments", "Management System", "Information Flow", "Goals", "Values and Beliefs", "Access to Resources" and "Structure and Organization" regarding various strategy models, such as the" Pigels & Roger" and "Branson & Freeman" strategy models as well as regarding the subject literature.

Having collected the completed forms of the weaknesses of affairs, they were also carefully investigated. The irrelevant, unimportant, and repeated cases were eliminated. The results, obtained from integration and refinement of the forms of weaknesses related to the affairs, have been presented in Table 4.

Table 3. Aggregated Table of Strengths Derived from Internal Experts' Viewpoint

Class	Dimensions to be Investigated	Strengths-S
1.	Manpower	1. High level of education [S1] 2. Having high experiences [S2] 3. Trainable forces [S3]
2.	Equipment	4. Reparability of previously installed pieces of equipment [S4]
3.	Information Flow	5. Simplicity and ease of using automation [S5] 6. Appropriate and Acceptable Access to Information [S6]
4.	Management	7. Using knowledge specialists to remove process defects [S7] 8. Holding Seminar Meetings [S8]
5.	Status of Goals	9. Continuous monitoring of purposes [S9]
6.	Values and Beliefs	10. Ability to do seemingly impossible works [S10]
7.	Access to Resources	11. Possibility of using laboratories outside the company for doing analyses [S11] 12. Access to abundant financial resources [S12]
8.	Structure and Organization	13. Existence of research units per production unit [S13]

Table 4. Weaknesses Taken from Internal Experts' Viewpoint

Class	Dimensions to Be Investigated	Weaknesses-W
1.	Manpower	1. Lack of proper planning for the allocation of forces [W1] 2. Lack of sufficient motivation and commitment [W2] 3. Lack of repair force in the mine [W3] 4. Existence of high expectations [W4] 5. Merely native selection [W5] 6. Existence of discrimination in a promotion [W6]
2.	Equipment	7. High energy consumption due to outdated technology [W7] 8. The burnout of the major part of loading and road construction machines and high cost of repairs [W8] 9. Lack of access to technologies tailored to the needs ahead [W9]
3.	Information Flow	10. Elimination of people's knowledge and experience after retirement [W10]
4.	Management	11. Management instability [W11] 12. Lack of meritocracy outlook [W12] 13. Insufficient motivational mechanisms and systems [W13]
5.	Status of Goals	14. Ignoring realities in compiling the goals [W14] 15. Involvement of other units in contradiction with the realization of the goals [W15]
6.	Values and Beliefs	16. Preference of personal interests over the corporation ones [W16]
7.	Access to Resources	17. Existence of a great deal of slowdown in the preparation of parts [W17]
8.	Structure and Organization	18. Mismatch of the description of duties with the position of individuals [W18]
9.	Others	19. Reduction of sales unit efficiency under sanction conditions [W19]

Second Step: Identifying External Factors by External Experts

In order to analyze the external factors [threat and opportunity] with regard to its nature, it was tried to use relevant and informed individuals in its investigation. Therefore, senior managers of the company, including managers and deputies [external experts], were used to complete the external factors forms. The PESTLE model and 5 Porter's competitive forces were used to explain the dimensions of external factors. The PESTEL model is investigated to describe the macro-environmental factors affecting a business. As a part of the strategic analysis technique, the PESTEL model is used in various sectors [Yoksel, 2012]. This model can be used to understand the macro image of the environment of businesses, industries, and countries. The components of this model include political, economic, social, technological, environmental, and legal factors. Porter's Competitive Forces, known as the Five Competitive Forces, have been proposed by Michael Porter [1947] and include suppliers, customers, alternative products, competitors in the industry, and potential competitors. Using these two models and investigating the subject literature in relation to external factors, 11 categories related to external factors can be used to fully cover external factors. These 11 categories include "Economy and Politics", "Cultural and Social", "Laws and Regulations", "Environment", "Technology", "Physical", "Suppliers", "Customers", "Alternative Products", "Competitors in the Industry" and "Potential Competitors". In Table 5 the identified threats obtained from collecting external experts' opinions have been presented.

The completed forms of opportunities were also carefully investigated after being collected. Irrelevant, unimportant, and repeated cases were eliminated. The results, obtained from the integration and refinement of the relevant forms have been presented in Table 6.

Table 5. Identified Threats from Collecting External Experts' Opinions

Class	Dimensions to Be Investigated	Threats-T
1.	Economic and Political Area	1. Emergence of many problems in the field of money transfer [t1] 2. The instability of the country's political and economic conditions [T2]
2.	Cultural and Social Areas	3. High unemployment rate in the adjacent areas of the factory [T3] 4. Exit of elite and capable forces from the country [T4]
3.	Area of Existing Laws and Regulations	5. Increasing the stringency of governmental organizations in the field of licenses [Natural Resources, Environment, Industries, and Mines Organization, and so on] [T5] 6. Bureaucracy and redundant rules for the clearance of required products and equipment [T6]
4.	Environmental Areas Such as Water, Air, Energy	7. The existence of a water crisis in the country and the continuation of droughts, thereby the possibility of the reduction of available water resources of the company in the future [T7] 8. Existence of pollutions despite establishing an acid factory due to the lack of continuity in acid production [T8]
5.	Technological Area	9. Unable to keep up with modern technologies due to the sanctions [T9] 10. Transferring technology incompletely [T10]
6.	Physical Area Such as Geography	11. Reduction of cutie in mines [T11]
7.	In the Area of Suppliers	12. Existence of some unique manufacturers and very high prices for parts [T12] 13. Continuous change in supplier companies [T13]
8.	In the Area of Customers	14. Loss of customers due to international applied restrictions [T14]
9.	In the Area of Competitors in the Industry	15. The reduction of the full price of the products of foreign competing companies regarding the new technologies [T15]
10	In the Area of Potential Competitors	16. Existence of various mines in Afghanistan and exploiting them in the near future [T16]

Table 6. Opportunities Identified from Collecting the Opinions of External Experts Council

Class	Dimensions to Be Investigated	Opportunities-O
1.	Economic and Political Areas	1. The price rise of base metals and their good prospects [O1]
2.	Cultural and Social Areas	2. Availability of skilled workforce [O2]
3.	Area of Existing Laws and Regulations	3. Making use of state monopoly conditions [O3] 4. Granting government credits for pollution reduction projects [O4]
4.	Environmental Areas Such as Water, Air, Energy	5. Existence of cheap energy in an industry sector [O5]
5.	Technological Area	6. Existence of new technologies for using low cutie mines [O6] 7. Emergence of new and efficient technologies in the fields of exploitation in terms of energy consumption and environmental impacts [O7] 8. Existence of highly creative and knowledge-based individuals and companies in the region as well as science and technology parks [O8]
6.	Physical Area Such as Geography	9. Having abundant mineral reserves [O9]
7.	In the Area of Suppliers	10. Existence of domestic and even indigenous suppliers to supply a large part of equipment [O10]
8.	In the Area of Customers	11. Development of downstream industries [O11]
9.	In the Area of Potential Competitors	12. Neighboring countries' need for geological knowledge, exploration, and production [O12]

Extracting Strategies Regarding the Strengths, Weaknesses, Threat, and Opportunity

In conducting this research, after collecting opinions regarding the strengths, weaknesses, opportunities, and threats of the mining company and receiving opinions from experts in the field of strategic planning, these cases were categorized. Finally, the most important cases in each of the internal and external factors were listed. Afterwards, considering the internal and external factors, the SWOT analysis matrix was extracted and after investigating the internal strengths and weaknesses as well as external opportunities and threats, strategies were compiled in four dimensions of the SWOT matrix. Classification of strategy types according to the SWOT matrix is as follows [Karimi and Mahboobfar, 2012]:

Offensive Strategies [SO] [Strength, Opportunity]

It indicates that the organization is in the best possible performance conditions and can utilize its strengths, to exploit the maxim use of its opportunities and to eliminate weaknesses and to prevent external threats too, and in such circumstances strategies such as concentration, diversity, integrity and other cases are adopted

Conservative Strategies [WO] [Weakness, Opportunity]

In this strategy, the organization while maintaining key strengths has to avoid being located in high-risk conditions; in such circumstances, strategies like productivity, service enhancement, and other cases are used.

Competitive Strategies [ST] [Strength, Threat]

It indicates that an organization while maintaining its strengths must use integrated and combined strategies such as market penetration, product development, services development, and creating organizational partnerships, and so on.

Defensive Strategies [WT] [Weakness, Threat]

In this strategy, the organization must remove its weaknesses and prevent external threats too. Defensive strategies can be stated in the modification of processes and the optimization of activities, cost leadership, outsourcing, and so on.

These strategies are as the Table 7.

Table 7. Alpha Mining Company SWOT Matrix

	Strengths [S]	Weaknesses [W]
Opportunities [O]	1. Increasing production by launching new lines [S1] [S2, S3, S5, S6, S8, S12, O1, O2, O8, O10] 2. Investing in neighboring countries' mines to increase market penetration and impact coefficient [S2] [S1, S2, S6, S10, S12, O1, O8, O10, O12] 3. Reduction of pollutants resulted from production [S3] [S1, S2, S3, S6, S8, S10, S13, O3, O4, O7, O8]	1.Comprehensive planning in human resources area to create an effective and efficient culture [S7] [W1, W2, W4, W15, W16, W18, O2, O8] 2.Renovating and equipping production lines by new machineries [S8] [W7, W8, O6, O7, O8, O10] 3.Reorganizing forces in various affairs [S9] [S1, S2, S3, S18, O2, O8]
Threats [T]	1. Developing downstream industries to create added value and dealing with unemployment and sanctions [S4] [S1, S2, S6, S11, S12, S13, T2, T3, T4] 2. Creating a Technology Transfer Office [TTO] in order to move towards self-sufficiency [S5] [S1, S6, S4, S7, S10, S11, S12, S13, T1, T2, T6, T9, T10, T12, T13] 3. Increasing productivity by using full price reduction and increasing quality [S6] [S1, S2, S3, S5, S6, S8, S10, S13, T9, T10, T14, T15]	1. Investing in researches related to low-cutie mines exploitation [S10] [W9, W10, T11] 2. Supply Chain Management System Deployment [S11] [W10, W16, T12, T13] 3. Investigating existing machinery and optimizing their energy consumption as much as possible [S12] [W7, W8, T5, T6, T9, T10, T15] 4. Deployment of knowledge management and surrogacy training systems [S13] [W6, W9, W11, W12, T2, T4] 5. Assigning a part of the sale to eligible individuals or private companies [S14] [W19, T1, T2, T14]

Determining the Strategic Position of the Company

After identifying the internal and external factors of the Alpha Mining Company, the Internal Factor Evaluation [IFE] Matrix and the External Factor Evaluation [EFE] Matrix that are respectively resulted from the strategic investigation of the internal and external factors of the Alpha Mining Company will be obtained. For this purpose, after identifying the internal and external factors, each of these factors should be given an importance coefficient. These coefficients actually indicate the importance ratio of a factor in the success of the organization in the relevant industry. In addition, the weights in each one of the matrices must be allocated in such a way that their total sum is equal to 1. For this reason, matrices were provided to the members of an expert group and to determine the relative coefficient of these factors, they were asked to allocate each one of the factors in terms of their importance degree a coefficient from zero [0=completely unimportant] to [10=having extreme importance]. As the coefficients of importance of each one of the internal and external factors have to be determined in a way that their sum becomes equal to 1, that is, the primary mean weight of each factor will be divided by the sum of the mean weights, hence the following formula is used:

$$\frac{\bar{x_\iota}}{\Sigma \bar{x_\iota}} = \text{Analyzed Weight}$$

Internal Factor Evaluation Matrix is obtained from a strategic investigation of factors within the organization. To prepare an internal factors evaluation matrix, the judgments of an expert group should be relied on. In a matrix, the expert group allocated the ranks 1 to 4 in a way that the rank 1 indicates basic weakness, the rank 2 indicates relative weakness, the rank 3 indicates relative strength and the rank 4 indicates high strength in the relevant industry. In the External Factor Evaluation Matrix, the expert group will allocate scores 1 to 4, in a way that the rank 1 indicates poor reaction, the rank 2 indicates moderate reaction, the rank 3 indicates proper reaction, and the rank 4 indicates a very excellent reaction against opportunities and threats. To determine the weighted rank, each factor's weight will be multiplied by its rank.

The sum of final scores will be between 1 and 4 and their mean is 2.5. The intersection point of the obtained numbers of [IEF] and [EFE] in the analyzed sample will be located in one of the four aspects of the table that determines the desired strategy. According to the Matrix [IE], four main strategies are used for overall policy-making and ultimately for determining tactics. In the geometric location of [opportunity/ strength], the offensive strategy will be, in the [opportunity/weakness] section, conservative strategy will be, in the [strength/threat] position, competitive strategy will be, and ultimately in the [threat/weakness] section, defensive strategy will be. Another method that can be named for determining strategy based on geometrical positioning is to use Internal and External Factor Evaluation [IEFE], which can be analyzed using different specific and diagram formulas. This matrix is presented in two 9-house and 4-house forms. In this article, the 4-house form has been used. Depending on the volume of computations, only expressing the result is sufficient.

Table 8. Internal and External Matrix

4	**Conservative Strategies**	**Offensive Strategies**
2.5	**Defensive Strategies**	**Competitive Strategies**
1	**2.5**	**4**

According to the results obtained from the Internal and External Factor Evaluation method, the strategic position of the organization is in a defensive position. Conservative, defensive, and competitive strategies should; therefore, be investigated and prioritized, because the Alpha Mining Company is not clearly in the offensive position.

Prioritizing Strategies

In this research, the WASPAS method is used to prioritize strategies. Criteria according to the ACCEPT method criteria include attainable, complexity, cost, effective, popularity, and time, that the definition of each one has been addressed below. Each selected strategy is weighted based on these six criteria [Abdullah & Adawiyah, 2014].

Attainable: The attainable of implementing the strategy according to current conditions and existing legal requirements,

Complexity: The complexity and difficulty of implementing a strategy such as specific skills to implement a strategy,

Cost: It takes into account the costs of implementing the strategy,

Effective: Effective of a strategy that emphasizes the creation of competitive advantage,

Popularity: The popularity of a strategy in the organization that considers intra- and inter-organizational resistances [such as strike and governmental and political requirements],

Time: Strategy implementation time [the shorter the strategy implementation time is, that strategy is located in priority].

The ACCEPT method uses six criteria to prioritize strategic goals. The criteria of the ACCEPT method provide an opportunity for the strategic planning team to evaluate the consequences of adopting a strategy from various aspects, and hence reducing the common mistakes and errors in adopting incorrect strategies.

Shannon Entropy method has been used to determine the weight of the criteria. Entropy is a very important concept in the social, physical sciences and information theory. When the data of a decision-making matrix is completely clear, the Entropy method can be used to evaluate weights. The idea of the above method is that the higher the dispersion in the values of an index is, that index is more important. In Table 8 the decision-making matrix obtained from the expert group's opinions has been drawn. In this matrix, 11 competitive, conservative and defensive strategies are evaluated according to the six ACCEPT criteria, including attainable, complexity, cost, effective, popularity, and time.

Table 9. Decision Matrix According to ACCEPT Criteria

	Attainable	Comple-xity	Cost	Effective	Popula-rity	Time
S4	4	3	2	5	5	3
S5	5	4	4	4	5	4
S6	2	3	4	4	3	2
S7	4	3	2	4	5	1
S8	3	3	2	4	3	1
S9	2	3	4	4	5	3
S10	4	1	2	3	4	3
S11	2	2	3	5	4	3
S12	4	3	4	4	5	3
S13	2	2	2	4	5	3
S14	3	2	2	5	4	4

According to the above table values, and using the Shannon Entropy method, the final weight of the criteria is extracted as Table 10.

Table 10. Shannon Entropy Method Output

No.	Criteria	Entropy Value [Ej]	Uncertainty Value [Dj]	Criterion Weight [Wj]
1	C1	0.978	0.022	0.21
2	C2	0.98	0.02	0.187
3	C3	0.977	0.023	0.215
4	C4	0.996	0.004	0.038
5	C5	0.993	0.007	0.065
6	C6	0.97	0.03	0.285

Since the complexity, cost and time indices are negative and the rest of the indices are positive, then the linear soft is used for normalization. In Table 11 the normalized matrix is observed. In this method, two different equations are used to normalize the index with positive and negative aspects. If the criterion has a positive aspect:

$$n_{ij} = \frac{r_{ij}}{r_j^{max}}$$

And if the criterion has a negative aspect:

$$n_{ij} = \frac{r_j^{min}}{r_{ij}}$$

Then according to equations [3], [4] and [5] the values of Q1, Q2 and Q3 are obtained that have been shown in Table 12.

Table 11. Normalized Decision Matrix

	Attainable	Complexity	Cost	Effective	Popularity	Time
S4	0.8000	0.3333	1.0000	1.0000	1.0000	0.3333
S5	1.0000	0.2500	0.5000	0.8000	1.0000	0.2500
S6	0.4000	0.3333	0.5000	0.8000	0.6000	0.5000
S7	0.8000	0.3333	1.0000	0.8000	1.0000	1.0000
S8	0.6000	0.3333	1.0000	0.8000	0.6000	1.0000
S9	0.4000	0.3333	0.5000	0.8000	1.0000	0.3333
S10	0.8000	1.0000	1.0000	0.6000	0.8000	0.3333
S11	0.4000	0.5000	0.6667	1.0000	0.8000	0.3333
S12	0.8000	0.3333	0.5000	0.8000	1.0000	0.3333
S13	0.4000	0.5000	1.0000	0.8000	1.0000	0.3333
S14	0.6000	0.5000	1.0000	1.0000	0.8000	0.2500

Table 12. Decision Matrix along with the Weights Applied

	Attainable	Complexity	Cost	Effective	Popularity	Time	Q2	Q1	Q3
S4	0.8000	0.3333	1.0000	1.0000	1.0000	0.3333	0.7597	0.6937	0.7267
S5	1.0000	0.2500	0.5000	0.8000	1.0000	0.2500	0.7318	0.6341	0.6829
S6	0.4000	0.3333	0.5000	0.8000	0.6000	0.5000	0.5439	0.5231	0.5335
S7	0.8000	0.3333	1.0000	0.8000	1.0000	1.0000	0.8567	0.8328	0.8447
S8	0.6000	0.3333	1.0000	0.8000	0.6000	1.0000	0.7249	0.6973	0.7111
S9	0.4000	0.3333	0.5000	0.8000	1.0000	0.3333	0.5837	0.5286	0.5561
S10	0.8000	1.0000	1.0000	0.6000	0.8000	0.3333	0.6796	0.6403	0.6599
S11	0.4000	0.5000	0.6667	1.0000	0.8000	0.3333	0.6064	0.5521	0.5793
S12	0.8000	0.3333	0.5000	0.8000	1.0000	0.3333	0.6977	0.6440	0.6708
S13	0.4000	0.5000	1.0000	0.8000	1.0000	0.3333	0.6135	0.5572	0.5853
S14	0.6000	0.5000	1.0000	1.0000	0.8000	0.2500	0.6586	0.5924	0.6255

Therefore, prioritizing the strategies based on Q amount has been shown in Table 13.

Table 13. Prioritizing Strategies Based on the WASPAS Method

Priorities	Strategies	Scores
First Priority	S14	0.8447
Second Priority	S5	0.7267
Third Priority	S7	0.7111
Fourth Priority	S4	0.6829
Fifth Priority	S13	0.6708
Sixth Priority	S9	0.6599
Seventh Priority	S6	0.6255
Eighth Priority	S8	0.5853
Ninth Priority	S11	0.5793
Tenth Priority	S10	0.5561
Eleventh Priority	S12	0.5335

According to the WASPAS method in the final matrix, the option with the highest Q will have the highest priority.

DISCUSSION AND CONCLUSION

Various approaches have already been proposed to prioritize strategies; in this research, the criteria have been specified using the ACCEPT approach and finally by the WASPAS method, the strategies have been prioritized. The ACCEPT method unlike the QSPM method, which prioritized strategies by taking into account strengths and weaknesses, opportunities and threats, regardless of environmental conditions and existing organizational status and externally by considering 6 main parameters of strategy evaluation including cost, time, popularity, effective, and so on, helps to prioritize strategies. In this research, it was tried to use one of the techniques of MADM according to relevant and important criteria to enhance the assurance coefficient of managers' decision making. Multi-criteria decision-making techniques have this advantage that they evaluate various options according to various criteria that do not have equal units. Another important advantage of multi-criteria decision-making techniques is that they are capable of analyzing quantitative and qualitative criteria simultaneously. In this article, using the WASPAS method, the strategies of "assigning a part of sale to eligible individuals or private companies", "creating a Technology Transfer Office [TTO] in order to move towards self-sufficiency" and "comprehensive planning in the field of human resources in order to create an effective and efficient culture" were selected as strategic priorities for the Alpha Mining Company. The first strategy is among defensive strategies, the second strategy is in the field of competitive strategies and the third strategy is in the field of conservative strategies. Of course, it was foreseeable that in the new sanctions situation, along with the disordered human resources situation, strategies associated with them are located in the selection priority. For the first strategy, in order to move from the current sanction situation the company should act with private companies or individuals to advance export goals. In other words, a part of the sales unit activity must be outsourced. In the second strategy, the creation of a Technology Transfer Office in line with self-sufficiency has been mentioned. Generally, the importance of technology as the main factor and driving engine of economic growth in the world is obvious and clear. There is no doubt that productivity improvement is very vital and important for an economic system that technology is the factor and the cause of such improvement. Technology transfer is a process that enables the flow of technology from one source to a receiver. In this case, the source is the owner or possessor of the knowledge, while the receiver is the beneficiary of such knowledge. The source can be an individual, a company or a country. Technology transfer, whether culturally, or politically and economically is among important and significant issues for developing countries as well as developed countries, and has required many international research organizations to conduct research and survey in this respect. The third strategy involves comprehensive human resource planning in order to create an effective and efficient culture, that with regard to the serious weaknesses that the Alpha Mining Company has in this area, and they have also been mentioned in the form of weaknesses, it hence seems that this strategy will be a very important priority, despite the fact that performing it takes time.

Future researchers are suggested use other multi-criteria decision-making techniques along with the WASPAS method to investigate strategy priorities and to compare them with macro goals and vision to prioritize strategies. In addition, the mentioned research can be performed for other mining or industrial companies in a similar way.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Abdullah L., Adawiyah CW., 2014. Simple additive weighting methods of multi criteria decision making and applications: A decade review. International Journal of Information Processing & Management, 5.

Alvani S. M., 2008. Public Management, Tehran, Publication of Ney, Edition 32. [in Persian]

Boesso, G., Favotto F., Michelon, G., 2014. Stakeholder Prioritization, Strategic Corporate Social Responsibility and Company Performance: Further Evidence, Corporate Social Responsibility and Environmental Management, 22. http://doi.org/10.1002/csr.1356

Chang D.Y., 1992. Extent Analysis and Synthetic Decision, Optimization Techniques and Applications, World Scientific, Singapore, 1.

Chang, C.-H., Xu, J., Dong, J. and Yang, Z., 2019. Selection of effective risk mitigation strategies in container shipping operations, Maritime Business Review, 4 (4), 413-431. http://doi.org//10.1108/MABR-04-2019-0013

Cigat Onat N., Gumus S., Kucukvar M., Tatari O., 2016, Application of the TOPSIS and intuitionistic fuzzy set approaches for ranking the life cycle sustainability performance of alternative vehicle technologies. Sustainable Production and Consumption. 6 (1), 12-25. http://doi.org/10.1016/j.spc.2015.12.003

Damitha B., Maria E. M., Laura A. M., 2014, "Priority dispatching strategies for EMS systems", Journal of the Operational Research Society, 65(4), 572-587. http://doi.org/10.1057/jors.2013.95

David M.E., David F.R., 2009. The Quantitative Strategic Planning Matrix [QSPM] Applied To A Retail Computer Store, The Coastal Business Journal, 8 (1), 42-52.

David R., Strategic Management, 2019. Translated by: Ali Parsaian and Seyed Mohammad Arabi, Office for Cultural Researches, Second Edition, Tehran

Elsheikh Y., Azzeh M., 2017. Prioritize E-Government Strategies Using SWOT-Ranked Voting Analysis Technique: The Case of Jordan. http://doi.org/10.13140/RG.2.2.27283.94245.

Hanger J. D., Thomas L. V., 2002. Fundamentals of Strategic Management, Translated by Seyed Mohammad Arabi and Davood Izadi, First Edition, Publication of the Office for Cultural Researches, Tehran

Idris, F., Naqshbandi, M.M., 2019. Exploring competitive priorities in the service sector: evidence from India, International Journal of Quality and Service Sciences, 11 (2), 167-186. http://doi.org/10.1108/IJQSS-02-2018-0021

Jingzheng R., Suzhao G., Shiyu T., Lichun D., 2015. Hydrogen economy in China: Strengths–weaknesses–opportunities–threats analysis and strategies prioritization, Renewable and Sustainable Energy Reviews, 41. http://doi.org/10.1016/j.rser.2014.09.014

Karimi J., Mohammad Reza M., 2012. Tourism Planning Techniques and Models, Publication of Arkan Danesh, First Edition, Isfahan. [in Persian]

Khalili Shavarini, S., Salimian, H., Nazemi, J. and Alborzi, M., 2013. Operations strategy and business strategy alignment model (case of Iranian industries), International Journal of Operations & Production Management, 33 (9), 1108-1130. http://doi.org/10.1108/IJOPM-12-2011-0467

Lerner, A. L., 1999. A Strategic planning primer for higher education, College of busuness Administratin and Economics, California state university. pdfs.semanticscholar.org

Longoni A., Cagliano R., 2015. Environmental and social sustainability priorities: Their integration in operations strategies, International Journal of Operations & Production Management, 35 (2), 216-245. http://doi.org/10.1108/IJOPM-04-2013-0182

Luis A., Fernandez P., Olexandr N., Lorenzo E. M., 2019. Use of the ANP methodology to prioritize rural development strategies under the LEADER approach in protected areas. The case of Lagodekhi, Georgia, Land Use Policy, 88. http://doi.org/10.1016/j.landusepol.2019.104121

Movahhedi M., Abooyi Mehrizi M. H., Hoseini A. M, 2012. Using QSPM in Analysis of SWOT as a tool for Sterategic Planning [case study: Saipa Automotive Group]. Journal of management. 28(9), 1-10. [in Persian]

Pearce J.A., Robinson R. B, 2000. "Cultivating Guanxi as a foreign investor strategy", Journal of Business Horizons, 43 (1), 1, 31-38.

Policastro M.L., 2000, Introduction to strategic planning.

Soleimani Damaneh J., Hamidi M., Sajadi N., 2011. “Evaluating The Performance Of Irainian Football Teams Utilizing Linear Programming”, American Journal Of Operation Research, 1, 2, 65-72. [in Persian] http://doi.org/10.4236/ajor.2011.12010

Yang, S.H. and Chung, C.C., 2013. “Direct shipping across the Taiwan strait: flag selections and policy issues”, Maritime Policy and Management, 40 (6), 534-558. http://doi.org/10.1080/03088839.2013.776715

OPRACOWYWANIE I PRIORYTETYZACJA STRATEGII PRZEDSIĘBIORSTWA ALPHA MINING COMPANY PRZY ZASTOSOWANIU METODY WASPAS

STRESZCZENIE. Wstęp: W obecnych czasach przedsiębiorstwa wydobywcze, jako organizacje non-profit, podobnie jak inne organizacje, działają w kompleksowych i zmieniającym się środowisku. Prawidłowe zarządzanie organizacją zależy od zrozumienia wewnętrznego jak i zewnętrznego środowiska oraz podejmowania strategicznych decyzji. Aby działać efektywnie, mając do czynienia z wieloma czynnikami wpływającymi na możliwości i ograniczenia wzrostu przedsiębiorstwa, organizacja potrzebuje strategicznego planowania dla rozwoju swoich zdolności, długoterminowego wzrostu jak i ograniczeniu ryzyka operacyjnego. Po etapie opracowania strategii, istotnym krokiem jest ich priorytetyzacja. Statystyczna populacja w tej pracy obejmuje 50 kierowników operacyjnych i wspierających (dla określenia czynników wewnętrznych) oraz 10 menadżerów (dla określenie czynników zewnętrznych). Strategie zostały wpierw poddane analizie SWOT (Strengths, Weaknesses, Opportunities, Threats) a następnie uszeregowane zgodnie z metodą WASPAS (Weighted Aggregates Sum Product Assessment).

Materiały i metody: Dodatkowo do podejścia QSPM, modele wieloczynnikowe podejmowania decyzji również mogą być zastosowane w procesie prirytetyzacji strategii. Obecnie wieloczynnikowe podejmowanie decyzji jest bardzo zintensyfikowane, z drugiej strony obserwowana jest tendencja nauk interdyscyplinarnych zastosowania teorii różnych obszarów w rozwiązywaniu kompleksowych problemów, konieczności zwrócenia uwagi na techniki analiz podejmowania decyzji oraz wykorzystywania ich w istniejących złożonych problemach. W tych modelach umożliwione jest wybranie jednej opcji wśród istniejących wielu możliwości. Wieloczynnikowe podejmowanie decyzji odnosi się do specyficznych (preferowanych) decyzji, takich jak szacowanie, priorytetyzacja lub wybór jednej wśród wielu opcji (co czasem musi być dokonane przy wielu przeciwnych czynnikach). Takimi wieloczynnikowymi modelami podejmowania decyzji są: AHP, ANP, ELECTRE, VICTOR, TOPSIS, SAW, GRA, SIR, PROMETHEE oraz WASPAS. W prezentowanej pracy zastosowano metodę WASPA dla określenia priorytetyzacji strategii.

Wyniki: Strategie wpierw zostały zidentyfikowane poprzez zastosowanie macierzy SWOT (Strengths, Weaknesses, Opportunities, Threats) a następnie uszeregowane przy zastosowaniu metody WASPAS (Weighted Aggregates Sum Product Assessment). W końcowym etapie strategie „przypisanie części sprzedaży do indywidualnych osób lub wykwalifikowanych prywatnych firm", „stworzenie TTO (Technology Transfer Office) w celu przesunięciu w stronę samowystarczalności" oraz „wszechstronne planowanie w obszarze zasobów ludzkich w celu wytworzenia efektywnych i wydajnej kultury" zostały wybrane jako strategiczne priorytety dla firmy Alpha Mining Company.

Wnioski: Różne metody były proponowane do użycia w celu priorytetyzacji strategii. W tej pracy kryteria zostały wybrane poprzez podejście ACCEPT oraz finalnie poprzez metodę WASPAS. Metoda ACCEPT pomaga w priorytetyzacji strategii w przeciwieństwie do metody QSPM, która priorytetyzuje strategie uwzględniając ich słabe i mocne strony, możliwości i zagrożenie w oderwaniu od warunków środowiskowych i aktualnego stanu organizacji, a uwzględniając 6 głównych parametrów oszacowywania strategii, takich jak koszt, czas, popularność, efektywność, itp. W pracy spróbowano użyć jednej z metod MADM w odniesieniu do istotnych kryteriów w celu zapewnienia współzależności podejmowanych decyzji przez zarządzających. Wieloczynnikowe techniki podejmowania decyzji mają tą przewagę, że umożliwiają ocenę różnych opcji w zależności od różnych kryteriów, które nie mają wspólnej jednostki przeliczeniowej. Inną zaleta wieloczynnikowych technik podejmowania decyzji jest możliwość jednoczesnej analizy czynników jakościowych i ilościowych.

Słowa kluczowe: macierz SWOT, planowanie strategiczne, WASPAS, ACCEPT

Seyed Moslem Seyed Mirzaee
Ph.D. Student of Industrial Management in Yazd University
Faculty of Economics, Management and Accounting
Department of Industrial Management
Yazd University, University Blvd, Safayieh, PO Box: 98195-741, Yazd, **Iran**
e-mail: S.seyedmirzaee@gmail.com

Corresponding author
Seyed Heydar Mirfakhredini
Associate Professor of the Department of Industrial Management in Yazd University
Faculty of Economics, Management and Accounting
Department of Industrial Management
Yazd University, University Blvd, Safayieh, PO Box: 98195-741, Yazd, **Iran**
e-mail: mirfakhr@yazd.ac.ir

Alireza Nasser Sadrabadi
Associate Professor of the Department of Industrial Management in Yazd University
Faculty of Economics, Management and Accounting
Department of Industrial Management
Yazd University, University Blvd, Safayieh, PO Box: 98195-741, Yazd, **Iran**
e-mail: alireza_naser@yazd.ac.ir

Ali Morovati Sharifabadi
Associate Professor of the Department of Industrial Management in Yazd University
Faculty of Economics, Management and Accounting
Department of Industrial Management
Yazd University, University Blvd, Safayieh, PO Box: 98195-741, Yazd, **Iran**
e-mail: alimorovati@yazd.ac.ir

LogForum
> Scientific Journal of Logistics <
2020, 16 (4), 475-485
http://doi.org/10.17270/J.LOG.2020.502
http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X
ORIGINAL PAPER

COVID-19 AND THE FOOD CHAIN? IMPACTS AND FUTURE RESEARCH TRENDS

Abderahman Rejeb[1], Karim Rejeb[2], John G. Keogh[3]

1) Széchenyi István University, Győr, **Hungary**, 2) Higher Institute of Computer Science, Ariana, **Tunisia**, 3) Henley Business School, University of Reading, **UK**

ABSTRACT. **Background:** Throughout history, the world has witnessed natural disasters affecting businesses and societies with varying degrees of disruption. COVID-19 (henceforth C19) constituted a significant system shock and a stark reminder of the fragility and sensitive nature of supply chains. The pandemic has exerted considerable societal and economic pressure and has had an adverse impact on food supply chains in particular. Many food processing operations were forced to alter activities or close temporarily due to outbreaks. Societal lockdowns, travel restrictions, business closures and quarantine have led to structural changes in the productivity of economies and impacted the mental health and financial wellbeing of citizens.

Methods: We present a critical review of the literature to explore the impact of C19 on the food supply chain. We collected data from journal articles retrieved from a leading scientific database (i.e., Scopus), books, chapters, conference proceedings, reports, and a variety of Internet websites. For the literature search, we used the following words; "COVID-19" and "food".

Results and conclusions: The findings of the review suggest that the C19 pandemic poses unprecedented challenges for food supply chains. We reveal that C19 has raised food insecurity and food safety concerns, increased supply chain and logistics costs and radically changed consumer behavior. On the positive side, the pandemic has improved awareness of food waste and the importance of self-grown foods. We generated nine research propositions to foster future academic research. Our study also highlighted the need to advance this literature and calls for increased attention from the supply chain management and logistics community to further analyse and quantify the impact of C19 on the food chain.

Keywords: COVID-19, food supply chain, food insecurity, food safety, consumer behavior, food waste.

INTRODUCTION

Supply chains have witnessed a series of natural disasters creating system shocks for businesses and societies worldwide. These shocks have included the nuclear disasters in Chernobyl Russia and Fukushima Japan, Hurricane Katrina in the USA and the volcanic eruption in Iceland that grounded air traffic and impacted supply chains. Compounding the above disasters are increasing incidents and frequency of zoonotic diseases such as SARS, H1N1, MERS, Ebola and the SARS-Cov-2 (COVID-19 pandemic) [Foust et al., 2020]. In less than three months after reporting the first confirmed case in Wuhan, China, SARS-Cov-2 (C19) was declared as a global pandemic on March 11th, 2020, and by June 30th, 2020, more than ten million people were infected, and five hundred thousand died [WHO, 2020]. As C19 is a new or novel disease, no vaccines or effective treatments are available, and most countries have imposed severe lockdowns measures to prevent the spread of the virus and protect their health systems from overloading. Outside of the well-known and effective term "flattening the curve" aimed at limiting the stress on the healthcare systems capacity, the lockdown strategies aimed to stop the disease spread apply various interventions such as social or physical distancing, shelter-in-place,

Citation: Rejeb A., Rejeb K., Keogh J.G., 2020. COVID-19 and the Food Chain? Impacts and future research trends. LogForum 16 (4), 475-485, http://doi.org/10.17270/J.LOG.2020.502
Received: 02.06.2020, Accepted: 22.07.2020, on-line: 18.09.2020.

wearing of facial masks, personal hygiene and the suspension of all non-essential business, social and travel activities [CDC, 2020].

The C19 pandemic is considered a potent reminder of the fragile and sensitive nature of global supply chain networks and highlights the risks and reality of the cascading consequences of multiple system failures [Keogh, Unis, 2020]. C19 has disrupted food access and impacted food security, generating severe individual and public health outcomes [Niles et al., 2020]. For example, Deaton and Deaton [2020] note that C19 has posed significant threats to Canadian food security, stretching the capacity of the food supply chain to ensure adequate food availability. Keogh [2020] notes the importance of effective signalling to address the information asymmetry between health experts, government officials and citizen-consumers. Hossain [2020] argues that the C19 pandemic may cause economic hardship and food security issues in Pakistan, with a greater risk of a global economic recession. Therefore, C19 represents a global crisis that has dramatically disrupted the functioning of societies. It has resulted in widespread human and economic losses that can exceed the capacity of the affected nations to respond. It may take sectors of the economy many years to recover, and many businesses will not survive.

The C19 pandemic has exerted significant pressure on food supply chains. This health crisis has also affected processes that extend from farm production to consumers [Poudel et al., 2020]. From the consumer perspective, the response to C19 has created an 'income shock' that is expected to exacerbate household food insecurity [Deaton, Deaton, 2020]. Likewise, the limit of social movement, containment, and quarantines have impacted on the mental health and wellbeing of citizens. Because of the reduced number of grocery shop trips, consumers have dramatically changed their food purchasing habits and revisited their food storage and sourcing options [Schmidt et al., 2020]. To mitigate against uncertainties, Schmidt et al. [2020] point out that the C19 pandemic has encouraged consumers to store (and potentially hoard) essential food items. Given that food supply chains are driven by consumer demand, when consumers change behaviours and preferences, they exert a significant impact on the entire food supply chain. Moreover, the initial shock on food supply chain operations has been captured through the adverse effects that the pandemic has on the food supply due to workers' infections, morbidity, soaring unemployment levels, and social/physical distancing practices [Espitia et al., 2020]. Apart from engendering a significant decline in the international trade flows, the pandemic has led to the supply and demand imbalances, creating conditions for food insecurity. The pandemic illustrates the need for rethinking the existing food system resilience as outlined by Keogh and Unis [2020]. They argue that the food industry must adopt a systems thinking approach to better understand the cascading consequences of system failures within and outside of the food system itself. For example, the pandemic urged academics and practitioners to question the effectiveness of the Just-in-Time (JIT) strategies in the food ecosystem as their underlying logistics structure cannot respond to supply chain disruptions and turbulences [Petetin, 2020]. As the pandemic continues to spread and interrupt healthy economic life around the globe, the shortage of local and temporary foreign workers for farms exacerbates food insecurity risks. Moreover, labour shortages in transportation, logistics, food processing, and food supply chain activities constitutes a pressing challenge to overcome. The unprecedented shutdowns of borders and airlines have impacted the movement and increased the costs of food exports. Moreover, from an existential perspective, food processing firms were forced to switch their supply efforts from foodservice to retail channels [Hailu, 2020] and direct to consumers. There is strong evidence that the mitigation strategies taken during the pandemic have complicated food distribution processes and intensified food crises in developing countries [Burki, 2020]. Poorer nations lag far behind developed economies in their ability to respond to the pandemic because of poor infrastructure, poverty, and siloed healthcare systems, which cannot support an integrated pandemic response [Austin et al., 2016]. Another adverse effect of the pandemic on the food supply chain lies in the vulnerability of import-dependent countries. In this context, Espitia et al. [2020]

note that import-dependent economies such as Botswana, Mexico and Jamaica would be extremely vulnerable to supply shocks in essential food products such as cereals, meat, and fresh fruits. Therefore, food industry actors should develop well-designed food supply networks as the pandemic persists because resilient supply chains are vital to prevent food shortages and rapid upswings in prices. The pandemic is a critical situation that necessitates immediate, coordinated responses, and proactive food supply networks that can ensure access to adequate agricultural inputs, supplies, and food. The purpose of this paper is to review the impact of C19 on food supply chains. While the pandemic has triggered abundant research quickly [Ivanov, 2020, Ivanov, Dolgui, 2020, Pierre, Simchi-Levi, 2020], studies reviewing the implications of C19 on food supply chains are a patchwork of insights. To close this research gap, we review the current scientific literature on the nexus of C19 and the food chain. More specifically, we attempt to examine the impact of C19 on the food industry and how the present crisis reshapes the operations of food businesses. We aim to offer a robust research agenda by providing various research propositions for fostering future academic endeavours and providing food practitioners and decision-makers with reliable insights for the development of resilient food chains in the future. In this study, we take the lead of research by trying to answer the following research questions:

- How does COVID-19 impact food supply chains?
- What are the future research questions framing food supply chains during COVID-19?

The contributions of the study are the following. First, our research systematises the growing knowledge related to C19 from the food supply chain perspective and provides a timely review. Second, we shed light on the main challenges posed by C19, which hamper the effective operation of food chains. Third, we identify various research propositions (RPs) to be explored in the near future.

In terms of organization, the next section highlights the methodology used in the study. Section 3 provides detailed answers to the research questions raised in this study. The last section concludes the paper and underscores other vital considerations.

DESIGN/ METHODOLOGY/ APPROACH

We performed a literature review and searched for journal articles, books, chapters, conference proceedings, and technical reports that contained the words "COVID-19" and "food*" in their titles, abstracts, or keywords. These resources were selected for conducting our study. Our review of the extant literature primarily focused on identifying the impact of C19 on the food supply chain. For the moment, the topic is still in a nascent stage, thus ruling out the chance for conducting a systematic literature review. Instead, we employed a critical literature review because it is more likely to provide insights into the current state of knowledge and the major questions being investigated so that gaps related to existing knowledge can be recognized with confidence [Carnwell, Daly, 2001]. During the search, priorities were given to all resources studying this topic from a management science and business perspective. Papers were also selected from the Scopus database and a variety of Internet websites, including Google Scholar, and ResearchGate through May 2020. The outcome of the review is a summary of discussions that captured the dynamics of food supply chains amid the pandemic.

REVIEW DISCUSSION

Food insecurity

C19 has heightened global awareness of the zoonotic risks posed by economic development. As there are no vaccines to protect against the virus, protective measures through personal protective equipment (PPE), together with physical distancing and personal hygiene, are being taken to stop the spread of the disease [Bhatta, 2020]. Besides affecting the global population and the functioning of economic activities, C19 has revealed that food systems are less equipped to deal with the unprecedented shock and disruption [FAO, CEPAL, 2020]. For food supply chains, this health crisis has posed unpredictable and severe risks to the continuity of food businesses. For instance, Goddard [2020] argues that food retail and foodservice sectors have encountered some of the most significant impacts of C19. The author further notes that the effects of C19 range from unemployment, higher transaction costs, to radical changes in consumer behaviour. More alarming, perhaps, is the very close link of food insecurity with national and household economic conditions. In this context, Niles et al. [2020] highlight that the pandemic has substantially increased unemployment, created an inability to afford food and affected all dimensions of food security. It is expected that there will be a higher prevalence of moderate to severe food-insecure households due to the lack of employment and loss of income [Deaton, Deaton, 2020]. The escalation of the pandemic and precautionary interventions taken by governments has led to the lowering of business and personal incomes, significant demand drops across certain commodities, and temporary or permanent closures of businesses [Hossain, 2020]. In the long-run, food supply chains could observe a reduction in particular agricultural products, especially for labour-intensive agriculture such as flowers and vegetables [Forsido et al., 2020]. Forsido et al. [2020] argue that the extended drop in demand for some foods such as dairy products and fresh fish might halt food chains and eventually lead to the collapse of businesses, worsen unemployment due to labour layoff, cause economic crises, and intensify food and nutrition insecurity gaps. The lack of income and the increase in unemployment have adverse demand-side effects. As such, many food supply chain actors would be unable to withstand the continuous business pressures, resulting in market withdrawals, jobless growth, income losses, and social unrest due to the inability to secure food supplies. Given the increasing intensity of C19 and its threat to food security, we suggest the following research propositions.

RP-1: The C19 pandemic hampers the efforts, policies, and strategies of food supply chains to ensure food security and economic empowerment of small farmers and rural economies.

RP-2: The spread of the virus constitutes a threat to food supply chains because it limits consumers' access to nutritious foods in several ways.

Supply chain and logistics costs

With rising unemployment and a massive slowdown in the global economy, traditional food supply chains have faced several challenges to operate on a worldwide basis and ensure highly coordinated flows of food products within and across national borders. According to Torry [2020], the C19 pandemic has deepened the digital divide, amplifying gains for businesses that cater to customers online, while companies with traditional retail distribution models have struggled to survive. Realizing the real dangers posed by C19 toward national development, several countries have mobilized resources to fight against the spread of the virus, implementing several interventions such as the suspension of public transportation, closure of airports, railway stations, and highways. While these measures are necessary to prevent further disease transmission, they have adverse implications on food supply chain distribution and overall transaction costs.

The pandemic impacts food accessibility due to its detrimental effects on infrastructure, including logistics, and distribution. Accessibility is compounded by shortages of certain products and price increase in others [Niles et al., 2020]. The restrictions imposed on food logistics are likely to increase transaction costs and, thus, food prices. The ability to supply food more quickly and at reasonable costs is a challenging task during the pandemic [Amanta, Aprilianti, 2020]. Larue [2020] suggests that C19 may cause an increase in the cost of farm labour, with wages amounting up to 80% of the cost of producing many fruits and vegetables. In the livestock sector, Zhang et al. [2020] indicate that the pandemic may generate difficulties in accessing animal feed and satisfying labour demand needs. The closure of borders presents a significant physical barrier for food access [Niles et al., 2020] and international transport

[Hossain, 2020]. As a result, countries that are heavily dependent on a variety of food items in both raw and processed forms will suffer economically as food suppliers deal with the uncontrollable external events caused by the pandemic [Hossain, 2020]. Specific perils could be noticed from this pandemic, such as the rising costs of transportation that are brought about by the rescheduling of orders, extension of transport times, and the additional prevention and control measures. As an illustration, food supply chain actors are compelled to adhere to the C19 disaster regulations and incur extra costs on transportation (i.e., to comply with the new transport regulations), social/physical distancing practices, and personal protection equipment (PPE) like facial masks and hand sanitizers. The difficulties faced by food businesses to adjust to the new normal require the orchestration of food processes and the commitment of additional resources in terms of time and costs, thus paving the way for operational inefficiencies [Petetin, 2020]. For example, several small meat plants have been working overtime in the United States as a result of the temporary closure of large plants due to infection outbreaks among staff. In such a scenario, these small food businesses are required to pay extra costs because the USA's Food Safety and Inspection Services charge overtime fees for food inspectors [Shearer, 2020]. Therefore, we propose:

RP-3: The C19 pandemic increases the costs of food preparation, processing, transportation, inspection, and distribution.

Changes in consumer behaviour

While the pandemic is unfolding, a long-term change may emerge in the way consumers purchase food products [Richards, Rickard, 2020]. Several recent studies have emphasized that consumers have changed their food purchasing habits in response to the pandemic [Kolodinsky et al., 2020, Schmidt et al., 2020, Worstell, 2020]. At first, the uncertainty and fear of food supply disruption have prompted panic buying and hoarding behaviour. Consumers have become increasingly interested in storing essential food products such as canned foods as well as frozen or dried foods [Schmidt et al., 2020]. In times of crisis, consumers may hold the belief that prices will increase, or that supply shortage will occur. As a result, panic-buying has prevailed during the early stages of the pandemic, and consumers emptied supermarket shelves of foods, personal hygiene products (e.g., soaps, hand sanitizers, toilet paper) and household cleaning products (e.g., anti-bacterial cleaning liquids, sprays and wipes). Supermarket shelves in Germany have been emptied by consumers even though Germany's flour association declared they had sufficient raw materials, and flour producers were working overtime to meet the peak demand [CBI, 2020]. In the United States, American consumers have raised concerns over the fragility of food supply chains and the depletion of specific stocks in supermarkets and grocery retail stores [Dickinson, 2020]. The risk of food insecurity and hunger has haunted several nations where infection preventative measures led to hoarding and resulted in food shortages in urban areas where vegetables such as cauliflower and green onions could not be shipped out [Galanakis, 2020]. These examples suggest dramatic changes are occurring in consumer buying behaviour and habits. Moreover, the lockdown conditions and social/physical distancing measures have continued to affect consumer purchase behaviour [Cranfield, 2020] in the sense that consumers have moved to online grocery shopping. There is a significant increase in online purchases made by infection-vulnerable retirees and households that have no previous experience in purchasing foods online [Charlebois, 2020]. The declaration of national emergencies across many countries has triggered a broader societal shift toward online grocery shopping. In their study, Jribi et al. [2020] highlight that online grocery shopping can offer attractive opportunities for consumers, including time savings, convenience, home deliveries, and eliminates the risk associated with the need for social/physical distancing in stores. However, the authors note that some consumers, including Tunisians, are still reluctant to engage in e-commerce because of a certain degree of mistrust of online purchases. In a similar vein, Richards and Rickard [2020] maintain that the long-term impact of C19 on the sale of fruits and vegetables (both fresh and processed) will depend significantly on consumer satisfaction with the engagement in online shopping experiences. There is growing evidence that online grocery shopping is increasingly accepted by consumers due to its convenience, availability of information, increased selection, and the lack of physical contact and reduced risk of infection. Evidence also shows that consumers tend to make healthier purchases when groceries are ordered using automated online shopping lists, thereby avoiding impulsive purchases [Pozzi, 2012]. Therefore, this element of the food distribution system is expected to receive a sustained upward shift in the adoption of online food ordering and delivery. Hence, the following research propositions emerge:

RP-4: The C19 pandemic significantly changes the flow of traditional consumption patterns for foods.

RP-5: The C19 pandemic contributes to the proliferation of online food marketplaces.

Food waste and self-grown food

As food waste is partially attributed to consumer behaviour, the pandemic has raised consumer awareness. On this point, Jribi et al. [2020] find that a vast majority (89%) of respondents claimed to be more aware of food waste during the pandemic. Food waste represents a growing global issue that threatens food security and environmental sustainability. Consumers need to further develop their awareness, skills and tools to address their food-related activities and habits [Jribi et al., 2020]. For example, Hobbs [2020] opined that the pandemic would intensify consumer interest in locally sourced foods, thus empowering local farmers. However, the widespread personal income losses due to the pandemic have the potential to shape consumer preferences and consumption decisions. Consumers seeking to protect themselves and boost their immune systems have become more committed to healthy and organic foods. More specifically, the perceived risk to human health during the C19 pandemic might be an impetus for consumers to adopt healthier diets and search for bioactive ingredients in food products. C19 acts as a strong motivation for certain consumers segments to reconsider their food provisioning practices and eating habits. However, lost income, employment uncertainty and rising costs serve to weaken consumer purchasing power. In turn, this undermines their ability to afford more nutritious or healthier choices, such as less processed foods and more natural or organic foods. As per a report by the World Economic Forum, urban farming is thriving during the pandemic as people with more free time have created home garden setups and use tools like indoor grow lights and outdoor planters to support their consumption with home-grown food [GritDaily, 2020]. Therefore, we suggest the following research propositions:

RP-6: The C19 pandemic raises awareness of food waste.

RP-7: The C19 pandemic constitutes a growth opportunity for self-grown foods.

Food safety

Food safety represents a critical public concern, and outbreaks of food-borne illnesses can be significant [Feng, Sun, 2012]. As food is a basic necessity for existence, the food industry must continue to operate at high standards during the pandemic. Despite efforts to ensure strict food control measures, the pandemic has revealed lapses in the existing food systems and exposed the risks facing the production and delivery of safe food products to consumers [Jawed et al., 2020]. Jawed et al. [2020] contend that unlike other industries, employees working in the food industry are not able to work from home owing to the very nature of the work and the need for physical presence. As a consequence, disease transmission is still possible through poor PPE or health and safety practices in food processing plants. Moreover, although scientifically contentious, if an infected worker touches a surface, tool or food product, and shortly afterward another worker comes in contact and touches his/her eyes or mucous membranes of the mouth, nose or throat, there may be an increased risk of infection [Galanakis, 2020]. Although scientific evidence is nascent and inconclusive, additional concerns arise because of the unknown risk of cross-contamination at different stages of the supply chain, and potential disruption of the safe supply of food.

The discontinuous supply of raw materials necessary for the production of food could pose significant food safety risks, especially for perishable foods and vegetables. Moreover, the pandemic has generated other sources of concerns that are associated with inadequate handwashing, packaging, and other food-handling practices. Inadequate personal hygiene and inappropriate use of PPE (e.g., a mask cover the mouth but not the nose) may increase the risk that respiratory droplets adhere to food packaging materials [Shahidi, 2020], thus exposing consumers to potential risk. Importantly, there is currently no evidence that consumers can be infected by eating food, and no recorded cases of infection through food packaging. Nevertheless, as of late June 2020, despite the lack of scientific evidence, China is demanding that all foreign food shipments carry a guarantee that the food and food containers have been tested for the presence of the virus before shipping to China [Patron, 2020].

Another critical supply chain activity that has been hindered by the pandemic is food audits. The travel restrictions and lockdown procedures following the pandemic have hampered the ability of food certification bodies to carry out onsite regulatory audits and issue certifications to food supply chain actors. Auditors have been unable to travel, perform onsite audits, confirm compliance, and ensure the consistency of food safety systems [Shahbaz et al., 2020]. Although some solutions could be implemented to augment the process and conduct food safety audits using remote auditing tools such as CCTV cameras, smart glasses, wearable and handheld devices, many food companies and supply chain partners still lack the technical expertise, infrastructure and insights to safely and efficiently perform remote audits. Therefore, the pandemic has exposed new challenges for the monitoring of food safety and the delivery of safe food products to consumers. The absence of effective food auditing measures could amplify consumer anxiety and increase the vulnerability to food-borne illnesses and increase the risk of food fraud. Reflecting these discussions, we present the following research propositions, intended to encourage future research:

RP-8: The C19 pandemic poses significant food safety risks in the food chain.

RP-9: The C19 pandemic changes the way food safety is monitored and gives rise to remote inspections and other technological solutions for food audits.

CONCLUDING REMARKS

The pandemic poses significant threats to food supply chains around the world. In this paper, we presented a critical literature analysis of the impacts of C19 on food supply chains and extracted nine (9) research propositions to foster future academic investigations. In reviewing publications on the interplay between the pandemic and the food supply chain, we found that the impacts of the C19 pandemic are mainly focused on food insecurity, food supply chain and logistics costs, consumer behaviour, food waste and self-grown food, and food safety. Inevitably, the pandemic will have long-lasting and potentially devastating effects on food supply chains. In tapping into this research area, we aspire to provide insights and inspiration for academics and practitioners to explore the impacts of this pandemic on food chains. To the authors ‘best knowledge, this is the first attempt to systematize the scant and rapidly evolving literature on the impact of C19 on the food chain. The results of our review offer valuable contributions to supply chain management and logistics functions. However, it should be noted that the paper has several limitations. Unlike systematic literature reviews, critical literature reviews do not aim to aggregate all existing literature but rather to extract valuable insights and advance the conceptual development of the topic under study. Moreover, the query used to search for resources and articles could be a barrier to investigate other food supply chain-related themes. To overcome these issues, future studies can use a systematic review method and build on this research to generate additional insights and outcomes. We acknowledge that the C19 impacts on food supply chains are not yet possible to quantify as the pandemic is still ongoing. Taking into account this limitation, future researchers may be interested in adopting empirical methods to analyze the ripple effects that C19 has on the food industry and the potential for food fraud.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

Abderahman Rejeb is grateful to Professor László Imre Komlósi, Dr. Katalin Czakó and Ms. Tihana Vasic for their valuable support. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Amanta F., Aprilianti I. 2020, April 30. [Policy Brief] Indonesian Food Trade Policy during Covid-19. CIPS. https://www.cips-indonesia.org/post/policy-brief-indonesian-food-trade-policy-during-covid-19

Austin K.F., DeSciscciolo C., Samuelsen L., 2016. The Failures of Privatization: A Comparative Investigation of Tuberculosis Rates and the Structure of Healthcare in Less-Developed Nations, 1995–2010. World Development, 78, 450–460. http://doi.org/10.1016/j.worlddev.2015.10.027

Bhatta A., 2020. Choice of Food: A Preventive Measure during Covid-19 Outbreak. Europasian Journal of Medical Sciences, 2(1), Article 1. http://doi.org/10.46405/ejms.v2i1.49

Burki T., 2020. COVID-19 in Latin America. The Lancet Infectious Diseases, 20(5), 547–548. http://doi.org/10.1016/S1473-3099(20)30303-0

CBI, 2020. COVID-19 disrupts supply chains for grains, pulses and oilseeds | CBI – Centre for the Promotion of Imports from developing countries. https://www.cbi.eu/news/covid-19-disrupts-supply-chains-grains-pulses-oilseeds/

CDC, 2020, February 11. Coronavirus Disease 2019 (COVID-19). Centers for Disease Control and Prevention. https://www.cdc.gov/coronavirus/2019-ncov/index.html

Charlebois S., 2020. Why COVID-19 Will Change Canadian Grocery Industry Forever: Expert. RETAIL INSIDER. https://www.retail-insider.com/retail-insider/2020/3/why-covid-19-will-change-the-food-industry-forever

Cranfield J.A.L., 2020. Framing consumer food demand responses in a viral pandemic. Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie. http://doi.org/10.1111/cjag.12246

Deaton B.J., Deaton B.J., 2020. Food security and Canada's agricultural system challenged by COVID-19. Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie. http://doi.org/10.1111/cjag.12227

Dickinson M., 2020. Food frights: COVID-19 and the specter of hunger. Agriculture and Human Values. http://doi.org/10.1007/s10460-020-10063-3

Espitia A., Rocha N., Ruta M., 2020. Covid-19 and Food Protectionism: The Impact of the Pandemic and Export Restrictions on World Food Markets (SSRN Scholarly Paper ID 3605887). Social Science Research Network. https://papers.ssrn.com/abstract=3605887

FAO, CEPAL, N., 2020. Analysis and responses of Latin America and the Caribbean to the effects of COVID-19 on food systems, 2. https://repositorio.cepal.org//handle/11362/45526

Feng Y.-Z., Sun D.-W., 2012. Application of Hyperspectral Imaging in Food Safety Inspection and Control: A Review. Critical Reviews in Food Science and Nutrition, 52(11), 1039–1058. http://doi.org/10.1080/10408398.2011.651542

Foust A.M., Winant A.J., Chu W.C., Das K.M., Phillips G.S., Lee E.Y., 2020. Pediatric SARS, H1N1, MERS, EVALI, and Now Coronavirus Disease (COVID-19) Pneumonia: What Radiologists Need to

Know. American Journal of Roentgenology, 1–9. http://doi.org/10.2214/AJR.20.23267

Galanakis C.M., 2020. The Food Systems in the Era of the Coronavirus (COVID-19) Pandemic Crisis. Foods, 9(4), 523. http://doi.org/10.3390/foods9040523

Goddard E., 2020. The impact of COVID-19 on food retail and food service in Canada: Preliminary assessment. Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie. http://doi.org/10.1111/cjag.12243

GritDaily, 2020, April 19. 4 Ways Technology Is Helping the Food Supply Chain During COVID-19. Grit Daily News. https://gritdaily.com/4-ways-technology-is-helping-the-food-supply-chain-during-covid-19/

Hailu G., 2020. Economic thoughts on COVID-19 for Canadian food processors. Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie. http://doi.org/10.1111/cjag.12241

Hobbs J.E., 2020. Food supply chains during the COVID-19 pandemic. Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie. http://doi.org/10.1111/cjag.12237

Hossain S.T., 2020. Impacts of COVID-19 on the Agri-food Sector: Food Security Policies of Asian Productivity Organization Members. Journal of Agricultural Sciences – Sri Lanka, 15(2), 116–132. http://doi.org/10.4038/jas.v15i2.8794

Ivanov D., 2020. Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. Transportation Research Part E: Logistics and Transportation Review, 136, 101922. http://doi.org/10.1016/j.tre.2020.101922

Ivanov D., Dolgui A., 2020. Viability of intertwined supply networks: Extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. International Journal of Production Research, 58(10), 2904–2915. http://doi.org/10.1080/00207543.2020.1750727

Jawed I., Tareen F.R., Cauchan K., Nayeem M., 2020. Food safety and COVID-19: Limitations of HACCP and the way forward. The Pharma Innovation Journal, 9(5), 01–04.

Forsido S.F., Mitiku F., Lemessa F., Tolemariam T., Belew D., Berecha G., Garedew, W., Bekele Y., Geda F., Eneyew A., 2020. COVID-19 Probable Impacts on Ethiopian Agriculture and Potential Mitigation and Adaptation Measures: No Food-No Health-No Life. Jimma, Ethiopia: Jimma University.

Jribi S., Ben Ismail H., Doggui D., Debbabi H., 2020. COVID-19 virus outbreak lockdown: What impacts on household food wastage? Environment, Development and Sustainability, 1–17. http://doi.org/10.1007/s10668-020-00740-y

Keogh J.G., 2020. COVID-19: Regaining trust of citizen-consumers through effective signalling. https://www.foodincanada.com/food-in-canada/covid-19-regaining-trust-of-citizen-consumers-through-effective-signalling-144143/ (accessed on 7/8/2020)

Keogh J.G., Unis C.J., 2020, June 24. Rethinking Future Food Chains: Systems Thinking and the Cascading Consequences of System Failures. Food Safety Magazine. https://www.foodsafetymagazine.com/magazine-archive1/junejuly-2020/rethinking-future-food-chains-systems-thinking-and-the-cascading-consequences-of-system-failures/ (accessed on 7/8/2020)

Kolodinsky J., Sitaker M., Chase L., Smith D., Wang W., 2020. Food Systems Disruptions: Journal of Agriculture, Food Systems, and Community Development, 9(3), 5–8. http://doi.org/10.5304/jafscd.2020.093.013

Larue B., 2020. Framing consumer food demand responses in a viral pandemic. Journal of Agricultural Economics, 68(n/a). http://doi.org/10.1111/cjag.12246

Niles M.T., Bertmann F., Belarmino E.H., Wentworth T., Biehl E., Neff R.A., 2020. The Early Food Insecurity Impacts of COVID-19. MedRxiv, 2020.05.09.20096412.

http://doi.org/10.1101/2020.05.09.20096412

Patron D., 2020, June 19. Food exporters to China asked to declare produce is coronavirus-free. Reuters. https://www.reuters.com/article/us-health-coronavirus-china-food-idUSKBN23Q1SB

Petetin L., 2020. The COVID-19 Crisis: An Opportunity to Integrate Food Democracy into Post-Pandemic Food Systems. European Journal of Risk Regulation, 11(2), 326–336. http://doi.org/10.1017/err.2020.40

Pierre H., Simchi-Levi D., 2020. How coronavirus could impact the global supply chain by mid-March. Harvard Business Review, 28.

Poudel B.P., Poudel M.R., Gautam A., Phuyal S., Tiwari G.K., Bashyal N., Bashyal S., 2020. COVID-19 and its Global Impact on Food and Agriculture. Journal of Biology and Today's World, 9(5), 221.

Pozzi A., 2012. Shopping Cost and Brand Exploration in Online Grocery. American Economic Journal: Microeconomics, 4(3), 96–120. https://doi.org/10.1257/mic.4.3.96

Richards T.J., Rickard B., 2020. COVID-19 impact on fruit and vegetable markets. Canadian Journal of Agricultural Econo-mics/Revue Canadienne d'agroeconomie, 1–19. https://doi.org/10.1111/cjag.12231

Schmidt C., Goetz S., Rocker S., Tian Z., 2020. Google searches reveal changing consumer food sourcing in the COVID-19 pandemic. Journal of Agriculture, Food Systems, and Community Development, 9(3), 1–8.

Shahbaz M., Bilal M., Akhlaq M., Moiz A., Zubair S., Iqbal H.M.N., 2020. Strategic Measures for Food Processing and Manufacturing Facilities to Combat Coronavirus Pandemic (COVID-19). Journal of Pure and Applied Microbiology, 14(2), 1–8.

Shahidi F., 2020. Does COVID-19 Affect Food Safety and Security? Journal of Food Bioactives, 9. https://doi.org/10.31665/JFB.2020.9212

Shearer S., 2020, May 29. Food supply protection legislation introduced. National Hog Farmer. https://www.nationalhogfarmer.com/business/food-supply-protection-legislation-introduced

Torry H., 2020, April 1. Coronavirus Pandemic Widens Divide Between Online, Traditional Businesses. Wall Street Journal. https://www.wsj.com/articles/coronavirus-pandemic-widens-divide-between-online-traditional-businesses-11585733402

WHO, 2020. Coronavirus disease (COVID-19) pandemic. https://www.who.int/emergencies/diseases/novel-coronavirus-2019

Worstell J., 2020. Ecological Resilience of Food Systems in Response to the COVID-19 Crisis. Journal of Agriculture, Food Systems, and Community Development, 9(3), 23–30. http://doi.org/10.5304/jafscd.2020.093.015

Zhang Y., Yang H., Cheng P., Luqman A., 2020. Predicting consumers' intention to consume poultry during an H7N9 emergency: An extension of the theory of planned behavior model. Human and Ecological Risk Assessment: An International Journal, 26(1), 190–211. http://doi.org/10.1080/10807039.2018.1503931

COVID-19 A ŁAŃCUCH DOSTAW ŻYWNOŚCI? ZALEŻNOŚCI I PRZYSZŁE TRENDY BADAŃ

STRESZCZENIE. Wstęp: W ujęciu historycznym, świat już nieraz doświadczał naturalnych katastrof, które miały wpływ w różnym nasileniu na biznes oraz społeczeństwo. COVID-19 (C19) spowodował istotny szok dla systemu oraz przypomniał o kruchości i wrażliwości łańcuchów dostaw żywności. Pandemia wywarła istotny wpływ w szczególności na tą część ogólnego łańcucha dostaw. Wiele przedsiębiorstw produkujących żywność musiało zmienił sposób swojej działalności lub czasowo ją przerwać. Lockdown, ograniczenia w podróżowaniu, zamknięcie części działalności

gospodarczej i kwarantanna doprowadziły do strukturalnych zmian w produktywności ekonomii i wpłynęły na zarówno psychiczne zdrowie jak i poziom zamożności obywateli.
Metody: W pracy zaprezentowany jest krytyczny przegląd literatury dotyczącej wpływu C19 na łańcuch dostaw żywności. Dane zostały zebrane na podstawie przeglądu artykułów prasowych z wiodących baz naukowych (np. Scopus), książek, rozdziałów, materiałów konferencyjnych, raportów oraz różnych stron internetowych. Przy wyszukiwaniu tych prac, słowami kluczowymi były słowa: „COVIS-19" oraz „żywność".
Wyniki i wnioski: Uzyskane wyniki badań sugerują, że pandemia C19 jest niespotykanym wyzwaniem dla łańcuchów dostaw żywności. C19 spowodował obniżenie bezpieczeństwa łańcucha dostaw żywności, zwiększył koszty logistyki i radykalnie zmienił upodobania konsumentów. Jak pozytywny efekt, pandemia zwiększyła świadomość marnotrawstwa żywności i istotność niezależności produkcji żywności. Zostały opracowane propozycje dalszych kierunków badań naukowych w tym obszarze. Pokreślono potrzebę tych badań oraz rozpracowanie wpływu C19 na łańcuch dostaw żywności w kontekście zarządzania łańcuchem dostaw.

Słowa kluczowe: COVID-19, łańcuch dostaw żywności, bezpieczeństwo dostaw żywności, bezpieczeństwo żywności, zachowanie konsumenckie, marnotrawstwo żywności

Abderahman Rejeb ORCID ID: https://orcid.org/0000-0002-2817-5377
Széchenyi István University
Kautz Gyula Faculty of Economics
9026 Győr, **Hungary**
Tunis Business School,
El Mourouj, Ben Arous,
Bir El Kassaa 2059, **Tunisia**
e-mail: abderrahmen.rejeb@gmail.com

Karim Rejeb ORCID ID: https://orcid.org/0000-0003-4053-2522
Higher Institute of Computer Science,
El Manar, 2, Rue Abou Raïhan El Bayrouni - 2080 Ariana, **Tunisia**
e-mail: karim.rejeb@etudiant-isi.utm.tn

John G. Keogh ORCID ID: https://orcid.org/0000-0002-7332-110X
Henley Business School, University of Reading,
Greenlands, Henley-on-Thames, RG9 3AU, **UK**
email: john@shantalla.org

LogForum

> Scientific Journal of Logistics <

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

2020, 16 (4), 487-502

http://doi.org/10.17270/J.LOG.2020.486

ORIGINAL PAPER

SMART „PLAN B" – IN FACE WITH DISRUPTION OF SUPPLY CHAINS IN 2020

Łukasz Marzantowicz[1], Katarzyna Nowicka[1], Mariusz Jedliński[2]

1) SGH Warsaw School of Economics, Warszawa, **Poland** 2) Maritime University of Szczecin, Szczecin, **Poland**

ABSTRACT. **Background:** Competitive supply chain management is the ability not only to take corrective actions against the risk occurred, but above all prevents such a situation on a daily basis. Risk management is permanent element of management abilities and one of the most important factor impacting on supply chain resilience. Today managers have access to many tools, i.e. digital technologies, supporting the development of contingency plans (Plan B) for risk mitigation. The aim of the paper is to identify supply chain resilience in terms of risk management during the beginning of the COVID-19/SARS-CoV-2 pandemic spread in 2020. The most important factors impacting on supply chain flows stability are pointed here together with the assessment of their preparation for these flows disruption.

Methods: The theoretical background is based on the literature review on disruption of supply chain management in general. The In-depth individual interview (IDI) method supported with questionnaire was used to conduct research among managers responsible for supply chain operations within the enterprises from the production, trade and services sectors in Poland. Opinions and a number of views on the impact of the coronavirus pandemic on business operations and supply chain management were obtained and analyzed. The survey was conducted in March 2020.

Results: The results obtained show that the first phase of pandemic spread unexpectedly strongly and impacted on disruption in the supply chains. Closed borders, sanitary and administrative restrictions have leaded to transport delays, additionally the lower number of orders was noted causing many disruptions in the further flow of the goods. Surprisingly the disruption happened even when managers synergistically cooperate and share information among partners.

Conclusions: Results of the research pointed out the critical problem with the lack of "Plan B" helping supply chains quickly react on disruptions occurring in the flows. Also managing risk based on the current way of sharing information is insufficient. Features of digital technologies and digitalization are currently one of the most important solution that might help to build smart "Plan B" for risk mitigation and supply chain competitiveness improvement.

Key words: supply chain risk management, COVID-19/SARS-CoV-2 impact on supply chain, digital technologies in risk mitigation.

INTRODUCTION

Risk management is a key aspect for competency improvement in managing flows within the supply chains. It results in abilities for overcoming disturbances and maintaining stability in business operations. One of the most significant tests for assessing the resilience of supply chains are events that occur in a macroeconomic environment that are difficult to predict [Pérez-González, et al., 2019]. They trigger immediate activities of the organization that protect it against the uncertainty and negative effects of the emerging risk [Vilko, et al. 2014]. These activities helping to develop so-called "Plan B" impact not only to survive period of crisis, but also they leverage supply chain competitive position during that time and in the further perspective. The ability to manage supply chain risk during a pandemic is subject of a unique test.

Introduced in Poland in mid-March 2020, in connection with the COVID-19/SARS-CoV-2

Citation: Marzantowicz Ł., Nowicka K., Jedliński M., 2020. Smart „Plan B" – in face with disruption of supply chains in 2020. LogForum 16 (4), 487-502, http://doi.org/10.17270/J.LOG.2020.486

Received: 26.04.2020, Accepted: 14.08.2020, on-line: 18.09.2020.

pandemic, restrictions on population mobility and on gastronomy, entertainment, shops and shopping malls (excluding some outlets), forced changes in consumer behavior and triggered a number of changes in supply chains. The lens-like pandemic phenomenon has shown that demand problems in supply chains are a threat to the functioning of not only the links directly serving final consumers, but also for thousands of companies in the supply chain, among them especially small and medium-sized players who do not have a financial reserve that would allow them to survive the period of crisis [Cichosz, et al. 2020].

These changes show the two-stage process of entering a new phase of the supply chains' development or rather transformation. The first period, quite dynamic and dramatic, made managers aware of the effectiveness of implemented processes and the quality of procedures related to risk management in the event of a sudden change in the rules of market functioning. The second period allows them to diagnose the level of adaptability of the company and its supply chain to changes in the ability to perceive market opportunities. Both of them are the starting point for reviewing supply chain's strategy.

The "Plan B" means having the risk management strategy implemented and being ready to reconfigure resources to overcome uncertainty and mitigate risks. There are several ways helping supply chains in risk mitigation and one of them are the digital technologies that enables protecting supply chains against risks occurrence and its materialization. Therefore they can be base for creating value in the supply chain management. They are also currently one of the most important tools helping managers in sharing information on real-time basis [Nowicka, 2019] and so protect supply chain against risky situations.

However even when these conditions are met the real exam could only be passed when the risk materializes. The pandemic period shows strengths and weaknesses of the supply chains' risk management and mitigation [Poirier, et al. 2020]. It also learns how the smart "Plan B" should be developed in the future.

LITERATURE REVIEW

The scope of literature analysis in the article is delimited to one year (2020) due to the period of global pandemic. Nevertheless, the problem raised in the article had many studies mainly in the area of considerations regarding Covid-19 and human health. It can be concluded that this has a direct impact on supply chain management in the era of pandemic risk. To develop the article, available databases such as Web of Science, Scopus, Emerald and Ebsco were analyzed. However, the review was performed using keywords – the most important was the combination of the words "supply chain risk management" and "COVID-19 / SARS-CoV-2 impact on supply chain". Due to the short period of analyzing the occurrence of a pandemic and its impact on the supply chain in the context of risk management, the feedback of query results is low. Both the Web of Science database and Scopus showed only one result in response to a query about the indicated keywords. This is a publication about the impact of a pandemic on global supply chains [Ivanov, 2020], also cited in further considerations. The Emerald and Ebsco databases also showed only one study, but the journal was not a scientific type. The mentioned combination of keywords also in Google Scholar does not give a satisfactory feedback. However, it is worth pointing out the scope of the literature that includes the keywords "COVID-19 / SARS-CoV-2". The Web of Science database shows 76 studies in 2020. They mainly concern the area of health and medicine [Ankarali et al. 2020, Ziegler et al. 2020]. For combinations of the words "COVID-19 / SARS-CoV-2" with the word "management" or "economy", the result is below 10 and there are still areas related to the social sphere [Volpert et al. 2020]. SCOPUS database finds much more literature items. In response to the keyword "COVID-19 / SARS-CoV-2" there are about 5,000 articles and other studies. Again, the vast majority of considerations concern health and social issues, but there are also items related to mathematical modeling [Tang, Wang, 2020] or the environment [Chakraborty, Maity, 2020].

The popular Google Scholar database also has a lot of feedback on articles related to Covid-19 - there are over 2,000. However, there are few studies on the problem considered in the article and (apart from one article already cited) one article on the food supply chain can be mentioned [Hobbs, 2020]. It is difficult to find a wide range of literature when less than one year is analyzed – the year of the pandemic. However, due to the fact that the article is empirical in nature, extensive analysis of literature from other areas has been excluded. At the same time, in some of the considerations regarding basic and broadly described issues, i.e. management, risk and supply chain, primary literature (older than the last 10 years) has been used.

GENERAL APPROACH TO RISK MANAGEMENT IN SUPPLY CHAINS

During the COVID-19/SARS-CoV-2 coronavirus pandemic, any supply chain management activity appears to be exposed to risk factors. Moreover, for obvious reasons, difficulties arise in estimating the effects of a global pandemic. From this perspective, it is difficult to talk about the possibility of verifying the effectiveness of management actions taken in the supply chain. This raises a number of threats in terms of maintaining business. The pandemic situation caused disturbances, which on the one hand limited the activity of enterprises, but on the other hand forced the companies to search for new solutions or adapt existing technical and technological possibilities not used in the enterprise so far. It should be assumed that the risk in a pandemic does not differ in terms of the general definition. It has a distinctly different but still predictable impact on the supply chain [Ivanow, 2020]. Pandemic is a source of risk. It is difficult to assess the effects, because threats and disruptions will be industry-specific [Stephany F, et al., 2020].

In general, risk should be considered through the prism of the supply chain itself but also from the perspective of the environment in which the supply chain and enterprises operate. The basic risk sharing is as follows [Kaczmarek, 2005]:

1. Macroeconomic risk - from the environment of the enterprise's operation.
2. Microeconomic risk - resulting from the business operations.
3. Risk of potential loss.
4. Speculative risk - related to the implementation of the plan.
5. Risks with a source in the environment have the greatest impact on management.

It becomes extremely important for supply chain managers to anticipate the future as a result of decisions and actions limiting the impact of risk factors on supply chain management. We are talking about the short and medium term. However, anticipating the future, forecasting phenomena and events is part of risk management but only when [Marzantowicz, 2019]:

- all factors are quantifiable,
- effects can be estimated,
- there is repeatability of reactions in the way decisions are made,
- there is appropriate instrumentation and competences to enable its proper use,
- one can encapsulate management processes or partially absorb external events.

In the event of incidental, unique and simply unpredictable phenomena, changes occur that affect the management process in a way that partially prevents making decisions based on a quantifiable set of effects. In this situation, one should talk about unpredictable factors creating conditions of uncertainty. Here, not only a set of factors is important, but also "... a set of effects that can create many options that make up the results portfolio ..." and that "... the effects of uncertainty create scenarios that can partly be subject to future forecasting ..." [Marzantowicz, 2017]. It should be stated that risk is the determinant of the effectiveness of the measures taken - so it results from uncertainty. However, from the perspective of supply chain management, the following systematic risk sharing can be distinguished (Table 1).

Table 1. Risk sharing in the supply chain

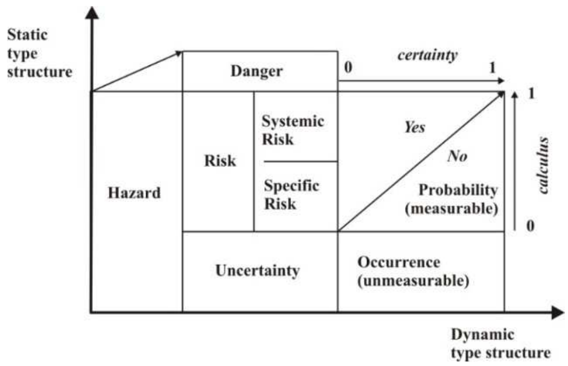
Risk of macroenvironment	Risk of an extended value chain	Operational risk	Functional risk (related to support processes)
– economic, – ecological, – social, – technology, – political.	– purchases, resources, – logistics operators, – distribution links, – demand.	– planning, design, – supply, purchases, – production, – distribution, – returns.	– human resources, – information technology, – finance, – law.

Source: elaboration based on [Rutkowski, 2015]

For many reasons, risk management in a pandemic era becomes difficult due to uncertainty conditions. From this perspective, the key factor in the effectiveness of supply chain management is the ability to at least partially forecast the effects of a pandemic and the efficiency of ongoing response to interference.

ASSESSMENT OF THE IMPACT OF THE EMERGING CORONAVIRUS PANDEMIC RISKS ON SUPPLY CHAINS

Supply chains and logistics management are always accompanied by danger and hazard. However, any threat (hazard) is less reliable than danger. Although we can deal with it in case of risk – it is measurable, but we cannot talk about measurability in the case of uncertainty. According to E.W. Deming, it can be assumed that, depending on the extent of the impact, the general nature of risk is both systemic and specific. Systemic risk in its essence concerns the whole of society, and although it exerts a direct impact on individuals, it is independent of them, therefore it cannot be controlled by any single person. Only central institutions, such as parliament, government, central institutions, but only to a certain extent, may influence to the level of this risk with their administrative decisions. However, specific (individual) risk is associated with future events that one person can predict and partially control (reduce). The threat (hazard) carries the danger. But as long as there is a control measure, a security threat does not have to lead to actual danger [Toma, et al. 2012]. The probability of measurability increases when the risk changes from specific to systemic. Hence its level depends on individual decisions aimed at taking or abandoning future actions [Fig.1].



Source: own study

Fig. 1. Relationship between hazard, danger, risk and uncertainty

Coronavirus pandemic undoubtedly has diffusive nature, combining the above two types of risks. In addition, this combined nature highlights the critical role of social infrastructure (production workers, managers at various levels and the organizational structures in which they operate or manage) in the potential of supply chains. It also determines its logistics potential, which in essence is the ability of the logistics system (enterprise or supply chain) to do some work that requires the use of a certain resources and at a certain time. It is therefore the ability of the company's logistics forces to perform the maximum production of the logistics service in the required time. This time is the most often required time set by the customer and is a compromise between the time expected by him and declared by the system (responsible for compliance with time). However, this work is the sum of the work done for the needs of the logistics process, as well as for the system's own needs, so that it can do the first one. The deficit of the human factor involved in the supply chain and logistics process results in numerous limitations. At the same time, own potential can be considered in two dimensions, i.e. endogenous, as an enterprise / supply chain system (e.g. material, personal, financial and information resources) and exogenous (which is primarily influenced by: the region, line and point infrastructure, local and national government administration).

The supply chain risks that occurred at the beginning of 2020 proved that any supply chain can be unconcerned to the risk associated with COVID-19/SARS-CoV-2, but also none of the risk levels can be voluntarily accepted. Therefore, it is no longer enough to focus solely on traditional business risk. The negative effects of a pandemic risk on other aspects of the supply chain should also be considered (especially social). Pandemic is definitely not a traditional source of risk [Ramelli, Wagner, 2020]. This risk has only negative associations with the following characteristics of the supply chains:

- they are not ready to take this risk voluntarily (they become hostage to the pandemic situation),
- they cannot remain indifferent to this risk because they are aware of it (subject to administrative restrictions),
- they do not have instruments (i.e. adequate technologies) for influencing the environment to minimize this risk.

This situation causes that the most resistant are those supply chains that are first of all reactive, because they are able to quickly introduce internal instruments that increase their resilience. Secondly, the shorter the supply chain, the more effective with introducing safe solutions for customers. Thirdly, the smarter the supply chain, the lower the possibility of making mistakes in the operational transmission of information, and the greater the potential for building smart "Plans B" in terms of their flexible configuration. The smartness of the supply chain could be reflected by usage of digital technologies helping to manage risk and prevent its negative impact on flows. This situation can be reflected on the changes in the fundamental requirements so-called The "Golden Logistics Triangle" – that can also represent supply chain priorities – and is shown in Table 2.

Table 2. Changes of logistics priorities within the "Gold Triangle Logistics"

	Regular priority	Pandemic priority
Time	The shortest	As possible
Cost	The lowest	Adequate
Quality	The best	The safest

Source: own study

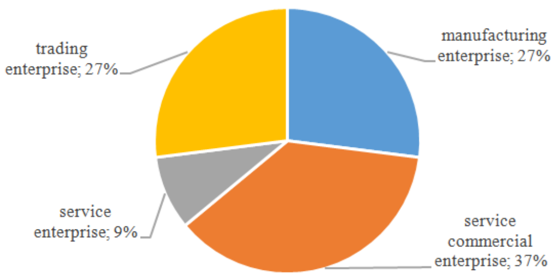
CORONAVIRUS AS A SET OF FACTORS DISRUPTING SUPPLY CHAIN MANAGEMENT – MANAGERS ASSESSMENT OF THIS ISSUE'S SIGNIFICANCE

Research methodology and characteristics

The main advantage of qualitative research is the possibility of a better, more accurate understanding of a given phenomenon. Qualitative research allows finding the causes, views, effects and diversified interpretations of phenomena than just the number of phenomena occurring. In addition, thanks to the so-called a naïve attitude makes it easier for respondents and researchers to be open. It cannot be said for obvious reasons that qualitative research shows some superiority (they are better) over quantitative research because the method of selecting the type of research depends primarily on the nature of the phenomena studied, the hypothesis and the subject of the study. Among the many qualitative research methods are e.g. observations, interviews or the so-called desk research [Eisenhardt, Graebner, 2007].

In-depth individual interview (IDI) is a classic tool for qualitative research conducted on a small group of study participants. This tool is based mainly on the analysis of opinions respondents on a specific topic. The results obtained with the help of the IDI tool constitute a set of opinions and views creating a plane of reflection on the features, impact, impact strength and development directions of a given phenomenon.

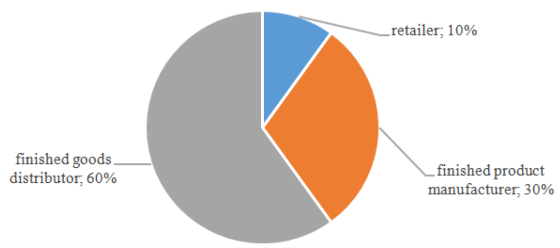
The IDI method supported with questionnaire was used to conduct research among managers of Polish enterprises, obtaining opinions and a number of views on the impact of a coronavirus pandemic on the functioning of enterprises and supply chain management. The survey was conducted among enterprises from the production, trade and services sectors, as illustrated in Fig. 2.



Source: own elaboration based on the IDI study results

Fig. 2. Share of enterprises by sectors of activity

IDI interview, although by its very nature is a method whose results cannot be applied to the entire population, it also allows you to explore many sides of the problem. In this case, it was possible to analyze the opinions of supply chain managers from both the supply and demand side. The survey was attended by 11 managers of enterprises producing finished goods, distributing finished goods and retailers. Share by location in the supply chain is presented in Fig. 3.



Source: own elaboration based on the IDI study results

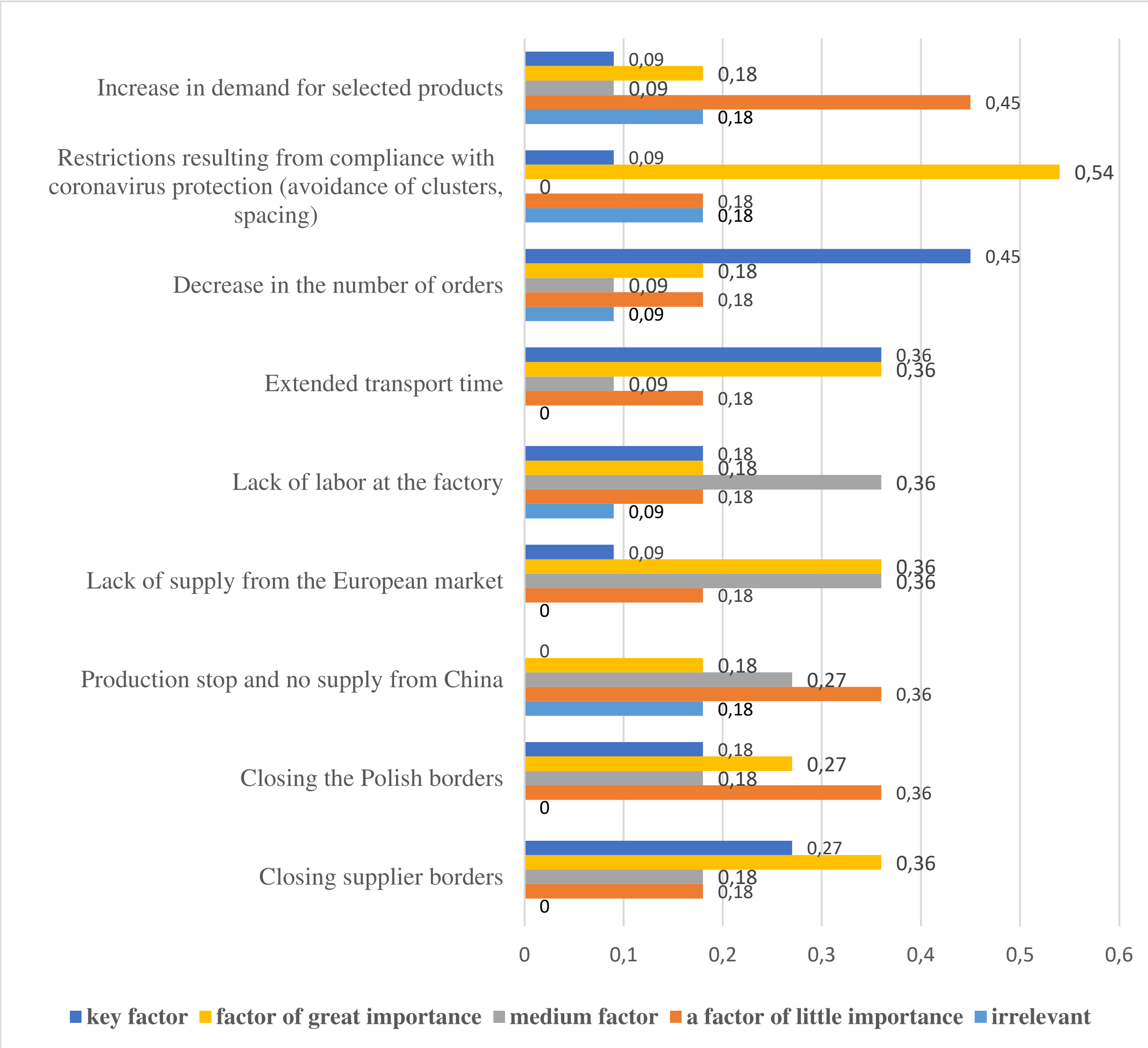
Fig. 3. Share of enterprises by place in the supply chain

The research was conducted at the beginning of pandemic diffusion in March 2020 in Poland. The aim of this preliminary empirical study was to identify the most important elements constituting the disturbance resulting from the COVID-19 pandemic, their impact on the supply chain flows, tools used for risk reduction and the reaction that disturbances would cause on further supply chain strategy and development.

Evaluation of the elements constituting the disturbance resulting from the COVID-19 pandemic

Restrictions in running a business, and thus hibernation in many sectors of the economy, have a definitely negative impact on the functioning of supply chains and their flows. One of the first topics subjected to in-depth IDI research was the identification of factors resulting from a coronavirus pandemic that have the greatest impact on the functioning of supply chains.

In the first part of the study managers were asked to assess factors with the greatest negative impact on their supply chains. The most important (key) factor was connected with restrictions resulting from compliance with coronavirus protection (avoidance of clusters, spacing) – more than half of respondents underlined this factor. The second factor was the decrease of the number of orders. Lower sales might be a reason of the restrictions that were put on the customers, i.e. avoidance of gathering (which was the factor of great importance for respondents). Managers underlined also the problem with extended transport time and lack of supply from the European market. All of the pointed problems are very important signals to revise current supply chain strategy in terms of prolonging Just-In-Time idea within the system and analyzing possibilities to configure supply chain based on local suppliers. Detail distribution of responses is shown of Fig. 4.



Source: own elaboration based on the IDI study results

Fig. 4. Factors impacting on the supply chain disruption due to COVID-19

The IDI study allows for a broader view of the coronavirus pandemic problem, therefore it is possible to identify additional factors negatively affecting supply chain flows. The following additional factors were pointed by respondents and should be considered individually:

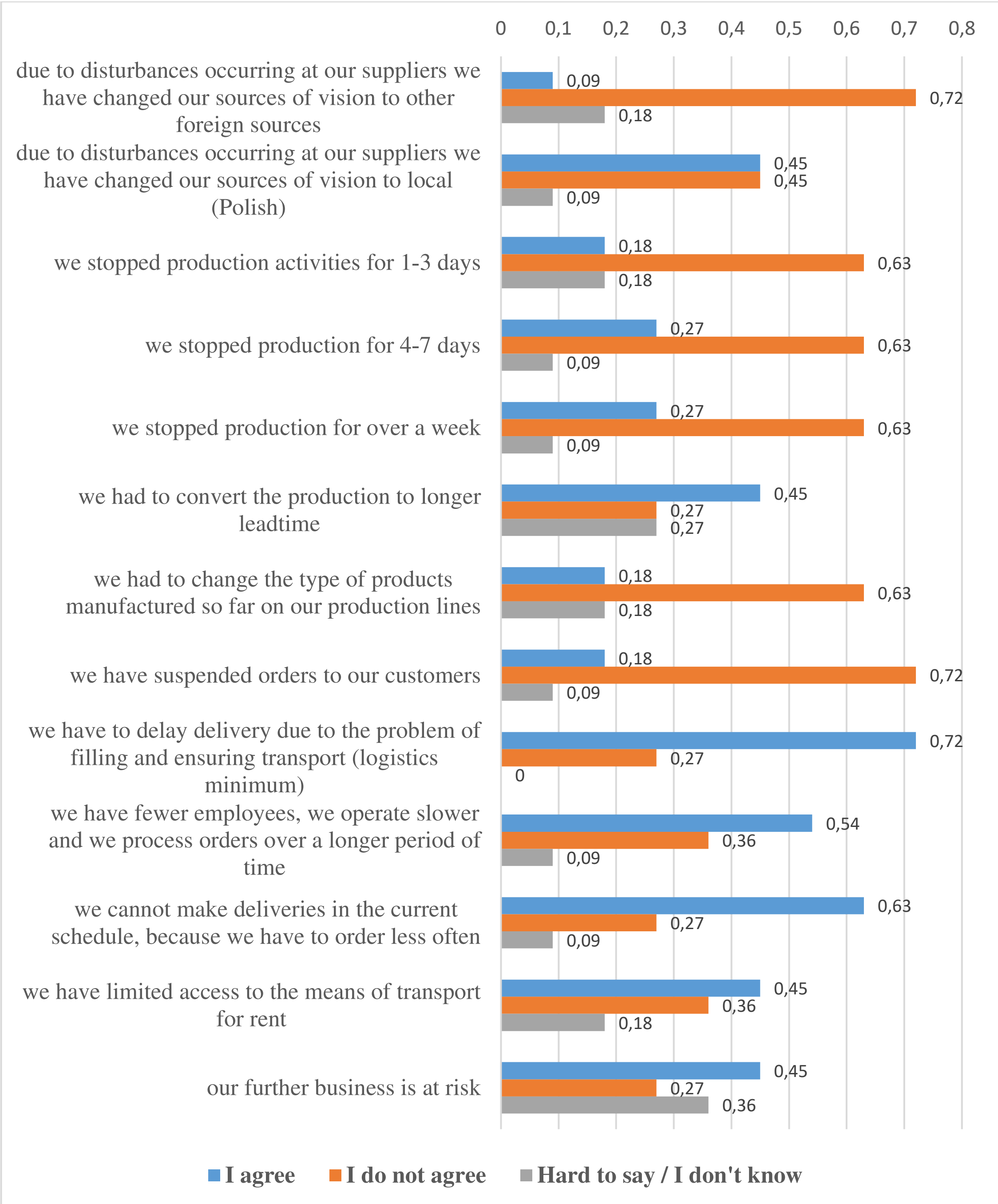
- closed borders and mandatory quarantine for people returning to the country makes it impossible to conduct trainings or receive scheduled deliveries of construction equipment directly from manufacturers, which in most cases is associated with traveling abroad,
- sudden increase in the prices of goods - semi-finished products and long waiting times for them,
- market uncertainty,
- customers' fear of purchasing and using services,
- closing factories in Germany, which resulted in stopping production,
- increase in orders, increase in demand for raw materials that suppliers are unable to deliver,
- extending customs clearance times,
- slowdown and reduction of profit,

– problem with finding a transport company, inability to schedule deliveries in advance.

Identifying factors negatively affecting the functioning of the supply chain from different perspectives (due to the diversity of study participants) allows one to identify how these factors are perceived from the perspective of the supply chain links.

Impact of the disruptions in the global flows on supply chains

Next, managers were asked to identify impact of the negative factors (disruptions) in the global flows on their supply chains. The biggest impact – that was underlined by 72% of respondents – occurred in delaying deliveries due to the problem of filling and ensuring transport (logistics minimum).



Source: own elaboration based on the IDI study results

Fig. 5. Impact of the disruptions in the global flows on supply chains

This situation presents kind of "Domino effect" as supplies in their supply chains were delayed too. The other reason for postponing the delivers – that was marked by 63% of respondents – was a decrease in the number of orders. Almost half of the surveyed managers agreed that the disturbances in the global flows caused lowering number of employees engaged, companies operated slower and processed orders over a longer period of time. To identify full range of possible effects managers were asked to complete the sentence: "Due to disturbances caused by the coronavirus pandemic…" Detailed answers are presented on the Fig. 5.

In addition to the most important answers, the study participants also pointed the following additional problems that enterprises have to face in the age of coronavirus:

- we do not carry out production activities, but we must extend the ordering and picking cycles due to lower frequency of deliveries and limitations in the number of employees (i.e. reduced workforce),
- lack of liquidity, withdrawal of investors,
- too high demand for products delivered to supermarkets, which causes shortage of some products and problems with their delivery,
- difficulties in finding drivers for some countries, or the obligation of a 14-day quarantine (e.g. Turkey),
- no protective measures available to the public.

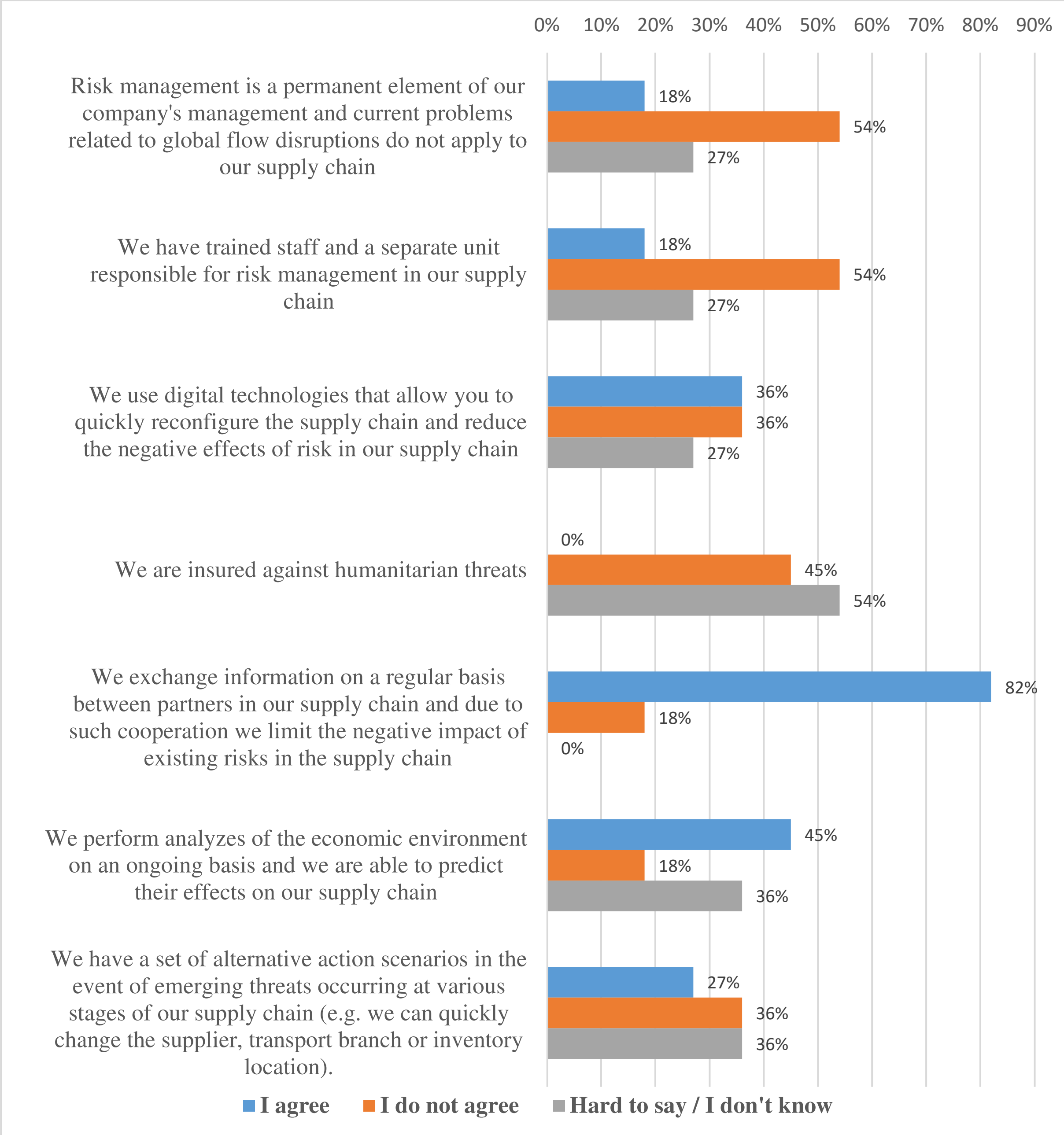
Supply chain resistance to disruption

Modern enterprises compete not only in the area of activity, but competition occurs at the supply chain level. The challenge is to be able to operate in the supply chain in a way that ensures the highest efficiency. In the event of coronavirus disruptions, companies face the dilemma of maintaining efficient supply chain flows to sustain their operations. The IDI study allowed to determine how it shapes the level of supply chain resilience through the prism of the resistance of individual links in the supply chain from the perspective of tools available to managers.

Therefore managers were asked for their approach to mitigate risk in the supply chain. Also it was important to diagnose, how (with what type of tools), the negative impact of disturbance on their supply chain was reduced. There were several different solutions predefined in terms of reducing uncertainty and risk in the supply chains. 82% of the respondents admitted that they exchanged information on a regular basis between partners and due to such cooperation they were able to limit the negative impact of existing risks in their supply chains.

Another interesting declaration was indicated by 45% of respondents – they pointed performing analyses of the economic environment on an ongoing basis and being able to predict their effects on our supply chain. Both of these statements implemented in business practice should serve to improve the security of flows in the supply chains and be a kind of alert for immediate implementation of "plan B". This alternative solution could help them to reduce the negative effects of risk occurred in the supply chains.

It should be underlined, that sharing information is one of the most important principles for developing competitive supply chains [Nowicka, 2018]. It is also a stable base for strengthening integration helping companies within supply chains to mitigate risk and reduce uncertainty. Currently, one of the most important resource for exchanging data and information among different stakeholders is digital technology [Nowicka 2019a]. Unfortunately, only 36% of respondents declared using digital technologies that allow them to quickly reconfigure the supply chain and reduce the negative effects of risk in their supply chains. Interestingly, many companies do not indicate having any form of insurance against the effects of a global pandemic directly affecting the company. All the responses are shown on Fig. 6.



Source: own elaboration based on the IDI study results

Fig. 6. Supply chain resilience to the disruptions in the global flows

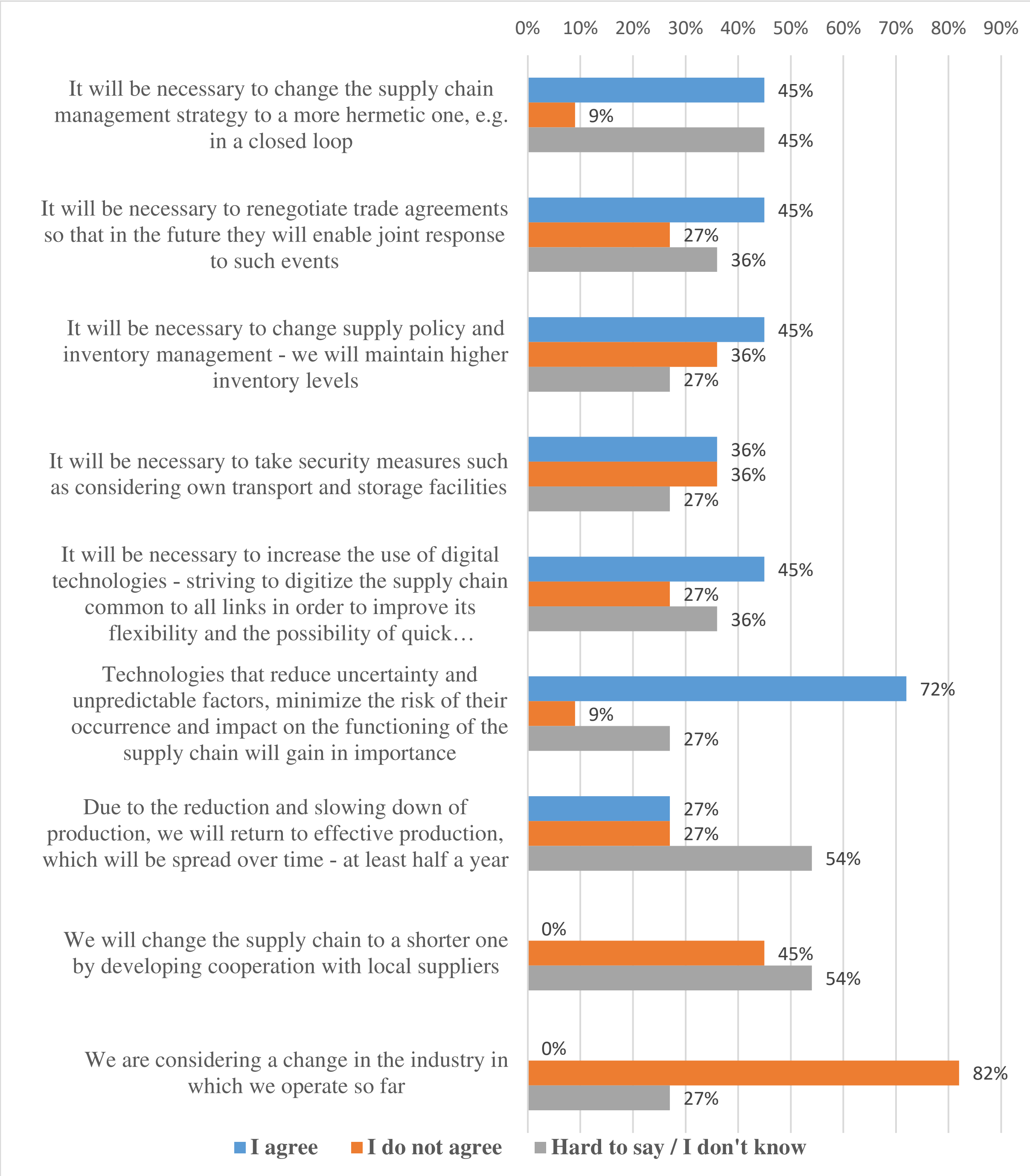
Impact of the current disruptions to global flows on the supply chains future

In a global pandemic situation, when global flows can be affected by unpredictable factors, changes occur in these flows in a way that can have long-term effects. It is possible to transfer new solutions to long-term operations. It is significant to take account of humanitarian disruption risks in everyday operations. It is worth noting here that the return to activity at the desired level of efficiency will take place taking into account permanently new ways of

Citation: *Marzantowicz Ł., Nowicka K., Jedliński M., 2020. Smart „Plan B" – in face with disruption of supply chains in 2020. LogForum 16 (4), 487-502, http://doi.org/10.17270/J.LOG.2020.486*
Received: 26.04.2020, Accepted: 14.08.2020, on-line: 18.09.2020.

reacting managers to sudden volatility and disruption.

In the last part of the study respondents were ask how the current disruptions to global flows would affect the future of their supply chains. Based on the results of this part of the study, it can be concluded that long-term effects may become one of the areas of activity, but these are not radical changes. First of all they admitted to stay in the industry they were currently operate in. Over 80% of managers strongly deny that a change of industry is necessary.



Source: own elaboration based on the IDI study results

Fig. 7. Impact of the disruptions in the global flows on the future of the supply chain management

Managers assume the development and implementation of technologies that reduce uncertainty and unpredictable factors, and minimize the risk of their occurrence and impact on the functioning of supply chains as a certain consequence, permanently remaining in the field of supply chain management as a result of a pandemic. More than 70% of surveyed managers pointed the role of technologies in their future operations. It is an important sign in the way of digitization or digital transformation that is expected to speed up due to COVID-19 pandemic. It is also an important solution that in the connection with previous declaration concerning the level of sharing information between partners might strongly impact on supply chain resilience. This is due to the fact that digital technologies are currently one of the best tools supporting sharing information [Frankowska, Nowicka, 2018] and warning of dangerous events, so building smart supply chains having smart Plan B enable for risk mitigation.

More detailed results concerning the aspect of future activities that would be undertaken by managers within the supply chain are presented on Fig. 7.

The level of compliance of the respondents' opinions with the questionnaires contained in the questionnaire was analyzed. First, it turned out that the COVID-19/SARS-CoV-2 pandemic had a strong impact on the supply chain network properties (maintenance of the logistics system). The pandemic changed the logistics process due to the problem of filling and ensuring transportation because of withdrawal of transport fleet by operators (necessity to achieve logistics minimum by suppliers). This contributed to the delays of deliveries (72% of consistent answers). There were also significant restrictions on the availability of materials and goods (with the current production schedule), which resulted in a forced change in the frequency of orders (orders are placed less frequently) - (63% of consistent answers).The potential for work has been reduced (the number of employees due to quarantine or holidays has been reduced), it caused the necessity to convert own production because of a longer lead time (45%) and, as a result, a longer lead time for clients (54% consistent answers).

Secondly, it has been clearly pointed out that the supply chain network resilience depends on the responsibility for the ability and willingness to exchange tactical and operational information between all partners regularly, which allows to limit the negative impact of existing risks significantly (82% of consistent answers). Confirmation is the joint implementation of corrective and preventive actions (in order to increase the probability of assumed effects - 45% of consistent answers). Considering the above, the exchange of information throughout the entire supply chain network should not only support the efficient logistics process processes at the operational level, but also enable in the strategic dimension, e.g.:

- activation of the attitudes of first and second-order suppliers so that they also develop their "B" plans for the future
- jointly analyzing the shape and reviewing the supply chain network to make it more resistant to disruptions
- reviewing contracts with suppliers and customers to take into account the eventuality and level of occurrence of specific disruptions, which were overlooked as pandemic usually
- re-prioritization of strategic clients (and their full logistical protection)
- plan to rebuild the full logistics network and existing partnerships.

CONCLUSION

Uncertainty and risk are a permanent parts of the supply chain management aimed at eliminating or minimizing endo- and exogenous hazards. The most important is a macroeconomic risk as it strong impacts on all of the other types of risks occurring in the supply chain. It is even more danger when analyzing international or global flows and its spread on different markets. Therefore adequate risk management enables supply chains not only to critically survive (negative) environmental circumstances (exogenous environment closer and further), but also significantly impacts on competitiveness improvement during the crisis period.

The aim of the paper was to identify the most important factors caused by COVID-19 pandemic which significantly impacting on supply chains and the assessment of their readiness for fighting with flows' disruption. For this purpose the IDI empirical research was conducted among managers responsible for operations in the supply chains in Poland. Research was carried on during the first part of COVID-19 pandemic diffusion in March 2020. Managers pointed closing of the borders of suppliers' countries, lack of substitution supply from the European market and the organizationally prolonged transport time of goods as the important factors disrupting flows in their supply chains. However, the key factor that negatively affects the functioning of the supply chain during a coronavirus pandemic was the dramatic decrease in the number of orders. This factor results from both – supply chain disturbed flows (limited potential of suppliers) and new priorities and current market behavior of the customers. In terms of the most important changes, being a response to the occurrence of variable factors caused by a coronavirus pandemic, respondents underlined these related to delivery delays associated with the problem of filling (ensuring full truck loads) and ensuring transport (its availability). Also lower frequency of orders, which results in extending the delivery schedule was problematic. The most frequently indicated way of responding to coronavirus pandemic disturbances in the supply chain was to ensure constant close cooperation at the tactical and operational level, which involves frequent exchange of precise and complete information. This enables processes to be coordinated across all parts of the supply chain. At the same time, enterprises regularly analyze economic environment and thus try to forecast the effects of risk on the supply chain. However, what is important, many companies do not indicate having any form of insurance against the effects of a global pandemic directly affecting the company. These responses are surprising as cooperation leading to exchange information used to be the one that is the most important in uncertainty reduction and is a base for supply chain reconfiguration to mitigate risk – to build and use the Plan B. Additionally managers declare that technologies that reduce uncertainty and unpredictable factors, minimize the risk of their occurrence and impact on the functioning of the supply chain would gain in importance in the supply chain further management. It is becoming important to increase the use of digital technologies in the pursuit of digitization of the supply chain common to all partners in order to improve flexibility and the possibility of rapid reconfiguration. This implies a change in management strategy, renegotiation (change) of trade agreements as well as transformations in the supply policy.

Technologies are a tool supporting the diversification of the offer, and their systemic implementation in the supply chain processes limits the set of risks appearing on the demand and supply side. Accelerated digitization also stimulates the acquisition of new knowledge and competences among supply chain managers. In this way, new technologies can play a special role in the risk management not only because of supporting the ability to survive in the short term – in the event of crisis, but also because of the impact on the development and competitiveness in the long term. Big Data, in combination with Blockchain and their properties are also important tool helping to leverage the smart Plan B in terms of building resilient, hermetic and safe supply chain business model.

LIMITATIONS AND FURTHER RESEARCH

This article aims to contribute to broadening the discussion about effects of the COVID-19/SARS-CoV-2 pandemic and its impact on disruptions in global supply chain networks. The research has been limited to Polish enterprises, but they are a contrasting example of the disruptions occurrence and increasing the role and importance of sharing information with all partners to use a set of the most appropriate actions to maintain the assumed logistics effects. It turns out that the enterprises, that built Plan B are in a much better position than those that have not made such an effort. The empirical material presented supports other emerging studies, for example the „EuroLogistics" probe with the target group of logistics company managers, titled „Logistics market during the Covid-19 pandemic", No. 1, Week 14/2020. Similar studies were undertaken in March 2020 by other authors. However they concentrated on households [Diertrich, Kuester, Muller, Schoenle, 2020] or on relations to the economy [Baker, Bloom, Davis, Terry, 2020].

The dynamics of the environment in which enterprises find themselves means that the situation from this March is radically different in the following months. This is mainly due to the fact that the governments of many countries are taking a number of activities to shield the economy from the negative effects of a pandemic (e.g. by aid programs in Poland: "Shield 1.0", "Shield 2.0" or "Shield 3.0" or a comprehensive package of the European Union "Next Generation EU" for 2021-2024). Therefore it would be important to monitor the situation from the companies' perspective, but – more importantly from the perspective of whole supply chain and its resilience in terms of developing smart Plan B into the risk management portfolio.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

Authors are grateful to the respondents of the empirical research for their participation in the study. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Ankarali H., Ankaralli S., Caskurlu H., Cag Y., Arslan F., Erdem H., Vahaboglu H., 2020. A Statistical Modeling of the Course of COVID-19 (SARS-CoV-2) Outbreak: A Comparative Analysis. Asia-pacific Journal of Public Health. http://doi.org/10.1177/1010539520928180

Baker S.R., Bloom N., Davis S.J., Terry S.J., 2020. Covid-induced economic uncertainty, National Bureau of Economic Research, Working Paper 26983, Cambridge. http://doi.org/10.3386/w26983.

Chakraborty I., Maity P., 2020. COVID-19 outbreak: Migration, effects on society, global environment and prevention. Science of The Total Environment, Vol. 728, 138882, http://doi.org/10.1016/j.scitotenv.2020.138882.

Cichosz M., Marzantowicz Ł., Nowicka K., Pluta-Zaremba A., 2020. Zmiany w kanałach dystrybucji dóbr konsumpcyjnych wynikające z pandemii COVID-19 – perspektywa krótko- i średnioterminowa [Changes in consumer goods distribution channels resulting from the COVID-19 pandemic - short and medium term], Open Eyes Economy Summit. [Online] Available at: https://oees.pl/wp-content/uploads/2020/04/EKSPERTYZA-8.pdf [Accessed 15 04 2020].

Dietrich A.M., Kuester K., Muller G.J., Schoenle R.S., 2020. News and Uncertainty about COVID-19: Survey Evidence and Short-Run Economic Impact. Federal Reserve Bank of Cleveland, Working Paper 20-12. http://doi.org/10.26509/frbc-wp-202012.

Eisenhardt K.M., Graebner M.E., 2007. Theory Building from Cases: Opportunities and Challenges, Academy of Management Journal, 50, 1, 25-32, http://doi.org/10.5465/amj.2007.24160888.

Logistics market during the Covid-19 pandemic, 1, Week 14/2020, EuroLogistics.

Frankowska M., Nowicka K., 2018. Smart Supply Chain – challenges of information-driven management, European Journal of Service Management, 1 (25), 91–97. http://doi.org/10.18276/ejsm.2018.25-11.

Hobbs, J. E., 2020. Food supply chains during the COVID-19 pandemic. Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie. Wiley, http://doi.org/10.1111/cjag.12237.

Ivanov D., 2020. Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. Transportation Research, Part E: Logistics and Transportation Review, 136, 101922, http://doi.org/10.1016/j.tre.2020.101922.

Kaczmarek T.T., 2005. Ryzyko i zarządzanie ryzykiem: ujęcie interdyscyplinarne [Risk and risk management: interdisciplinary approach], Difin, Warszawa.

Marzantowicz Ł., 2019. Cyfrowe innowacje w świetle ryzyka i niepewności [Digital innovations in the light of risk and uncertainty], [in:] K. Nowicka, ed., Biznes cyfrowy. Perspektywa innowacji cyfrowych, [Digital business. Digital innovation perspective], Oficyna Wydawnicza SGH, Warszawa, 153, 174.

Marzantowicz, Ł., 2017. Niepewność i nieprzewidywalność w łańcuchu dostaw – rozważania teoretyczne [Uncertainty and unpredictability in the supply chain – Theoretical considerations], Nauki o Zarzadzaniu, 2 (31), 62-70, http://doi.org/10.15611/noz.2017.2.09.

Nowicka K., 2019. Digital innovation in the supply chain management, Research Papers of Wrocław University of Economics, 63, 8, http://doi.org/10.15611/pn.2019.8.16.

Nowicka K., 2019. E-supply network management - unused potential?, [in:] SMART Supply Network, A. Kawa, A. Maryniak, eds., Springer International Publishing AG, Cham, http://doi.org/10.1007/978-3-319-91668-2.

Nowicka K., 2018. Trust in Digital Supply Chain Management, Logistics & Transport, 39, 2. http://doi.org/10.26411/83-1734-2015-3-39-3-18.

Pérez-González C.J., Colebrook M., Roda-García J.L., Rosa-Remedios C.B., 2019. Developing a data analytics platform to support decision making in emergency and security management, Expert Systems with Applications, 120, http://doi.org/10.1016/j.eswa.2018.11.023.

Poirier D., Scott S.D., Tompkins J., 2020. Navigating your business through the COVID crisis: 'Black swan' disruption requires the right response to survive, thrive. Industrial & Systems Engineering at Work. Jun2020, 52, 6, 40-45.

Ramelli, S., Wagner, A., 2020. What the stock market tells us about the consequences of COVID-19. [Online] Available at: https://voxeu.org/article/what-stock-market-tells-us-about-consequences-covid-19 [Accessed 15 05 2020].

Rutkowski K, 2015. Rekonfiguracja międzynarodowych łańcuchów dostaw jako narzędzie zapobiegania zagrożeniom kryzysowym – szansa dla Polski [Reconfiguration of international supply chains as a tool to prevent crisis threats - an opportunity for Poland], Research Papers of Wrocław University of Economics, 382, 92-104, http://doi.org/10.15611/pn.2015.382.07.

Stephany, F., Stoehr, N., Darius, P., Neuhäuser, L., Teutloff, O., Braesemann, F., 2020. The CoRisk-Index: A data-mining approach to identify industry-specific risk assessments related to COVID-19 in real-time. arXiv preprint arXiv:2003.12432.

Tang, Y., Wang, S., 2020. Mathematic modeling of COVID-19 in the United States, Emerging Microbes & Infections, 9:1, 827-829, http://doi.org/10.1080/22221751.2020.1760146.

Toma S.V., Chitita M., Sarpe D., 2012. Risk and Uncertainty, Procedia Economics and Finance, 3. 975, http://doi.org/10.1016/S2212-5671(12)00260-2.

Vilko J., Ritala P., Edelmann J., 2014. On uncertainty in supply chain risk management, The International Journal of Logistics Management, 25, 1, http://doi.org/10.1108/IJLM-10-2012-0126.

Volpert, V., Banerjee, M., d'Onofrio, A., Lipniacki, T., Petrovskii, S., Tran, V. C., 2020. Coronavirus–Scientific insights and societal aspects. Math. Model. Nat. Phenom. 15 E2, http://doi.org/10.1051/mmnp/2020010.

Ziegler, C. G., Allon, S. J., Nyquist, S. K., Mbano, I. M., Miao, V. N., Tzouanas, C. N.,… & Feldman, J. (2020). SARS-CoV-2 receptor ACE2 is an interferon-stimulated gene in human airway epithelial cells and is detected in specific cell subsets across tissues. Cell. 181, 5, 1016-1035, http://doi.org/10.1016/j.cell.2020.04.035.

INTELIGENTNY „PLAN B" - W OBLICZU ZAKŁÓCEŃ W ŁAŃCUCHACH DOSTAW W 2020

STRESZCZENIE. **Wstęp:** Konkurencyjne zarządzanie łańcuchem dostaw to zdolność nie tylko do podjęcia działań naprawczych w stosunku do ryzyka, ale przede wszystkim do zapobiegania takiej sytuacji na co dzień. Zarządzanie ryzykiem jest kluczowym elementem zarządzania przedsiebiorstwem i jednym z najważniejszych czynników wpływających na odporność łańcucha dostaw. Obecnie menedżerowie mają dostęp do wielu narzędzi, tj. technologie cyfrowe, wspierające opracowywanie planów awaryjnych (Plan B) w celu ograniczenia ryzyka. Celem artykułu jest określenie odporności łańcucha dostaw w zakresie zarządzania ryzykiem na początku rozprzestrzeniania się pandemii COVID-19 / SARS-CoV-2 w 2020 r. Wskazano tutaj najważniejsze czynniki wpływające na stabilność przepływów w łańcuchu dostaw wraz z oceną ich przygotowania do pojawiających się zakłóceń w tych przepływach.
Metody: Teoretyczne podstawy opierają się na przeglądzie literatury dotyczącej zakłóceń zarządzania łańcuchem dostaw. Do przeprowadzenia badań wykorzystano metodę pogłębionych wywiadów indywidualnych (IDI) podpartych kwestionariuszem. Badania przeprowadzono wśród menedżerów odpowiedzialnych za operacje łańcucha dostaw w przedsiębiorstwach z sektora produkcji, handlu i usług w Polsce. Uzyskano i przeanalizowano opinie na temat wpływu pandemii koronawirusa na zarządzanie łańcuchem dostaw. Ankieta została przeprowadzona w marcu 2020 r.
Wyniki: Uzyskane wyniki pokazują, że pierwsza faza pandemii rozprzestrzeniła się nieoczekiwanie silnie i wpłynęła na zakłócenia w łańcuchach dostaw. Zamknięte granice, ograniczenia sanitarne i administracyjne doprowadziły do opóźnień w transporcie, dodatkowo odnotowano mniejszą liczbę zamówień skutkującą dalszymi zmianami w przepływach towarów. Jak się okazało negatywne skutki zakłóceń następowały nawet wtedy, gdy menedżerowie deklarowali pogłębioną współpracę i dzielenie się informacjami między partnerami w łańcuchu dostaw.
Wnioski: Wyniki badań wskazały na kluczowy problem związany z brakiem „planu B", który pomaga łańcuchom dostaw szybko reagować na zakłócenia w przepływach. Także zarządzanie ryzykiem w oparciu o obecny sposób udostępniania informacji jest niewystarczające. Funkcje technologii cyfrowych i digitalizacja są obecnie jednym z najważniejszych rozwiązań, które mogą pomóc w budowie inteligentnego „planu B" w celu ograniczenia ryzyka i poprawy konkurencyjności łańcucha dostaw.

Słowa kluczowe: zarządzanie ryzykiem łańcucha dostaw, wpływ COVID-19 / SARS-CoV-2 na łańcuch dostaw, technologie cyfrowe w ograniczaniu ryzyka

Łukasz Marzantowicz
SGH Warsaw School of Economics
Collegium of Business Administration
Department of Logistics
ul. Niepodległości 162, 02-554 Warszawa, **Poland**
e-mail: lukasz.marzantowicz@sgh.waw.pl

Katarzyna Nowicka ORCID ID: https://orcid.org/0000-0001-7830-7457
SGH Warsaw School of Economics
Department of Logistics
Al. Niepodległości 162, 02-554 Warsaw,, **Poland**
e-mail: katarzyna.nowicka@sgh.waw.pl

Mariusz Jedliński
Maritime University of Szczecin
Faculty of Economics and Transport Engineering
Department of Management and Logistics
ul. H.Pobożnego 11, 70-507 Szczecin, **Poland**
e-mail: m.jedlinski@am.szczecin.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (4), 503-519

http://doi.org/10.17270/J.LOG.2020.495

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

CORPORATE MATURITY DESIDERATA IN THE FACE OF THE COVID-19 PANDEMIC – THE DIGITAL PLANE OF LOGISTICS MICROFOUNDATIONS

Przemysław Niewiadomski

Uniwersytet of Zielona Góra, **Poland**

ABSTRACT. **Background:** In the light of the economic slowdown and significant strategic uncertainty resulting from the currently prevailing SARS-Cov-2 epidemic crisis, it is reasonable to undertake research to identify key competences that are relevant to the continuity of the supply chain functioning. The logistics processes in their current shape will undergo a significant change. Therefore, based on a widespread discussion that has been recently taking place in the environment of scientists, politicians, local government officials and management practitioners, the question once again arises about the level of preparation of enterprises for functioning in this specific environment. Aiming to fill the existing gap in knowledge, a series of studies was conducted, the main purpose of which was to recognize key competences from the point of view of existence in the conditions triggered by the COVID-19 crisis. Considering the empirical evidence confirming the existence of a strong relationship between company stability and an effective supply chain, the following research direction aggregates logistic microfoundations to the attribute of a "mature" enterprise.

Methods: Referring to the outlined objective, using the method of reconstruction and interpretation of the literature on the subject, it was recommended to nominate questions assessing the level of maturity of logistics subsystems (theoretical layer) as a necessary action. At the conceptual (design) level, it was crucial to compile the research tool being the resultant of the related literature exploration (theoretical model) and discussion among deliberately selected experts ("virtual" brainstorming). At the empirical level, this enabled the recognition of competences that determine the survival of enterprises in crisis conditions, and thus allowed the development of recommendations for managers of manufacturing enterprises.

Results: The paper proposes a procedure and a tool to identify key capabilities that determine the survival of enterprises in COVID-19 crisis conditions. The brainstorming research model reflects the areas of digital technology that the manufacturers, in the context of the current pandemic, should absorb (coincidence). Moreover, it was established that the process of economic recovery will take place in cooperation with enterprises absorbing the logistic management model based on digital technologies. To sum up, it should be noted that the maturity of such an enterprise is manifested in the use of descriptions defined in the research, not only in terms of production, but also in the entire supply chain. All these activities need to be harmonized, creating a crisis-proof enterprise. The organization of such an enterprise is characterized by delegating as many tasks as possible to competent employees who, using the knowledge and available digital technologies, add value throughout the entire chain.

Conclusions: The results of the research confirmed the author's belief that on the one hand digital technologies imply the possibility of surviving in the face of the crisis caused by COVID-19 (continuity of the supply chain, remote work without participation, or with limited human participation, etc.), on the other, implemented by enterprises, can be a kind of "protective shield" against the negative effects of a pandemic; from the perspective of the issue taken in the research work, they determine the maturity of the company's logistics subsystems. It seems that relatively small scientific recognition and complexity of problems occurring in business practice justify treating the COVID-19 issue as the subject of research, which is reflected in this publication.

Key words: COVID-19, maturity, logistics subsystems, agricultural machinery sector.

Citation: *Niewiadomski P., 2020. Corporate maturity desiderata in the face of the COVID-19 pandemic – the digital plane of logistics microfoundations. LogForum 16 (4), 503-519, http://doi.org/10.17270/J.LOG.2020.495*

Received: 15.05.2020, Accepted: 22.07.2020, on-line: 18.09.2020.

INTRODUCTION

Facing the constant uncertainty and crisis situations, the concept of "maturity" is becoming increasingly popular in logistics management [Rohloff 2009; Cronemyr and Danielsson 2013; Wendler 2012]. It develops gradually as a result of a process during which progressive digitization significantly determines the implementation of daily tasks. It is the result of the accumulation of many factors, among which logistic subsystems responsible for the effective implementation of the flow of products from the supplier to the customer can be listed. Therefore, especially in the face of the economic slowdown and significant strategic uncertainty resulting from the SARS-Cov-2 epidemic crisis, it is reasonable to undertake research to identify key competences that are important from the point of view of supply chain continuity, and thus implying the possibility of survival in the pandemic conditions. An indispensable action is therefore the recognition of abilities [Fawcett et al. 2011; Hammervoll, Leif-Magnus and Beske 2012; Wilden and Gudergan 2015] and competences [Antti and Greenhalgh 2012; Quintana, Ruiz, and Vila 2014], which on the one hand will allow companies to limit the negative impact of the pandemic, but on the other hand may be the basis for assessing their logistics subsystems.

To sum up, one can indicate the question: is there, at all, a need to measure maturity from the perspective of logistic microfoundations? Is such an assessment justified from the point of view of business practice? Assuming that the higher the level of maturity of individual microfoundations reflects the company, the greater the chance of survival (especially in the face of a crisis), and maybe even a chance of development (orientation on opportunities); the answer is affirmative. The research on the maturity of logistics microfoundations is quite difficult, nevertheless the paper attempts to recognize it, which may imply the development of recommendations for managers of manufacturing enterprises.

In relation to the above, the main purpose of the work was to recognize key competences from the point of view of existence in the conditions of the crisis caused by COVID-19. Referring to the outlined objective, using the method of reconstruction and interpretation of the literature on the subject, it was recommended to nominate questions assessing the level of maturity of logistics subsystems (theoretical layer) as a necessary action. At the conceptual (design) level, it was crucial to compile the research tool being the resultant of the related literature exploration (theoretical model) and discussion among deliberately selected experts ("virtual" brainstorming). On an empirical level, this enabled: (1) recognizing competences that determine the survival of enterprises in the conditions of the crisis, (2) identifying the catalogue of activities that should absorb enterprises, (3) developing recommendations for managers of manufacturing enterprises.

The gathered research material enabled to draw conclusions of a general and cognitive nature. The paper proposes a procedure and a tool that allowed to identify key capabilities and competences, which determine the survival of enterprises in crisis conditions. The solutions desirable from the experts' point of view were identified, on the one hand implying the minimization of the negative impact of the pandemic, and on the other, underpinning the assessment of their maturity, which, according to the author, will contribute to filling the knowledge gap in the presented scope. The material collected in the research procedure made it possible to verify the adopted presumptions; the above confirmed in the entire conducted theoretical and empirical argument. Hence, in the face of the COVID-19 pandemic, manufacturers should exhibit a relatively high level of technological organization (digitization), especially within procurement logistics and customer service logistics (P1). What is more, the brainstorming research model reflects the areas of digital technology that the manufacturers, in the context of the current pandemic, ought to absorb (P2). It was established that the process of economic recovery will take place in cooperation with enterprises absorbing the logistic management model based on digital technologies (P3).

The results of the research confirmed the author's belief that on the one hand digital technologies imply the possibility of surviving in the face of the crisis caused by COVID-19 (do not disrupt the supply chain, remote work without participation, or with limited human participation, etc.), on the other, implemented highly by the studied enterprises, are a kind of "protective shield" against the negative effects of a pandemic, and from the perspective of the issue taken in the research work, they determine the maturity of the company's logistics subsystems.

The presented pieces of research do not exhaust the raised problems; however it is important that they at least should be a guide for those who want to survive in the face of the upcoming recession and limitations in the supply chain. It seems that relatively small scientific recognition and complexity of problems occurring in business practice justify treating the COVID-19 issue as the subject of research, which is reflected in this publication.

MATURITY OF LOGISTICS MICROFOUNDATIONS – A STARTING POINT

According to the author of the paper, the problems with assessing maturity occur mainly due to the fact that in management and quality sciences there are a multitude of different fields, trends, approaches, schools of thought, and approaches incompatible with each other. Therefore, the first step in determining the theory of maturity should be the adoption of a new theoretical framework where one could logically group together the statements that make up the theory of maturity management. Difficulties in measuring maturity also arise from the fact that individual researchers creating lists of assessment criteria usually come from literature descriptions; there is no reference to practical needs in this area. The author ascertains that the diagnosis of such criteria is too general, artificial and hardly legible, not to say detached from reality. It should be borne in mind that environmental conditions change over time, and therefore the features of maturity should be modified situatively, in line with current market requirements, which can also be observed in reference to the SARS-Cov-2 pandemic.

When assessing the maturity of logistics subsystems, a number of methodological problems must be solved. How to design a maturity assessment system by referring it to individual logistic subsystems? How to construct maturity assessment indicators? How and with what frequency to measure it? How to analyse the obtained results? These are the most common questions that researchers and entrepreneurs seek answers to. From this point of view, the attempts made in the study to capture significant desiderata appear justified.

One of the most important problems associated with determining an unvalued maturity assessment is establishing the power of the created set of features. The set of features may contain quantitative features, whose states can be expressed in the form of numbers. In this case, particular criteria are given weight. It is necessary to obtain information from the decision-maker regarding the validity of the criteria, as the information may be subjective. Also, linguistic features might occur. Their states can be expressed in words, terms, sentences, which are most often gradable. The linguistic method of determining quality is based on the semiotic assumptions of the adopted language of description and first of all concerns the formulation of the content of each feature taken into account.

Achieving growing maturity through the improvement of logistics subsystems should be treated as a cyclical activity, which is focused on the constant search for more and more effective and more efficient abilities, competences or solutions adequate to emerging problems. In this sense, maturity means a state of readiness to implement certain activities. It is about the ability of an organisation and processes implemented by it to systematically provide better and better activity outcomes. This determines the degree to which all resources and competences of the organization are optimally allocated in stable processes that enable the organization to function. An enterprise is mature if its logistic subsystems can be considered mature from a qualitative point of view. Maturity is gradually developed as a result of improvement, during which the desired abilities and competences are shaped to perform specific tasks.

The maturity of logistics microfoundations is relatively difficult to define. There is a multitude of definitions, there is no homogeneity, and sometimes different phenomena are defined using the same concept. Consequently, this leads to many misunderstandings in the interpretation of the concept. Management theory and practice shows that there is still a long way to accept one commonly accepted definition. Therefore, it is recommended to use definitions that are meaningful in the context of organizational conditions and can be used consistently in conducted research.

A mature logistics system implies supply chain continuity, especially in a dynamic, turbulent, unstable and uncertain environment. It is adequate to the conditions in which contemporary enterprises have to function. An expression of the system's maturity may be an immediate response to the need for changes in internal management systems, including shortening life cycles of not only technologies but also products, transition of many functions to the area of e-business, or implementation of innovations in individual subsystems. A mature logistics system is flexible, allows for introducing improvements and changes, and ensures business continuity. Therefore, it allows efficiently manage the organization so as to focus on actions and activities that bring the greatest added value and eliminate those activities and activities that at a given moment generate only high costs without bringing measurable benefits to the company.

The maturity of logistics systems today is one of the areas of logistics management discussed in theory as well as used in practice. This is one of many coherent and holistic management methods that are currently used. The author hopes that this idea is not a short-lived fashion, but a new approach to doing business.

Summing up, there is undoubtedly a confusion that sometimes leads to contradictory opinions, and even disputes about what the maturity of logistics systems really is, and thus what desiderata should describe it. This knowledge gap was the germ of this publication.

MATERIAL AND RESEARCH METHODOLOGY

Questions and presumptions

In-depth studies in the area of the problem studied above, own observations of economic practice and conducted empirical research conducted so far led to the formulation of specific questions, the solution of which was the answer to the main problem:

– What direction of strategic orientation should Polish manufacturers designate?
– What level of technological organization (digitization) in the area of logistics subsystems should reflect manufacturers operating in the Polish agricultural machinery sector?
– Which of these digital solutions should be absorbed by manufacturers in the face of the pandemic?
– What tools supporting logistics management, in the context of COVID-19, are crucial from the point of view of not disrupting the supply chain?

The formulated questions and belief on the existence of economic demand for results of application nature on the one hand were the main inspiration to undertake the research, while on the other, they became the starting point for formulating the below presumptions:

P1: In the face of the COVID-19 pandemic, manufacturers should exhibit a relatively high level of technological organization (digitization), especially within procurement logistics and customer service logistics.

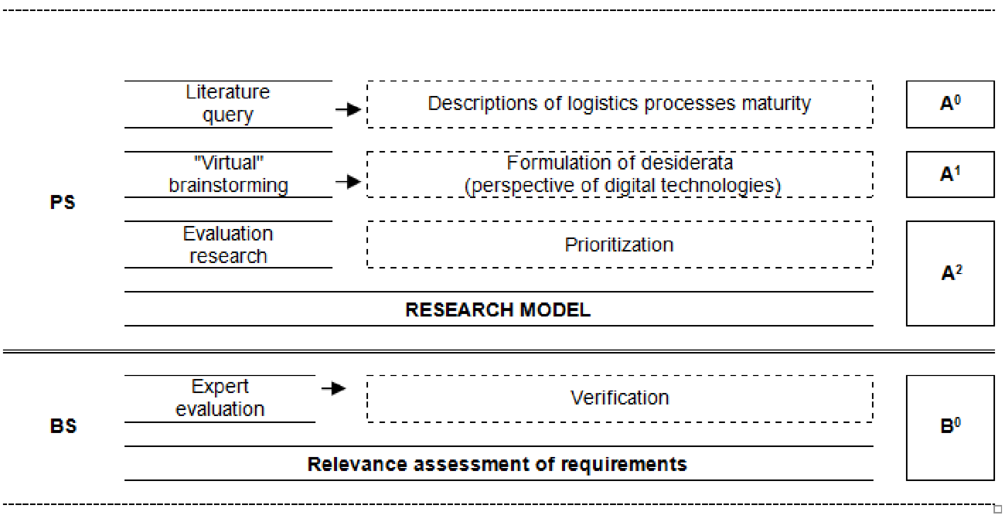
P2: The flexibility of the production process, also in the face of the COVID-19 pandemic, determines the application of solutions that are proper for the Lean Management concept.

P3: The research model resulting from the expert discussion reflects the desired directions of activities that in the face of COVID-19 should be absorbed by the surveyed enterprises. (research coincidence).

P4: The business model, in which digital technologies are the reference point, should imply the possibility of remote work, flexibility of working time organization forms as well as automation of supply, distribution and sales processes.

Research implementation scheme

In order to obtain objective information on the maturity of logistics subsystems, on the one hand, considered from the perspective of capabilities and competences, and on the other, implying the degree of probability of survival of enterprises in the face of COVID-19, a series of identifying studies, including the preparatory study [PS], was designed, including interpretation of the literature [A0], "virtual" expert discussion (brainstorming) [A1], expert study (evaluation team) [A2] and basic study (verification) [BS] including interviews in micro, small, medium and large manufacturing companies [B0]. The above is shown in Figure 1.



Source: own study

Fig. 1. Research implementation scheme

Formulation of the research model [PS]

Achieving the purpose of the work required – in the first place – to compile a catalogue of microfoundations that significantly identified the maturity of logistics systems. The research technique that was chosen to collect primary data oriented at the development of the research model was the reconstruction and interpretation of the literature related to the subject among others: [Lasi at al. 2014; Gibson, et al. 2015; Schmidt at al. 2015; Asdecker, Felch 2018; Du et al. 2019; Zhu et al. 2020; Yue et al. 2020; Wang et al. 2020; McKibbin and Fernando 2020]. Such action – at the design level – made it possible to compile a general catalogue of competences underlying the design of the research tool in the form of an assessment sheet; the preparatory study conditioned the conduct of the actual study. In order to verify the accuracy of the selection of individual desiderata, another study was conducted using brainstorming. As outstanding experts were needed to identify competences, a number of guidelines were adopted in the methodology for selecting a creative team. It was assumed that the basic value of expert knowledge would be based primarily on the so-called "best practices", i.e. examples of the practical application of knowledge.

A representative number of experts was selected to ensure the adequacy of expert assessments. When selecting experts, the key requirement was competence and experience in the area highlighted by the study. As the precision of decisions and assessments made by a small expert group can be considered as reliable as the evaluation of a large group, only 13 people were invited to the study (Table 1), although the experts' high level of knowledge allowed limiting their number to even five.

Table 1. Characteristics of the experts

EXPERT	Age				Education			Company size			Nature of production				Business form			Production process	
	31 to 40 yrs	41 to 50 yrs	51 to 60 yrs	above 60 yrs	Higher	Secondary	Vocational	Low	Medium	Large	Unit	Short-series	Mass	Batch	Self-employed	General partnership	Limited liability company	Own production	External production
A.S.				X		X				X				X			X	X	X
B.K				X			X		X		X	X	X			X		X	
B.P.	X				X				X		X	X		X			X	X	
B.W.	X				X			X				X			X			X	X
D.W.			X				X	X			X	X			X			X	X
G.W.				X	X			X				X			X			X	
H.K.			X		X				X		X	X			X			X	
I.K.		X			X				X			X	X			X		X	
M.S.			X			X			X				X		X			X	X
P.L.		X			X					X			X				X		X
P.N.		X			X			X			X	X			X			X	X
T.K.	X				X				X		X	X			X			X	
T.P				X		X			X			X		X			X	X	

Source: own development

In order to carry out expert research, a coordinator (author of the publication) was appointed, whose task was to organize the resources necessary to implement the project. At this stage, it was vital to establish a creative thinking team and ensure project sustainability until the implementation of selected ideas. Also, the preparation and dissemination of information on the research among the interested parties, taking into account the quarantine related to the present situation, was not a simple task. Due to the inability to organize a direct meeting, the so-called "Virtual" brainstorming was applied. Access to the "virtual" brainstorm system was possible through a computer connected to the Internet via a web browser, which allowed the application to become independent of the operating system. The use of IT tools eliminated the difficulties associated with organizing and conducting idea generating sessions. The combination of traditional group work methods with a computer system has created the opportunity to organize a meeting "on the web" and has influenced the positive effects of the search for ideas. Thanks to this solution – in order to select the best group of ideas – each invited user could present their suggestions (brainstorming), and other members of the "virtual" community could debate it (selection of ideas). After the end of the session, the author summed up the obtained results. The research coordinators wrote down all the listed competences, confronted them with the proposals of selected researchers, grouped similar ideas, which later on allowed to determine the final list of 61 resources and competences, which in the COVID-19 perspective may prove to be crucial from the viewpoint of the functioning of the supply chain.

The competences identified in the literature and design studies were further verified in the research procedure. In order to be able to discuss the key ones (constituting the strongest determinants of maturity), it was necessary to reduce them by the method of expert organization (hierarchy/prioritization of importance implied by the current functioning conditions); it was assumed that the introduction of such a large number of variables would definitely complicate and prevent the formulation of significant conclusions. To achieve this goal, it was decided to conduct an additional preliminary study. To this end, an evaluation team, consisting of 6 purposely selected experts, was established (Table 2). The evaluation team was only composed of specialists involved in the problem being solved, which was verified on the basis of the competence coefficient determined according to the following relationship:

$$X = \frac{1}{2}(K_i+K_a) \qquad (1)$$

where $0 < K \geq 1$

Informativeness coefficient (Ki) was determined on the basis of an expert's self-assessment (from 0 to 10 points) multiplied by 0.1. The argumentation factor (Ka) was determined on the basis of an interview with a given expert. Competence expressing the expert's level of qualification in the field was determined on the basis of the expert's creative analysis, knowledge of the field and understanding of the issues raised in the paper.

Table 2. Characteristics of the evaluation team experts

Institution / Position	Symbol	Specialisation	^{W}K
Owner of a manufacturing company in the agricultural machinery sector (Fortschritt)	G.W.	Organization and Management	0.9
Supplier Relationship Manager (Granit Parts)	J.K.	Optimization of purchasing processes, integrated cost reduction; building relationships with suppliers	0.95
University Professor (University of Zielona Góra)	P.N.	Supply chain management	0.8
Centrum Superkomputerowo-Sieciowe (IT centre)	K.K.	Modelling of advanced applications, scheduling and resource management.	1.0
Vice director (Marshal's Office of the Greater Poland Province)	M.K.	Greater Poland development strategy and province program projects	0.8
IT Director –E-commerce (Internet Plus)	B.M.	SEO (positioning), PPC (on-line advertising), social media, copywriting, Web developers, link building.	1.0

Legend: ^{W}K - *Competency coefficient (expresses the relationship between the informativity coefficient [Ki] (knowledge of a given issue) and argumentation coefficient [Ka]).*

Source: own development

Based on expert suggestions, a list was drawn up consisting of selected descriptions of the maturity of logistics microfoundations. Considering the need to take into account known and traditional ideas, as well as a large number of new and original proposals, the criterion of materiality (the context of the issue taken) was adopted as the key one.

Basic study [BS]

The effect of COVID-19 seems to be further accelerated digitization. In the face of the pandemic, the digital revolution is accelerating, and at the same time companies can self-assess and determine which Industry 4.0 desiderata they can regard as promising in the future, and which of them should be subject to improvement.

The basic research was carried out on a sample of 53 enterprises representing the agricultural machinery sector. Respondents were selected in a targeted manner, assessing their "added value" on the basis of creative analysis of their activities and implementation of the strategic goals of the company from which they originate or for which they act. The implementation of research with the participation of experts seems appropriate, especially in relation to those research areas that require advanced professionalisation (the author considers recognition of maturity in the face of the pandemic to be such an area). It should be emphasized that the area of research – specified in this paper – required those who take actions to have appropriate expertise (a randomly selected respondent may be deprived of it); especially since it concerns primarily problems in the field of professional activity. The application of expert interviews seems appropriate and desirable, bringing specific cognitive benefits and organizing the research process in a friendly and attractive way for the respondents themselves, which – from a 'qualitative' point of view – was also important.

The diagnosis was made among experts representing micro (11.32%), small (30.19%), medium (50.94%) and large (7.55%) manufacturing companies operating in the agricultural machinery sector. A group of people between 31 and 40 years old (32.08%) dominated among the respondents; 7.55% were respondents in the age group up to 30 years old, 28.30% of the respondents were between 41 and 50 years old, 20.75% were from 51 to 60 years old, 11.32% were over 60. The detailed results are shown in Table 3.

Table 3. Characteristics of experts in terms of age (N=53) – basic study (BS)

Bracket	Experts	
	Number	[%]
Uu to 30 years	N=4	7.55
31 to 40 yrs	N=17	32.08
41 to 50 yrs	N=15	28.30
51 to 60 yrs	N=11	20.75
above 60 yrs	N=6	11.32
In total:	N=53	100.00

Source: own development

Among the respondents, the group of persons with higher education clearly dominated (60.38%); 24.53% had secondary education, 15.09% had vocational education. Detailed characteristics are shown in Table 4.

Table 4. Characteristics of experts in terms of education (N=53) – basic study (BS)

Bracket	Experts	
	Number	[%]
Vocational	N=8	15.09
Secondary	N=13	24.53
Higher	N=32	60.38
In total:	N=53	100.00

Source: own development

Within the conducted research, an attempt was made to interpret the results and conduct a thorough analysis based on the respondents' declarations. A key stage was a description of the obtained data and its interpretation as highlighted in the further part of this publication.

RESULTS AND DISCUSSION

The descriptions identified in the literature and design studies were subjected to detailed verification. The collected results were analysed in terms of average values, while isolating those that were assessed by the respondents as important. In total, on this basis, a hierarchically compiled – according to the highest assigned significance/materiality (highest average) – model of resources, competences and tasks was determined, on the one hand determining the survival of enterprises in the conditions of COVID-19, on the other hand determining the maturity of logistics subsystems.

In the context of maturity assessment, seven descriptions were identified in the strategic management domain (Table 5).

The progressive increase in the difficulty and complexity of the operating conditions of modern enterprises affects the possibility of achieving the assumed action objectives. Making strategic decisions in conditions of uncertainty is implied by structuring the company's operations. The unpredictability of the environment affects the need to adapt short-term goals. Survival is considered to be the most general. Indeed, survival is a prerequisite for achieving the goals themselves, but survival in a rapidly changing environment translates into slow dying of the enterprise – by achieving the survival goal, the enterprise must also be focused on developing and implementing an expansion-oriented business model. Regardless of what strategic choice the company makes, the business model should be formulated based on certain principles. This is particularly important during the COVID-19 pandemic due to the fact that these entities often choose their goals instinctively, without using formalized pre-emptive strategy building processes.

Table 5. Strategic management – relevance assessment of requirements

Item	DESCRIPTIONS	1	2	3	4	5	Avg.
		%					
STRATEGIC MANAGEMENT	Redefining the key goals of the organization (current status)	1.0	3.0	3.0	20.0	26.0	4.26
		1.9	5.7	5.7	37.7	49.1	
	Structuring of the company's activity	1.0	3.0	8.0	21.0	20.0	4.06
		1.9	5.7	15.1	39.6	37.7	
	Development of short-term action plans	-	2.0	8.0	22.0	21.0	4.17
		-	3.8	15.1	41.5	39.6	
	Development and implementation of the currently defined business model	-	3.0	5.0	22.0	23.0	4.23
		-	5.7	9.4	41.5	43.4	
	Establishing project teams; using flexible forms of working time organization	-	1.0	6.0	21.0	25.0	4.32
		-	1.9	11.3	39.6	47.2	
	Introducing solutions supporting the management of own and team time (work scheduling)	-	1.0	6.0	22.0	24.0	4.30
		-	1.9	11.3	41.5	45.3	
	Introducing new management methods and techniques (management through goals, management through tasks, etc.)	-	2.0	6.0	18.0	27.0	4.32
		-	3.8	11.3	34.0	50.9	

Source: own development

The desired effect of COVID-19 seems to be further accelerated digitization. This means eliminating a reduction in availability. For the vast majority of companies, we can observe a more flexible time or work organization that will allow to combine work with other duties. One of the most important skills that a manager should demonstrate in the era of coronavirus is managing the project team. Both the manager and his/her team members should know the basic methods of project management and techniques for their practical application in everyday work. It is worth, therefore, that every company should have an implemented risk management procedure together with a list of the most common problems in the industry, or a need to monitor work progress, preparation of a change and risk management plan, as well as the ability to identify, analyse and address emerging issues, which helps to prevent negative effects in times of crisis.

One of the priorities in the times of pandemic is planning daily work. Currently, there are many methods and ways to better organize work. In the current circumstances, however, there is a problem with the implementation of all planned tasks and performance of duties. Although technological development in recent years has contributed to the gradual dissemination of work-support technologies, significantly during the pandemic period, the usefulness of tools supporting own and team time management (work scheduling), including improving communication and data exchange in this regard, is voiced. The changing environment of the organization, uncertainty and risk force companies to look for management methods and concepts that will guarantee the maximum use of their material (work, capital, land) and intangible (intellectual capital: human, structural, relationships, knowledge, brand) resources. Attention is drawn to the need to retain customers, increase employee responsibility, efficiency and effectiveness of organization processes, as well as to ensure the functioning of the supply chain. Therefore, the implementation of modern solutions supporting decision making in chaos conditions and the introduction of modern technologies implying the possibility of remote work and automation of logistics processes is crucial.

When assessing the level of maturity in the field of supply logistics, seven identifiers were highlighted (Table 6. Diversification of raw material supply sources, i.e. creating safe (stable) ways of obtaining them, especially in the face of a crisis, is an imperative task of every manufacturing enterprise. The scope (level) of diversification of supply sources should be adequate to a given situation. It is critical to ensure the stability of supplies in terms of timeliness, unchanging supply of raw materials and the awareness and certainty of the supplier's competence.

Table 6. Purchase management – relevance assessment of requirements

Item	DESCRIPTIONS	1	2	3	4	5	Avg.
		%					
SUPPLY LOGISTICS: PURCHASE POLICY	Supplier diversification (making the supply system more flexible)	-	-	4.0	19.0	30.0	4.49
		-	-	7.5	35.8	56.6	
	Qualification of suppliers	-	1.0	7.0	21.0	24.0	4.28
		-	1.9	13.2	39.6	45.3	
	Implementation of supply management procedures, i.e. accepting deliveries, verifying deliveries	-	2.0	7.0	19.0	25.0	4.26
		-	3.8	13.2	35.8	47.2	
	Management of material rotation, raw materials, semi-finished products in relation to the production offer and goods flows	1.0	2.0	7.0	17.0	26.0	4.23
		1.9	3.8	13.2	32.1	49.1	
	Introducing the purchase contracting model (obtaining priority order on the market)	1.0	-	5.0	18.0	29.0	4.40
		1.9	-	9.4	34.0	54.7	
	Implementation of the dynamic order flow management model (submission, verification and control of orders)	1.0	1.0	8.0	20.0	23.0	4.19
		1.9	1.9	15.1	37.7	43.4	
	Implementation of the purchasing group management model	-	2.0	9.0	22.0	20.0	4.13
		-	3.8	17.0	41.5	37.7	

Source: own development

Flexible adaptation to the situation only distinguishes the best suppliers. Increasing the order size, expediting the delivery date or expanding the product range of the order compose supply efficiency. The sustainability of solutions is of great importance in this case. Therefore, the qualification of suppliers plays a key role. When choosing a supplier, it is beneficial to get involved in long-term contracts, which will definitely allow to respond to the needs, especially in the event of unforeseen incidents. Qualifying suppliers affects the stability of the production process. Regardless of the situation, raw materials, production materials or components are likely to be delivered on time, in accordance with the adopted specification. In the context of a pandemic, it is postulated to have supply management procedures, i.e. accepting deliveries, verification (quantitative and qualitative, delivery statuses). It is reasonable to manage the rotation of materials, raw materials, semi-finished products in relation to the production offer and goods flows (achieving the priority of supply on the market). Among the surveyed companies, the need to introduce a purchasing contracting model, as well as a dynamic processing and order flow model (submission, verification and control of orders) can be noted. Aggressive enterprises appearing in the face of the crisis, which, among others, use low cost strategy, cause a situation that independent operation on the market becomes very difficult and risky. Grouping and creating multi-stakeholder organizations, such as purchasing/procurement groups, is becoming a very good solution. Motives arising from external threats and removal of internal difficulties associated with COVID-19 imply the legitimacy of creating a group, which jointly controls and improves material and information flows from suppliers. The use of mutual transactions allows to supplement material shortages, but above all to improve financial liquidity. Manufacturers can also take advantage of long trade credits granted by the central unit. They gain time to repay them and time to collect cash, which in the face of a pandemic significantly determines the possibility of their functioning.

When assessing maturity from the perspective of production logistics, seven descriptions were distinguished (Table 7).

Table 7. Production logistics – relevance assessment of requirements

Item	DESCRIPTIONS	1	2	3	4	5	Avg.
		%					
PRODUCTION LOGISTICS	Having a material base, own transport/logistics facilities	-	-	5.0	20.0	28.0	4.43
		-	-	9.4	37.7	52.8	
	Having new machines and devices, own manufacturing technologies	-	-	5.0	22.0	26.0	4.40
		-	-	9.4	41.5	49.1	
	Availability of own office/project team	-	2.0	8.0	22.0	21.0	4.17
		-	3.8	15.1	41.5	39.6	
	Active employees have the freedom to act	1.0	3.0	9.0	20.0	20.0	4.04
		1.9	5.7	17.0	37.7	37.7	
	Conducting research and development work	1.0	4.0	7.0	23.0	18.0	4.00
		1.9	7.5	13.2	43.4	34.0	
	Executive staff skills focused on multitasking; operation of many machines at the same time	1.0	1.0	5.0	20.0	26.0	4.30
		1.9	1.9	9.4	37.7	49.1	
	Ergonomics and safety in the field of applied technology and at the workstation	1.0	1.0	7.0	20.0	24.0	4.23
		1.9	1.9	13.2	37.7	45.3	
	Having technical means and automatic devices operating on the basis of self-control and operating without or with limited participation of human intervention.	1.0	2.0	4.0	16.0	30.0	4.36
		1.9	3.8	7.5	30.2	56.6	
	Production based on current demand resulting from orders; no actions based on forecasts	1.0	-	7.0	19.0	26.0	4.30
		1.9	-	13.2	35.8	49.1	
	The possibility of making tooling internally	1.0	2.0	7.0	16.0	27.0	4.25
		1.9	3.8	13.2	30.2	50.9	

Source: own development

In the context of the conducted research, attention was paid to the possibility of transferring the entire function of managing the manufacturing process to specialized devices, mainly computers, while partially leaving a certain range of these functions to people. This is especially important as one employee should operate several machines or several workstations at the same time. Therefore, all devices should work without the need of supervision; the ratio of the device's operating time to the service time must ensure handling another product. Attention should be paid to the correct determination of the technological process, the selection of starting materials as well as to machinery and equipment. The material stocks owned by the company that can be used in production processes ought to be taken into consideration too. It is imperative to own material base, transport and logistics facilities (it is postulated to keep inventory at 20% of annual demand). Also, much focus was placed on the implemented methods in the field of raw material processing, materials and objects, the manner tasks were performed and to have own machines, tools and devices used for processing and manufacturing. The implementation of the manufacturing process is favoured by the availability of own design team and the ability to execute internal tooling. The lack of ergonomics and safety at the workplace – especially in the era of a pandemic – is a significant barrier to the implementation of the manufacturing process. That is why it is fundamental to oblige employees to comply with the company's operating procedures that define the rules of conduct when performing specific tasks. The flexibility of a generating unit concerns the stage of production and is closely related to setting up the technological process and its implementation. The main conditions conducive to technological flexibility include the possibility of freedom of action for active employees, which is implied by the executive's understanding of the "lean" idea.

Taking up the maturity assessment from the perspective of customer service logistics, seven descriptions were distinguished (Table 8).

A system that efficiently implements all sales processes is the main factor affecting sales effectiveness in the conditions of overwhelming panic caused by coronavirus. Appropriate design of an application supporting customer service has a huge impact on the level of sales. Intuitive and easy-to-use sales platforms are very practical. Such an application should be fully scalable and allow for its easy expansion with further functionalities. One of the possibilities to improve its functionality are integration with outsourcing support or services offered by external suppliers, but also other IT systems and applications used in the company. Depending on the needs of the manufacturer, but also the expectations of buyers, such integration, e.g. automates certain activities, saves time and reduces business costs. It also contributes to better customer service and builds trust. Real-time data synchronization reduces the risk of misinformation and the occurrence of an error, which is very easy in a pervasive pandemic.

When assessing maturity from the perspective of warehouse management, six descriptions were distinguished (Table 9).

Table 8. Customer service logistics – relevance assessment of requirements

Item	DESCRIPTIONS	1	2	3	4	5	Avg.
		%					
USTOMER SERVICE LOGISTICS:	Having sales platforms that are open for integration (panels: orders, customer, products, marketing, content management (CMS), customer and relationship management (CRM)	-	-	4.0	18.0	31.0	4.51
		-	-	7.5	34.0	58.5	
	On-line store platforms integrated with other internal systems, such as: Warehouse Management Systems (WMS), Enterprise Resource Planning (ERP),	-	2.0	4.0	18.0	29.0	4.40
		-	3.8	7.5	34.0	54.7	
	Editable and individually developable sales platform; ease of administration and operation	1.0	2.0	4.0	16.0	30.0	4.36
		1.9	3.8	7.5	30.2	56.6	
	An on-line store platform integrated with supplier systems, logistics services, external partners, advertisers, agents, customers, etc.	1.0	-	3.0	15.0	34.0	4.53
		1.9	-	5.7	28.3	64.2	
	Sales platform enabling product architecture management (“virtualization ”of the offer)	1.0	2.0	5.0	17.0	28.0	4.30
		1.9	3.8	9.4	32.1	52.8	
	Availability of tools (including ICT) for contracting sales	1.0	3.0	5.0	19.0	25.0	4.21
		1.9	5.7	9.4	35.8	47.2	
	Availability of tools supporting electronic customer service; elements of transaction marketing	-	-	4.0	14.0	35.0	4.58
		-	-	7.5	26.4	66.0	
	Implementation of tools supporting communication with the customer; elements of relationship marketing	-	-	5.0	15.0	33.0	4.53
		-	-	9.4	28.3	62.3	
	Use of social media	-	1.0	7.0	17.0	28.0	4.36
		-	1.9	13.2	32.1	52.8	
	Dynamic mailing management (e-mail Automation)	-	2.0	7.0	17.0	27.0	4.30
		-	3.8	13.2	32.1	50.9	

Source: own development

Table 9. Warehouse logistics – relevance assessment of requirements

Item	DESCRIPTIONS	1	2	3	4	5	Avg.
		%					
WAREHOUSE LOGISTICS	Availability of Warehouse Management Systems (WMS), Enterprise Resource Planning (ERP), etc.	-	2.0	5.0	18.0	28.0	4.36
		-	3.8	9.4	34.0	52.8	
	Implementation of warehouse service standards (codification, cataloguing, bar codes, data collectors, data terminals, data flow automation); Optimization of internal warehouse logistics (product location, markings, entry, service and exit buffer)	-	2.0	5.0	15.0	31.0	4.42
		-	3.8	9.4	28.3	58.5	
	Introducing product base management functionality (item list, product groups and lines); integration with the sales platform	-	3.0	5.0	16.0	29.0	4.34
		-	5.7	9.4	30.2	54.7	
	Multidirectional data processing in the warehouse (minimum inventory, procurement of raw materials and materials); The functionality of dynamic management of inventory updates	1.0	1.0	5.0	16.0	30.0	4.38
		1.9	1.9	9.4	30.2	56.6	
	Standards for dealing with product defects at the level of assortment management (i.e. omissions, errors, low quality of products, incorrect markings, etc.)	-	3.0	6.0	17.0	27.0	4.28
		-	5.7	11.3	32.1	50.9	

Source: own development

The current trends in the field of warehouse services set directions in the field of automation of all kinds of work related to warehouse management. The basic tools of IT systems that support warehouse management are primarily Warehouse Management Systems (WMS). WMS class solutions are primarily used to coordinate warehouse work. They belong to highly specialized systems that streamline all processes in warehouses, which in the face of an existing pandemic greatly facilitates its functioning; especially during the period of increased number of diversified shipments directed to many recipients. WMS systems – with their technology – often support the Enterprise Resource Planning (ERP) management system. This system integrates key processes that take place in the company and provides a full picture of its activities. Efficient warehouse management, above all, means control over all processes taking place in the warehouse and proper handling of the accumulated inventory. The main activities are primarily the identification of goods arriving at the warehouse and proper storage, ensuring readiness for collecting and shipping in accordance with customer orders. Therefore, warehouse management should be supported by tools that imply its automation. In the context of the above, particular attention is paid to the implemented warehouse service standards (codification, cataloguing, bar codes, data collectors, data terminals, data flow automation). The new operating standards force the organization of product data and the implementation of solutions to facilitate product information management. All of it in order to develop even more towards the digitization of sales. In view of the above, there is much focus on the multi-directional data processing in the warehouse. The key feature is therefore the dynamic management of inventory updates. The implemented standards for dealing with product defects, as well as the optimization of the logistics system inside the warehouse (product location, markings, entry, service and exit buffer) are of particular importance. The proposed solutions allow the creation of product catalogues and their implementation in various sales and e-commerce channels. In this way, its main goal is achieved, i.e. content management in all channels and platforms from one administrative panel. Owing to which, one source of product information is available, which can then be shared with other IT systems, without the need to manually enter data in each channel again from the beginning. This enables the collection of diverse product data in one place, ensuring high quality information or faster and simpler creation as well as provision of descriptions that are attractive to recipients, which is a very important competence during a pandemic.

Table 10. Distribution logistics – relevance assessment of requirements

Item	DESCRIPTIONS	1	2	3	4	5	Avg.
		%					
DISTRIBUTION LOGISTICS	Integration of systems with external systems of freight forwarding companies supporting logistics (semi-automation or full automation of the order distribution process with the element of customer communication support, e.g. secondary statuses from operators, information on errors in delivery, operator flexibility in modelling shipment flow)	-	-	4.0	14.0	35.0	4.58
		-	-	7.5	26.4	66.0	
	Introducing the model of dynamic management of the progress path with the customer's order (flexible customer panel, statuses, notifications, feedback tools, etc.)	-	1.0	4.0	15.0	33.0	4.51
		-	1.9	7.5	28.3	62.3	
	Implementation of standards for exchanges and returns	-	2.0	7.0	16.0	28.0	4.32
		-	3.8	13.2	30.2	52.8	
	Introducing solutions in the field of order fulfilment and distribution, i.e. shipment	-	2.0	7.0	18.0	26.0	4.28
		-	3.8	13.2	34.0	49.1	
	Implementation of complaint management standards	-	2.0	6.0	18.0	27.0	4.32
		-	3.8	11.3	34.0	50.9	
	Introduction of packaging standards and preparation of final shipments. Workstation equipment and operation according to procedures	-	1.0	3.0	15.0	34.0	4.55
		-	1.9	5.7	28.3	64.2	

Source: own development

When assessing maturity from the perspective of distribution logistics, six descriptions were distinguished (Table 10).

The implementation of IT systems leads to an increase in the efficiency of enterprise service by rationalizing the forwarding department, concentrating all the most important logistics functions, as well as competences, in the organization and management of logistics processes. Moreover, IT systems supporting business management allow for ensuring high quality information used in decision-making processes. In this regard, attention is paid to the integration of systems with the external systems of freight forwarding companies handling logistics, use and application of standards for handling exchanges and returns, and the introduction of solutions in the field of order fulfilment and distribution. The standardization of complaint management and unified standards of packaging and preparation of final shipments is imperative. The complaint management process is one of the critical elements related to restoring the efficiency of sales processes. It affects the level of customer satisfaction and loyalty. It is also an element of communication with customers, which is why enterprises – of course not only during a pandemic – should treat this process with extreme care and use it as a strategic tool for business development.

SUMMARY AND CONCLUSIONS

Just as you cannot imagine the functioning of an enterprise without an adopted business model, it is impossible to build a mature logistics system without using modern technologies. This means that technologies, especially in the face of a pandemic, have become synonymous with an uninterrupted supply chain. The author hopes that research on the correlation between the degree of maturity of logistics subsystems and the productivity of enterprises contribute, even to a minimal extent, to the development of theoretical and empirical output, while generating consistent results regarding the direction and strength of this relationship. Thus, it is even more reasonable to propose a method of assessing maturity in this area.

This research paper might show companies the directions of introducing such solutions in the area of individual logistic subsystems, as the study indicates; with particular emphasis on digital competences that will ensure maximum productivity in the entire supply chain. Bearing in mind the current COVID-19 crisis, this is a desirable objective for management and quality sciences.

Table 11. Test results of the presumptions

Item	*Presumption*	*Test results*
P_1:	*In the face of the COVID-19 pandemic, manufacturers should exhibit a relatively high level of technological organization (digitization), especially within procurement logistics and customer service logistics.*	✓
P_2:	*The flexibility of the production process, also in the face of the COVID-19 pandemic, determines the application of solutions that are proper for the Lean Management concept.*	✓
P_3:	*The research model resulting from the expert discussion reflects the desired directions of activities that in the face of COVID-19 should absorb the surveyed enterprises.*	✓
P_4:	*The business model, in which digital technologies are the reference point, should imply the possibility of remote work, flexibility of working time organization forms as well as automation of supply, distribution and sales processes.*	✓

Source: own development

The gathered research material enabled to draw conclusions of a general and cognitive nature. The presumptions contained in the paper were fully confirmed by the theoretical and empirical arguments (Table 11).

To sum up, it should be acknowledged that the significance of digitization of logistics systems is considerable and cannot be underestimated by managers seriously thinking about effective action in such an uncertain environment in which manufacturers have to currently operate. These systems allow to streamline work, reduce operating costs or expedite manipulation, and thus determine the ability to perform specific tasks. Therefore, it is necessary to agree with the statement that comprehensive – open to integration – systems play the role of a catalyst that, on the one hand, protects the maintenance of an adequate level of customer service and the survival of an enterprise, and on the other is an indicator of its maturity in the area of individual logistics subsystems.

The presented research do not exhaust the issue of maturity in the logistics processes, nevertheless it is vital so that they at least could become a guide for those who want to make changes in their company. It seems that relatively small scientific recognition and complexity of problems occurring in business practice justify treating these issues as the subject of research, which is reflected in this publication.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

Statutory fund of University of Zielona Góra.

REFERENCES

Antti M., Greenhalgh N., 2012. Leadership competencies: a reference point for development and evaluation, Library Management, 33(6/7), 421-428. http://doi.org/10.1108/01435121211266249

Asdecker B., Felch V., 2018. Development of an Industry 4.0 maturity model for the delivery process in supply chains, Journal of Modelling in Management, 13, 4, 840-883, http://doi.org/10.1007/978-3-319-67383-7-10.

Cheshmberah M., Beheshtikia S., 2020. Supply chain management maturity: An allencompassing literature review on models, dimensions and approaches, LogForum, 16 (1), 103-116. http://doi.org/10.17270/J.LOG.2020.377.

Ciesielski M., 2011. Zarządzanie łańcuchami dostaw [Supply chain management], PWE, Warszawa.

Cronemyr P., Danielsson M., 2013. Process Management 1-2-3 – a maturity model and diagnostics tool, Total Quality Management & Business Excellence, 24, 7–8, 933-944. http://doi.org/10.1080/14783363.2013.791114

Du Z., Wang L., Cauchemez S., Xu X., Wang X., Cowling B.J., Meyers L.A, 2020. Risk for Transportation of 2019 Novel Coronavirus Disease from Wuhan to Other Cities in China. Emerg. Infect. Dis., 26 (5), 1049–1052. http://doi.org/10.3201/eid2605.200146

Fawcett S.E., Wallin C., Allred C., Fawcett A.M., Magnan G.M., 2011. Information technology as an enabler of supply chain collaboration: a dynamic-capabilities perspective, Journal of Supply Chain Management, 47(1), 38-59. http://doi.org/10.1111/j.1745-493X.2010.03213.x

Gibson D., Ostashewski N., Flintoff K., Grant S., Knight E., 2015. Digital badges in education. Educ. Inf. Technol., 20, 2, 403–410. http://doi.org/10.1007/s10639-013-9291-7

Hammervoll T., Leif-Magnus J., Beske P., 2012. Dynamic capabilities and sustainable supply chain management, International Journal of Physical Distribution & Logistics Management, 42(4), 372-387. http://doi.org/10.1108/09600031211231344

Lasi H., Fettke P., Kemper H., Feld T., Hoffmann M., 2014. Industry 4.0, Business &Information Systems Engineering, 6, 239-242. http://doi.org/10.1007/s12599-014-0334-4

McKibbin W.J., Fernando R., 2020. The Global Macroeconomic Impacts of COVID-19: Seven Scenarios, SSRN Electron. J., 1-43. http://doi.org/10.2139/ssrn.3547729

Quintana C.D.D., Ruiz J.G.M., Vila, L.E., 2014. Competencies which shape leadership, International Journal of Manpower, 35(4), 514–535. http://doi.org/10.1108/IJM-05-2013-0107

Rohloff M., 2009. Case study and maturity model for business process management implementation, International conference on BPM, Springer, Berlin-Heidelberg. http://doi.org/10.1007/978-3-642-03848-8_10

Schmidt R., Möhring M., Härting R. C., Reichstein C., Neumaier P., Jozinović P., 2015. Industry 4.0 - Potentials for Creating Smart Products: Empirical Research Results, [w:] Business Information Systems, W. Abramowicz (ed.), Springer International Publishing, Switzerland, 16-27. http://doi.org/10.1007/978-3-319-19027-3_2

Urbaniak M., 2010. Kierunki doskonalenia systemów zarządzania jakością [Directions of improvement of quality management systems], Wydawnictwo Uniwersytetu Łódzkiego, Łódź.

Wang C., Cheng Z., Yue X.-G., McAleer M., 2020. Risk Management of COVID-19 by Universities in China, Journal of Risk Financial Management, 13, 36, 2-6. http://doi.org/10.3390/jrfm13020036

Wendler R., 2012. The maturity of maturity model research: a systematic mapping study, Information and Software Technology, 54, 12, 1317–1339. http://doi.org/10.1016/j.infsof.2012.07.007

Wilden R., Gudergan S., 2015. The impact of dynamic capabilities on operational marketing and technological capabilities: investigating the role of environmental turbulence, Journal of the Academy of Marketing Science, 43(2), 181-199. http://doi.org/10.1007/s11747-014-0380-y

Yue X.-G., Shao X.-F., Li R.Y.M., Crabbe M.J.C., Mi L., Hu S., Baker J.S., Liang G., 2020. Risk Management Analysis for Novel Coronavirus in Wuhan, China, Journal of Risk Financial Management, 13, 22, 2-6. http://doi.org/10.3390/jrfm13020022

Zhu N., Zhang D., Wang W., Li X., Yang B., Song J., Zhao X., Huang B., Shi W., Lu, R. et al., 2020. A Novel Coronavirus from Patients with Pneumonia in China, New Engl. J. Med., 382, 727–733.

DEZYDERATY DOJRZAŁOŚCI PRZEDSIĘBIORSTW W OBLICZU PANDEMII COVID-19 - CYFROWA PŁASZCZYZNA MIKROFUNDAMENTÓW LOGISTYCZNYCH

STRESZCZENIE. **Wstęp:** W obliczu spowolnienia gospodarczego i znaczącej niepewności strategicznej będącej wynikiem panującego obecnie kryzysu epidemicznego SARS-Cov-2, zasadne jest podjęcie badań rozpoznających kompetencje kluczowe, istotne z punktu widzenia ciągłości funkcjonowania łańcucha dostaw. Procesy logistyczne w dotychczasowym kształcie ulegną bowiem istotnej zmianie. Dlatego też, na fali szerokiej dyskusji jaka się ostatnio toczy w środowisku naukowców, polityków, samorządowców czy praktyków zarządzania, po raz kolejny pojawia się pytanie o poziom przygotowania przedsiębiorstw do funkcjonowania w tym specyficznym otoczeniu. Dążąc do uzupełnienia istniejącej luki w wiedzy przeprowadzono cykl badań, których zasadniczym celem ustanowiono rozpoznanie kompetencji kluczowych z punktu widzenia egzystowania w warunkach kryzysu wywołanego COVID-19. Zważywszy na empiryczne dowody potwierdzające istnienie silnego związku pomiędzy stabilnością firmy a skutecznym łańcuchem dostaw, poniższy kierunek badań agreguje mikrofundamenty logistyczne do miana atrybutu „dojrzałego" przedsiębiorstwa.

Metody: W nawiązaniu do nakreślonego celu, wykorzystując metodę rekonstrukcji i interpretacji literatury przedmiotu, jako działanie niezbędne zarekomendowano nominowanie pytań opiniujących poziom dojrzałości podsystemów logistycznych (warstwa teoretyczna). Na płaszczyźnie koncepcyjnej (projektowej) kluczowe było skompilowanie narzędzia badawczego będącego wypadkową eksploracji piśmiennictwa (model teoretyczny) oraz dyskusji wśród celowo dobranych ekspertów („wirtualna" burza mózgów). Na płaszczyźnie empirycznej umożliwiło to rozpoznanie kompetencji przesądzających o przetrwaniu przedsiębiorstw w warunkach kryzysu i tym samym pozwoliło na opracowanie rekomendacji dla zarządzających przedsiębiorstwami wytwórczymi.

Wyniki: W pracy zaproponowano procedurę i narzędzie umożliwiające identyfikację kluczowych zdolności przesądzających o przetrwaniu przedsiębiorstw w warunkach kryzysu COVID-19. Model badawczy powstały w wyniku burzy mózgów odzwierciedla obszary technologii cyfrowej, które w kontekście obecnej pandemii powinni absorbować wytwórcy (koincyndencja). Ponadto ustalono, iż proces odbudowy gospodarki będzie odbywał się przy współudziale przedsiębiorstw absorbujących model zarządzania logistycznego oparty na technologiach cyfrowych. Reasumując trzeba nadmienić, że dojrzałość takiego przedsiębiorstwa przejawia się zastosowaniem - zdefiniowanych w badaniach deskryptów – nie tylko w zakresie wytwarzania, ale także w zakresie całego łańcucha dostaw. Wszystkie te działania wymagają zharmonizowania, tworząc przedsiębiorstwo „odporne" na kryzys. Organizacja takiego przedsiębiorstwa charakteryzuje się przekazaniem możliwie największej liczby zadań kompetentnym pracownikom, którzy przy wykorzystaniu wiedzy i dostępnych technologii cyfrowych dodają wartość w całym łańcuchu.
Wnioski: Wyniki badań utwierdziły autora w przekonaniu, że technologie cyfrowe z jednej strony implikujące możliwość przetrwana w obliczu kryzysu wywołanego COVID-19 (ciągłość łańcucha dostaw, praca zdalna bez udziału, lub przy ograniczonym udziale człowieka, itp.), z drugiej zaś implementowane przez przedsiębiorstwa, mogą stanowić swego rodzaju „tarczę ochronną" przed negatywnymi skutkami pandemii; z perspektywy podjętego w pracy zagadnienia stanowią o dojrzałości podsystemów logistycznych przedsiębiorstwa. Wydaje się, że stosunkowo małe naukowe rozpoznanie i złożoność problemów występujących w praktyce biznesowej uzasadniają traktowanie kwestii COVID-19 jako przedmiotu badań, czego wyraz stanowi niniejsza publikacja.

Słowa kluczowe: COVID-19, dojrzałość, podsystemy logistyczne, sektor maszyn rolniczych

Przemysław Niewiadomski ORCID ID: https://orcid.org/0000-0002-2805-4671
Uniwersytet of Zielona Góra
Podgórna 50, 65-246 Zielona Góra, **Poland**
e-mail: p.niewiadomski@wez.uz.zgora.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (4), 521-534

http://doi.org/10.17270/J.LOG.2020.513

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

SUPPLY CHAIN MANAGEMENT IN FRANCHISING LITERATURE REVIEW: SYNTHESIS OF CONCLUSIONS

Nurul Ashykin Abd Aziz[1], Mohd Hizam Hanafiah[2], Mohd Nasrulddin Abd Latif[3]

1) Universiti Malaysia Kelantan, Kelantan, **Malaysia**, 2) Universiti Kebangsaan Malaysia, Selangor, **Malaysia** 3) Politeknik Mukah Sarawak, Sarawak, **Malaysia**

ABSTRACT. **Background:** Supply chain management is the heart of any business, even for the franchise industry. A competitive supply chain is critical for the success of a franchising business in today's world. There have been observations and reviews conducted to find out the trends and focuses seen in this area, in the previous studies. The aim of this paper is to set out the analysis on existing past studies on supply chain management in franchising.

Methods: Using the Preferred Reporting Items for Systematics Review and Meta Analyzes (PRISMA) method, the analysis was performed using article data obtained from the Web of Science (WOS) and Scopus databases from year 2000 to 2020.

Results: Forty-one articles were filtered through the final process, and the analysis was performed to see the patterns of article citation, the settings of previous study (country-based), and the fields of study. This study discovered ten themes on the field of study, namely channel management, supply chain coordination, corporate strategies, network relationship, logistic, production, closed-loop supply chain, distribution channel, industrial management and others.

Conclusions: Several recommendations are made to provide guidance for future researchers to study these areas of supply chain management of franchising business.

Key words: systematic review, supply chain, franchising.

INTRODUCTION

In general, supply chain management within a franchise system is usually established by a franchisor. Each franchise business itself has little potential to influence the arrangement of supply chain franchises. Indeed, there may be 'core' supply arrangements that the franchisee must follow, and others that the franchisor may need to make. According to Chen, Chung and Guo [2018], franchise business is defined as a special operating model in the supply chain management of retailers, where it plays an increasingly important role in today's industry. Ballou [2004] highlighted that logistics activities are important for any firm, because logistics management and supply chain provide a wide range of thoughts, philosophies and methods to many disciplines. Importantly, logistics is a part of supply chain management that leads to value creation for the company's customers, suppliers, and shareholders. Undoubtedly, the value generated by logistics activities is expressed by time and place. Without doubt, efficient and systematic logistics management depicts each activity across the supply chain as a continuous contribution to the value-added process [Ballou 2004].

On the other hand, supply chain management depends on process integration across the entire domain of marketing, logistics, purchases, and operations. Generally, marketing channels manage downstream

Citation: Aziz N.A.A., Hanafiah M.H., Latif M.N.A., 2020. Supply chain management in franchising literature review: synthesis of conclusions. LogForum 16 (4), 521-534, http://doi.org/10.17270/J.LOG.2020.513

Received: 27.06.2020, Accepted: 10.08.2020, on-line: 18.09.2020.

relationships, and link companies with end customers [Kozlenkova, Hult, Lund, Mena, Kekec, 2015]. In fact, Chancey, Flores, Palma, Valenzuela, and Cabrera [2016] emphasised that logistics activities are always important for companies and organizations. The area of supply chain logistics and management represent the synthesis of various business concepts including marketing, production, accounting, warehousing, and purchasing. The uniformity in managing the supply chain means that the franchisors and their franchisees as business partners do not only agree with their current distribution's network provider but must also be able to work more closely together, to ensure the right mix of products being available, always. In addition, supply chain management can include various classifications of activities such as product and information flow, supply and supply negotiations with suppliers, distribution processing tasks, transport, handling, and storage. Finally, they must ensure that the quality is adhered to, and the availability of the goods and services offered is consistently available [Cooper, Douglas, Janus, 1997, Davis, 1993, Mentzer et al., 2001].

A systematic literature review is a comprehensive method of reviewing past studies by appraising, summarizing and attempting with the aim to synthesize the retrieved information [Dempster, 2011, Petticrew, Roberts, 2006]. Hanley and Cutts [2013] also claimed that a systematic review is intended to be more rigorous to overcome bias, as well as being a way to revise the studies in a particular context. Despite having plenty of studies on supply chain management in franchising, efforts to conduct the systematic review on this field are still lacking. In this article, the researchers attempt to fill the gap by providing an understanding of the past studies' patterns. Moreover, in the process of building the relevant systematic reviews, the current study is guided by the main research question of "What is the focus area of supply chain management in the franchise business?". The main purpose of this study is to explore areas that the past studies have explored in the context of franchising, and this study also tries to identify the most-referenced scholars' articles in the last 20 years. Therefore, the present study intends to review this issue systematically.

METHODOLOGY

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)

The method used for this article to retrieve and revise related past studies on supply chain management in franchising is discussed. According to Moher, Liberati, Tetzlaff and Altman, [2009], Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which is principally entailed of Cochrane authors, has developed the PRISMA guidelines in 2009 to overcome issues in writing systematic reviews. Moher et al. [2009] highlighted that a comprehensive systematic review of all reports published on the subject in search of answers to clear research question. Moreover, systematic reviews are useful for identifying, evaluating, and summarizing evidence from various studies to address research questions or caps in the same context [Stewart et al., 2015]. Shamseer et al. [2015] supported that systematic review is important for several reasons: (i) enables systematic reviewers to plan carefully and anticipate potential problems; (ii) explicitly allows documentation review of what is planned before beginning to review, and this will allow others to make comparisons between protocols and the completed reviews, to replicate the review method if required, and to evaluate the validity of the proposed method; (iii) prevents illogical decision making to include criteria and data extraction; and (4) reduces overlapping efforts and enhances cooperation, if any.

Sources of Database

In the present article, the main source relies on two major journal databases: Web of Science (WOS) and Scopus. As highlighted by Falagas, Pitsouni, Malietzis and Pappas [2008], the evolution of the electronic age leads to the development of many medical databases on the World Wide Web, thus offering search facilities at specific field of studies and the ability to make citation analysis. In addition, Guz [2009] supported that WOS and Scopus are the most extensive and widely available databases that contain different scholarly fields, and are often used to search for literature.

Scopus is a large multidisciplinary database with citations and abstracts from literary journals, trade journals, books, patent records, and conference publications. This database provides tools for detecting, analyzing, and visualizing search results. The Scopus database was launched in November 2004 and it is the largest database of abstracts and collections with more than 21,500 titles from more than 5,000 international publishers. In addition, the Scopus database also provides the most comprehensive overview of the world's research outcomes in science, technology, medicine, social science, and arts and humanities [Boyle & Sherma, 2006]. As of January 2020, it was reported that there were more than 25,100 articles from over 5000 international publishers. Scopus delivers an overview of the world's most comprehensive study covering areas such as medicine, science, technology, the humanities and social arts science [Elsevier, 2020]

Meanwhile, WOS database search has approximately 11,400 journals in over 45 different languages across the fields of science, social science, and the arts and humanities to find the most relevant high-quality research. Also, it provides link between relevant notes using citation references and exploits the subject-matter relationships between articles created by expert researchers working in specific fields. The comparison of WOS and Scopus determines that WOS has robust reporting which goes back to 1990 and most of its journals written in English [Joshi, 2016]. As reported by Web of Science (2020), There are 21,294 articles in the WOS database and cover areas such as sciences, social sciences and art and humanities

Systematic Review Process

There are four stages involved in the systematic review process: (i) identification; (ii) screening; (iii) eligibility; and (iv) included. The identification process is carried out in stages. The first stage is identified using keywords that are integrated in the search process for related articles in the WOS and Scopus databases. Based on previous studies and synonymous terms in thesaurus, keywords like supply chain management, franchising, franchise, franchisor and franchisee were used. After carrying out a careful screening at this stage, 47 duplicate articles were issued. Next, the second stage was the screening process. At this point, there were 124 eligible articles for review, after that, 49 articles were released because they were the same on both WOS and Scopus databases. In the third stage, the eligibility to which full article was accessible was considered, and later carefully examined. A total of 33 articles were found to be published because some of them were in conflict with the focus of supply chain and franchising. Finally, the last review was done, and the final filter produced a total of 41 articles used for analysis by researchers in this study.

In details, for eligibility and exclusion process, there were several criteria outlined by the researchers to ensure that the article search was performed accurately and appropriately [Strech, Sofaer, 2012]. First and foremost, with respect to source types published in both databases, only empirical article data was selected. Other types of articles such as book chapters, books, conference proceedings and review papers were all excluded in order to get the empirical evidence only. Secondly, the search also focused on articles written and published in English to avoid difficulties and confusion in language translation. Finally, the search was focused on papers within the range of 20-year period from year 2000 to the current year of 2020, as the era of global franchise development develops as the evolution of franchising began to grow around that year. Importantly, the search only focused on supply chain management in franchising, and any unrelated articles were excluded after the screening process was completed.

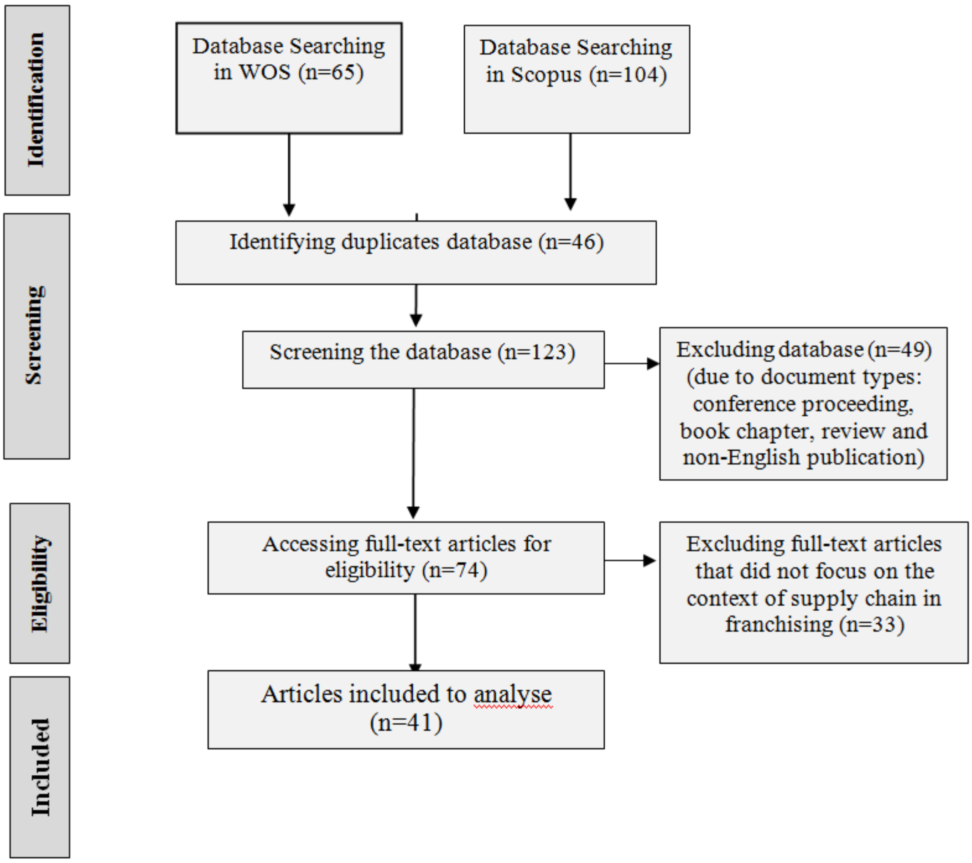


Fig. 1. The Flow Diagram of The Study

ANALYSIS AND DISCUSSION

Analysis of Articles in the Scopus Database

In the process of searching the articles in the Scopus database,104 articles were found in the abstracts, article titles or keywords using the following search: TITTLE-ABS-KEY (("supply chain" OR "supply chain management") AND ("franchising" OR "franchise" OR "franchisee" OR "franchisor*"). The search of articles ranged in between year 2000 to 2020, and the details of each article are shown in the Figure 2.

Figure 2 shows the number of articles published in Scopus for the search year of 2000 to 2020. The analysis of the number of publications was monitored by paternity over a ten-year period, so, the researchers separated 2000 to 2010's publications from the observations of 2011 to 2020. Given the first ten years, the number of publication articles on franchising in supply chain management was relatively favorable, and the distribution was on average of five to seven. Furthermore, the production began in 2002 and its volume rose in 2004, but slightly declined in the next two years, and gradually increased over the next four years. It should be noted that the number of publications for article franchising in the context of supply chain management dropped dramatically in 2011 and 2012. Nevertheless, the number of publications increased gradually over the next three years, but slightly decreased in the next two years (2016-2017). Clearly, the volume of publications in this context was increasing again in the next year (2018) and drop in 2019. General analysis in this Scopus database includes areas of business management and accounting, social sciences, economics, and others.

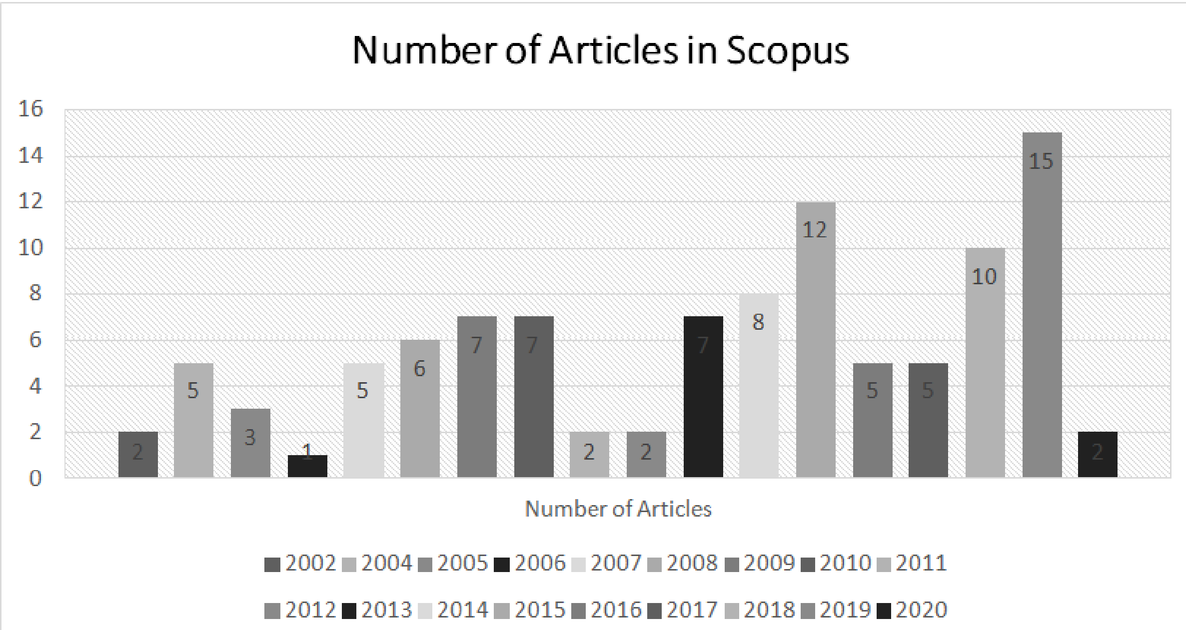


Fig. 2. Number of Articles in Scopus Database

Analysis of Articles in the WOS Database

In the process of searching for articles in the Web of Science (WOS) database, 65 articles were found in the abstracts, article titles, or keywords using the following search: TS= (("supply chain" OR "supply chain management") AND ("franchising" OR "franchise" OR "franchisee" OR "franchisor*"). The article search ranged from year 1999 to 2020, and the details of each article are shown in the figure 3.

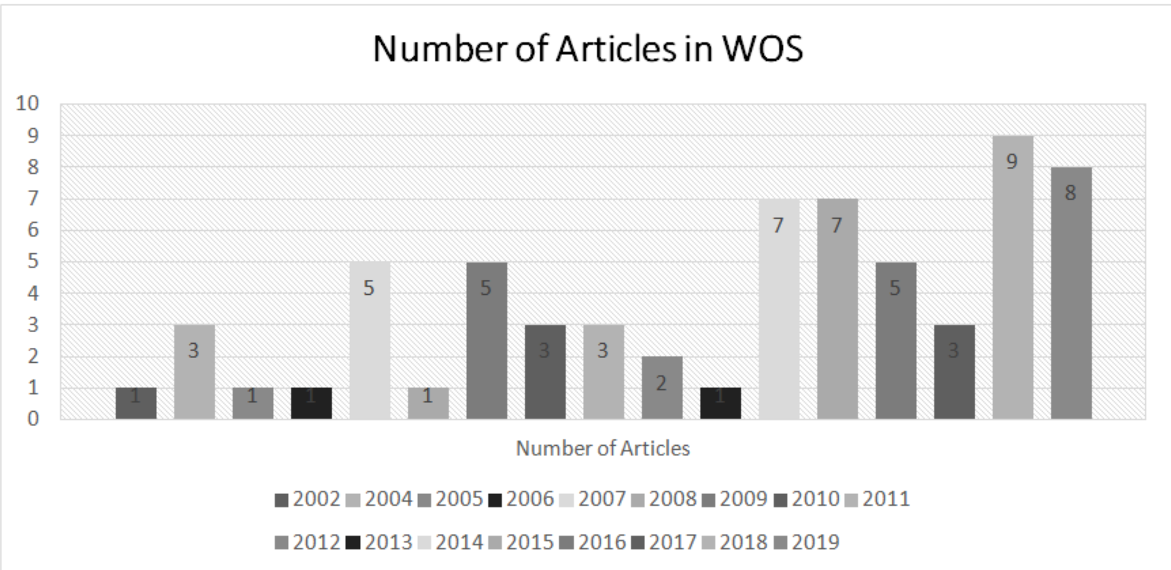


Fig. 3. Number of Articles in WOS Database

Figure 3 shows the number of articles published in the Web of Science (WOS) database for the search year of 2002 to 2019. The analysis of the number of publications was monitored by paternity over a ten-year period, so, the researchers divided them from 2002 to 2011, and then divided the observations for 2012 to 2019. The number of publication articles on franchising in supply chain management was relatively favorable for the first nine years, and the distribution was on average of one to three. Furthermore, the production began in 2002 and its volume rose in 2004, but slightly declined in 2005, and maintained the volume until 2006, and increased back in 2007. Then, in 2008, the volume slightly decreased before increasing back in 2009. The next couple years, the volume maintained before falling in 2013. In 2014 and 2015, the volume maintained before decreasing in 2017. Then, in 2018, the volume rose again until decreasing back in 2019. The general analysis of this WOS database covers areas like operations research management, science, management, business, and other related fields.

Analysis on Citation Number of Articles

Citation is the reference portion used by a researcher and it is included in the main body of work, each time a writer directly quotes, paraphrases, summarizes or refers to the work produced by another author [Shibly, 2016]. In the present study, the researchers have listed 10 out of the many articles cited by previous studies. The search was performed by the researchers on both databases - Scopus and WOS. By looking at it, only one article had the highest citation value in both databases: "Supply chain coordination with revenue-sharing contracts: Strengths and limitations" by [Cachon & Lariviere, 2005].

The Table 1 shows the list of the 10 most cited articles in the Scopus database.

Meanwhile, the Table 2 lists the 10 most cited articles in the WOS database.

Table 1. Number of Citations – Scopus

Title	Authors/Year	Number of citations
Supply chain coordination with revenue-sharing contracts: Strengths and limitations	(Cachon & Lariviere, 2005)	1485
Channel coordination and volume discounts with price-sensitive demand	(Qin, Tang, & Guo, 2007)	105
The impact of Internet referral services on a supply chain	(Ghose, Mukhopadhyay, & Rajan, 2007).	39
Motivating retail marketing effort: Optimal contract design	(Samar, Xuemei, & Ghose, 2009)	42
Franchisor-franchisee supply chain cooperation: Sharing of demand forecast information in high-tech industries	(Yan & Wang, 2012)	28
Contract design for cooperative product service system with information asymmetry	(Xie, Jiang, Zhao, & Shao, 2014)	27
Integration of capacity, pricing, and lead-time decisions in a decentralized supply chain	(Zhu, 2015)	31
Closed-loop supply chains under reward-penalty mechanism: Retailer collection and asymmetric information	(Wang, Zhang, Li, Zhao, & Cheng, 2017)	26
Three-echelon supply chain coordination considering duopolistic retailers with perfect quality products	(Modak, Panda, & Sana, 2016b)	55
Pricing policy and coordination for a two-layer supply chain of duopolistic retailers and socially responsible manufacturer	(Modak, Panda, & Sana, 2016a)	41

Table 2. Number of Citations-WOS

Title	Authors/ Year	Number of Citations
Supply chain coordination with revenue-sharing contracts: Strengths and limitations	(Cachon & Lariviere, 2005)	1186
Manufacturer-retailer supply chain cooperation through franchising: A chance constrained game approach	(Li, Huang, & Ashley, 2002)	19
Channel coordination and volume discounts with price-sensitive demand	(Qin et al., 2007)	77
Motivating Retail Marketing Effort: Optimal Contract Design	(Samar et al., 2009)	38
On contracts for VMI program with continuous review (r,Q) policy	(Guan & Zhao, 2010)	33
Coordination via cost and revenue sharing in manufacturer-retailer channels	(Kunter, 2012)	86
Contract design for cooperative product service system with information asymmetry	(Xie et al., 2014)	21
Integration of capacity, pricing, and lead-time decisions in a decentralized supply chain	(Zhu, 2015)	22
Pricing policy and coordination for a two-layer supply chain of duopolistic retailers and socially responsible manufacturer	(Modak et al., 2016a)	32
Managing a dual-channel supply chain under price and delivery-time dependent stochastic demand	(Modak & Kelle, 2019)	36

In this article, the researchers also decided to analyze the pattern of articles cited by many researchers in their research. This pattern was analyzed from 2000 to 2020's papers. In this case, the study was oriented to identifying the articles with the largest contribution to the supply chain in franchising. The analysis' results are shown in the Table 2. Obviously, the researchers focused on the 10 most cited articles from the Scopus database. In addition, as seen in the graph, from year 2007 to 2017, the number of articles quoted retained at a lower level of moderate persistence compared to this particular article that was published in 2005. According to the citation number, the higher citation for authors of the publications were Carchon, G.P and Lariviere, M.A [2005]. This study is related to research on revenue sharing contracts in the general supply chain model with revenue determined by each retailer quantity and purchase price. This study introduces a model that shows that revenue sharing aligns supply chains with each other retailer. Comparison of yields with a number of other supply chain contracts (e.g. franchise contracts) is also discussed [Cachon, Lariviere, 2005].

Analysis on Study Setting

Based on Table 3, the volume of research is related to supply chain in franchising, hence, the researchers analyzed the country as a setting for the research conducted. The analysis shows that most previous studies on supply chain in franchising field focused on China, one of the countries focusing on most franchisees to supply raw materials and carry out production activities. As supported by Alon and Kruesi [2019], China is the largest franchise market in the world, and it has more than 4,500 franchise systems and about 400,000 franchise stores in over 70 industries.

Furthermore, the second most studied country is the United States of America, as it is the home-base to many of the world's leading franchise brands today. As reported by U.S. Commercial Service [2018], the franchise sector is an important component of the United States. Inside the franchise business, the United States directly has over 733,000 companies supporting nearly 7.6 million direct jobs, $674.3 billion of economic output for the U.S. economy and 3 percent of Gross Domestic Product. In addition, studies on supply chain in franchising have also been carried out in other countries as the setting of the study such as India, the United Kingdom, Australia, Canada and others, as stated in the table. Obviously, franchising industry is seen as an important industry that contributes to the development of the global economy in more than 40 countries around the world, and is growing over time (Alon & Welsh, 2002; Samsudin et al., 2018).

Table 3. Number of Study Based on Country

Country	Number of Study	
	Scopus	WOS
China	32	25
USA	20	16
India/UK	6	6
Austria/Brazil/Germany/Ghana/Japan/Malta/New Zealand/Pakistan/South Korea/Spain/Tanzania/Thailand	1	3
Hong Kong/Italy	7	-
India/UK	6	-
Australia/ France	5	-
Canada	4	-
Netherlands/Norway	3	-
Denmark/Poland/Taiwan	2	-
Undefined	8	-

Analysis on Field of Study Covered in WOS and Scopus Databases

In the analysis of the entire selected final articles, the researchers identified the area of supply-chain-related studies conducted in the franchising context. In general, channel management is widely used in today's franchise business. This is the process by which franchise companies develop a variety of marketing techniques and sales strategies to reach the widest possible customer base. Channel management involves managing closely related channels by reaching out customers, managing partners that help with the distribution process, and managing vendors that keep internal controls running smoothly. In addition, channel management successfully acquires and maintains the cooperation of various organizations by aligning the enterprise with customer needs. Every department and stream of information can potentially affect customer service, affecting the entire organization and reputation. Figure 4 shows that 21 percent or the majority of the filtered final articles were studies in the field of channel management [e.g. Geng, Mallik, 2007, Kunter, 2012, Modak et al., 2016a, 2016b, Qin et al., 2007].

The components of the supply chain may be very different from one franchise system to another, depending on the industry and type of business of the franchise system, as well as the level of complexity of its product offerings. Supply chain management affects the operations of a franchise company in a number of ways, including the availability of inputs required for production processes, costs and profitability of manufactured goods, company infrastructure, and the way companies interact with their suppliers and customers. Obviously, production operations in supply chain management makes products or services becoming more attractive to potential users, to the extent that demand is created. According to the analysis, nine percent of the selected final articles focused on the field of production [e.g. Ritchie, Young, Shahzad, Kolodinsky, Melnyk, 2015, Samar et al., 2009, Wong, Lai, 2008].

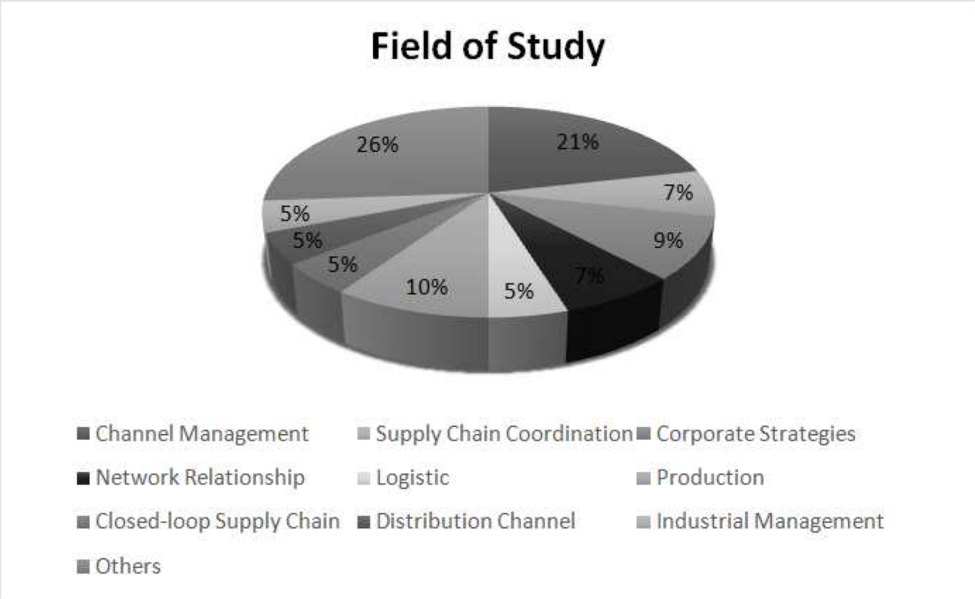


Fig. 4. Field of Study

Corporate strategies are also a function of logistics and the key to success in the supply chain. It is an important part of the supply chain and management where franchise companies need to make strategic decisions in their logistics network. The analysis shows that nine percent of the selected final articles focused on the corporate strategies area [e.g. Bouchet, Troilo, Spaniel, 2015, Sebastiani, Corsaro, Montagnini, Caruana, 2014, Utgård, 2018]. Other than that, the analysis also shows that seven percent % of the selected final articles focused on the field of supply chain coordination, as the main focus in channel coordination is to improve the supply chain performance by aligning the plans and objectives of a franchise business. Generally, it focuses on inventory management and decision making in a distributed company setting. Meanwhile, the analysis also shows that seven percent of the analyzed final articles focused on network relationship [e.g. Shaikh, Biswas, Yadav, Mishra, 2017, Shaikh, Sharma, Vijayalakshmi, Yadav, 2018, Shockley, Turner, 2016], where supply chain management is a network of interconnected companies engaged in physical product and service requirements from key suppliers to end-users offered by franchise companies, both locally and internationally.

Among other things, there are three other areas of focus from previous studies, each representing two percent of the total number of the filtered final articles in this analysis. For articles that focused on the field of logistics [e.g. Fenies, Gautier, Lagrange, 2014], it can be said that logistics is an integral part of the operations of a franchise company through various stages of development to meet the demands of the their franchisees as business partners, as well as to ensure the smoothness of their business supply chain activities. The next area focused on the field of closed-loop supply chain [e.g. Wang et al., 2017, Wang, Zhou, Zhang, Sun, He, 2018] where the closed loop supply chain essentially combines traditional supply chain (forward logistics) with reverse logistics. It considers the item after its original purpose is included. The focus of closed-loop supply chain is to maximize economic benefits while reducing consumption resources and energy, and to reduce emission of pollutants. It is related to efforts to create socially responsible companies, and to balance economic interest.

Also, closed-loop supply chain is environmentally friendly performance that includes internal and external management of company franchise. Besides that, the other focus was on distribution channel [e.g. Samar et al., 2009] - it is a network of businesses or intermediaries through which goods or services pass through to the end buyer or end user. Distribution channels within the franchise system include franchisees, raw material suppliers and third-party logistics. Besides, the other area also focuses on industrial management [e.g. Yan, Wang, 2012] as it is an organizational process that includes strategic planning, setting, objectives, resource management, the use of human assets, and financial management to achieve objectives, and to measure outcomes. In short, the analysis also shows that 26 percent of the articles were found in other categories under the supply chain management.

RECOMMENDATION FOR FUTURE RESEARCH

Based on the 41 studies examined, several aspects need attention. First, supply chain management is not considered a key concept in a franchise business operation. Even supply chain management is crucial in order to keep the franchising system works, most studies do not focus on the factors that lead to better and more efficient supply chain management. Also, studies explaining the relationship of practice in supply chain management and franchise business performance are minimal. Therefore, it is suggested that future research focus on this scope. Besides, most studies use only quantitative methods, and very few studies on supply chain management in franchise businesses employed qualitative methods such as case studies [i.e. Fenies et al., 2014; Wong, Lai, 2008]. Thus, it is recommended that future research may explore deeper into understanding supply chain management issue in franchising business sector. The qualitative case study methodology offers tools for researchers to study complex phenomena in their context. When appropriately applied, it becomes a valuable method for research to develop theory, evaluate programs, and develop interventions [Baxter, Jack, 2010].

CONCLUSIONS

To sum up, the literature research conducted by the researchers has made it conceivable for a conclusion to be formulated. The breakdown of the years was made to look at the pattern of the publications over two phases namely year 2000-2010 (first phase), and year 2011-2020 (second phase). In the first phase, the study of the WOS and Scopus databases found that most articles focused on the concept of supply chain in franchising that began in 2002, but the numbers were moderate. Meanwhile, as seen in the second phase, the focus of this area was growing and the number of articles in 2014 and above increased. Regarding the databases as the main medium used by today's researchers, the Scopus database is seen as a great source for finding articles related to supply chain management in franchising compared to the WOS database. In addition, a study entitled "Supply chain coordination with revenue-sharing contracts: Strengths and limitations" by Cachon and Lariviere [2005] is an article that received a lot of citations in both WOS and Scopus databases. Overall, the researchers in the present study found that most recent studies focused on channel management compared to other areas in the context of supply chain management. Therefore, future researchers can explore other areas for future studies such as closed-loop supply chain and industrial management in franchising business.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The authors received no financial support for the research, authorship, and/or publication of this article.

REFERENCES

Alon I., Kruesi M., 2019. The Enigma of Franchising in China. Journal of Business Strategy. http://doi.org/10.1108/JBS-06-2019-0108

Alon I., Welsh D.H.B., 2002. Global Franchising In Emerging And Transitioning

Economies. International Journal of Business and Economics, 2(1), 332–343.

Ballou R., 2004. Business Logistic Management. Pearson Education.

Baxter P.E., Jack S.M., 2010. Qualitative Case Study Methodology: Study Design and Implementation fo Novice Researchers. Qualitative Report, 13(4), 544–559.

Bouchet A., Troilo M., Spaniel W., 2015. International sourcing, social responsibility and human assets: A framework for labor procurement negotiations in baseball's talent supply chain. Corporate Governance (Bingley), 15(2), 214–228. http://doi.org/10.1108/CG-09-2014-0108

Boyle F., Sherma D., 2006. Scopus: The Product and Its development. The Serials Librarian, 49(3), 147–153. http://doi.org/10.1300/J123v49n03_12

Cachon G.P., Lariviere M.A., 2005. Supply chain coordination with revenue-sharing contracts: Strengths and limitations. Management Science, 51(1), 30–44. http://doi.org/10.1287/mnsc.1040.0215

Chancey E., Flores J.L.M., Palma M.B., Valenzuela O.D.B., Cabrera M.A.S., 2016. Redesign of The Supply Chain of A Restaurant Franchise In The Food Industry. Global Journal of Business Research, 10(2), 103–111.

Chen Y., Chung S.H., Guo S., 2018. Franchising Contracts in Fashion Supply Chain Operations. Annals of Operations Research. http://doi.org/10.1007/s10479-018-2998-5

Cooper M.C., Douglas M.L., Janus D.P., 1997. Supply Chain Management: More Than A New Name For Logistics. International Journal of Logistics Management, 8(1), 1–14.

Davis T., 1993. Effective Supply Chain Management. Sloan Management Review, 34, 35–46.

Dempster M., 2011. A Research Guide For Health and Clinical Psychology. Hampshire: Palgrave Macmillan.

Elsevier, 2020. Research Intelligencce: Scopus Content Coverage Guide.

Falagas M.E., Pitsouni E.I., Malietzis G.A., Pappas G., 2008. Comparison of PubMed, Scopus,Web of Science and Google Scholar: Streghts and Weakness. The FASEB Journal, 22, 338–342. http://doi.org/10.1096/fj.07-9492LSF

Fenies P., Gautier F., Lagrange S., 2014. A decisional modeling for network franchise and supply chain management. Supply Chain Forum, 15(3), 52–64. http://doi.org/10.1080/16258312.2014.11517351

Geng Q., Mallik S., 2007. Inventory competition and allocation in a multi-channel distribution system. European Journal of Operational Research, 182(2), 704–729. http://doi.org/10.1016/j.ejor.2006.08.041

Ghose A., Mukhopadhyay T., Rajan U., 2007. The impact of Internet referral services on a supply chain. Information Systems Research, 18(3), 300–319. http://doi.org/10.1287/isre.1070.0130

Guan R., Zhao X., 2010. On contracts for VMI program with continuous review (r, Q) policy. European Journal of Operational Research, 207(2), 656–667. http://doi.org/10.1016/j.ejor.2010.04.037

Guz A.N., 2009. A System For The Evaluation of Scientific Journals. International Applied Mechanics, 45(4), 351–362. https://doi.org/10.1007/s10778-009-0189-4

Hanley T., Cutts L., 2013. What is a Systematic Review? The British Psychological Society, 28(4), 3–6.

Joshi A., 2016. Comparison Between Scopus and ISI Web of Science. Journal Global Values, 7(1), 1–11.

Kozlenkova I.V, Hult G.T.M., Lund D.J., Mena J.A., Kekec P., 2015. The Role of Marketing Channels in Supply Chain Management. Journal of Retailing, 91(4), 586–609.

Kunter M., 2012. Coordination via cost and revenue sharing in manufacturer-retailer channels. European Journal of Operational Research, 216(2), 477–486. http://doi.org/10.1016/j.ejor.2011.07.001

Li S.X., Huang Z., Ashley A., 2002. Manufacturer-Retailer Supply Chain Cooperation Through Franchising: A Chance Constrained Game Approach. Information Systems and Operational Research, 40(2), 131–148. http://doi.org/10.1080/03155986.2002.11732647

Mentzer J.T., William D., James S.K., Soonhong M., Nancy W.N., Carlo D.S., Zach G.Z., 2001. Defining Supply Chain Management. Defining Supply Chain Management, 22(2), 1–25.

Modak N.M., Kelle P., 2019. Managing a dual-channel supply chain under price and delivery-time dependent stochastic demand. European Journal of Operational Research, 272(1), 147–161. http://doi.org/10.1016/j.ejor.2018.05.067

Modak N.M., Panda S., Sana S.S., 2016a. Pricing policy and coordination for a two-layer supply chain of duopolistic retailers and socially responsible manufacturer. International Journal of Logistics Research and Applications, 19(6), 487–508. http://doi.org/10.1080/13675567.2015.1085499

Modak N.M., Panda S., Sana S.S., 2016b. Three-echelon supply chain coordination considering duopolistic retailers with perfect quality products. International Journal of Production Economics, 182, 564–578. http://doi.org/10.1016/j.ijpe.2015.05.021

Moher D., Liberati A., Tetzlaff J., Altman D.G., 2009. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. Journal of Clinical Epidemiology, 62(10), 1006–1012. http://doi.org/10.1016/j.jclinepi.2009.06.005

Petticrew M., Roberts H., 2006. Systematic Review in The Social Sciences: A Practical Guide. Oxford: Blackwell Publishing.

Qin Y., Tang H., Guo C., 2007. Channel coordination and volume discounts with price-sensitive demand. International Journal of Production Economics, 105(1), 43–53. http://doi.org/10.1016/j.ijpe.2006.02.005

Ritchie W.J., Young G., Shahzad A.M., Kolodinsky R.W., Melnyk S.A., 2015. The influence of plural organizational forms on beliefs and outcomes related to new product adoption. Management Decision, 53(7), 1619–1641. http://doi.org/10.1108/MD-05-2014-0287

Samar K.M., Xuemei S., Ghose S., 2009. Motivating retail marketing effort: Optimal contract design. Production and Operations Management, 18(2), 197–211. http://doi.org/10.1111/j.1937-5956.2009.01014.x

Samsudin F., Sazali A.W., Latiff A.S., Osman S.I., Zawawi N.F., Fazal S.A., 2018. Strategic Direction and Sustainable Development in Franchising Organizations: A Conceptual Study. Journal of Sustainable Development, 11(4), 89–98. http://doi.org/10.5539/jsd.v11n4p89

Sebastiani R., Corsaro D., Montagnini F., Caruana A., 2014. Corporate sustainability in action. Service Industries Journal, 34(7), 584–603. http://doi.org/10.1080/02642069.2014.886191

Shaikh A., Biswas S.N., Yadav V., Mishra D., 2017. Measuring fairness in franchisor-franchisee relationship: a confirmatory approach. International Journal of Retail and Distribution Management, 45(2), 158–176. http://doi.org/10.1108/IJRDM-11-2015-0174

Shaikh A., Sharma D., Vijayalakshmi A., Yadav R.S., 2018. Fairness in franchisor–franchisee relationship: an integrative perspective. Journal of Business and Industrial Marketing, 33(4), 550–562. http://doi.org/10.1108/JBIM-04-2017-0093

Shamseer L., Moher D., Clarke M., Ghersi D., Liberati A., Petticrew M., Stewart L.A., 2015. Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015: Elaboration and Explanation. The BMJ Journal, 1–25. http://doi.org/10.1136/bmj.g7647

Shibly A., 2016. Referencing and Citation. Sri Lanka.

Shockley J., Turner T., 2016. A relational performance model for developing innovation and long-term orientation in retail franchise organizations. Journal of Retailing and Consumer Services, 32(2016), 175–188. http://doi.org/10.1016/j.jretconser.2016.06.013

Stewart L.A., Clarke M., Rovers M., Riley R.D., Simmonds M., Stewart G., Tierney J.F., 2015. Preferred Reporting Items For a Systematic Review and Meta-analysis of Individual Participant Data. Clinical Review and Education, 313(16), 1657–16665.

Strech D., Sofaer N., 2012. How to Write a Systematic Review of Reasons. Journal of Medical Ethics, 38(2), 121–126. http://doi.org/10.1136/medethics-2011-100096

Thomas D.J., Paul M.G., 1996. Coordinated Supply Chain Management. European Journal of Operational Research, 94(1), 1–15.

U.S. Commercial Service, 2018. Franchising Industry: A Reference for U.S Exporters. United States America. Retrieved from www.franchise.org

Utgård J., 2018. Retail chains' corporate social responsibility communication. Journal of Business Ethics, 147(2), 385–400. http://doi.org/10.1007/s10551-015-2952-2

Wang W., Zhang Y., Li Y., Zhao X., Cheng M., 2017. Closed-loop supply chains under reward-penalty mechanism: Retailer collection and asymmetric information. Journal of Cleaner Production, 142, 3938–3955. http://doi.org/10.1016/j.jclepro.2016.10.063

Wang W., Zhou S., Zhang M., Sun H., He L., 2018. A closed-loop supply chain with competitive dual collection channel under asymmetric information and reward-penalty mechanism. Sustainability (Switzerland), 10 (7). http://doi.org/10.3390/su10072131

Web of Science, 2020. Web of Science Platform: Web of Science: Summary of Coverage. Retrieved June 26, 2020, from https://clarivate.libguides.com/webofscienceplatform/coverage

Wong C.W.Y., Lai K., 2008. Organizational Mindfulness and the Development of Information Technology for Logistics Operations: The Experience of an Apparel Company. Research Journal of Textile and Apparel, 12(3), 30–37. http://doi.org/10.1108/RJTA-12-03-2008-B003

Xie W., Jiang Z., Zhao Y., Shao X., 2014. Contract design for cooperative product service system with information asymmetry. International Journal of Production Research, 52(6), 1658–1680. http://doi.org/10.1080/00207543.2013.847293

Yan R., Wang K.Y., 2012. Franchisor-franchisee supply chain cooperation: Sharing of demand forecast information in high-tech industries. Industrial Marketing Management, 41(7), 1164–1173. http://doi.org/10.1016/j.indmarman.2012.06.013

Zhu S.X., 2015. Integration of capacity, pricing, and lead-time decisions in a decentralized supply chain. International Journal of Production Economics, 164, 14–23. http://doi.org/10.1016/j.ijpe.2015.02.026.

ZARZĄDZANIE ŁAŃCUCHEM DOSTAW WE FRANCZYZIE – PRZEGLĄD LITERATURY

STRESZCZENIE. **Wstęp:** Zarządzanie łańcuchem dostaw jest określane jako serce biznesu, również w przypadku biznesu opartego na systemie franczyzy. Konkurencyjny łańcuch dostaw jest krytyczny dla osiągnięcia sukcesu. Istnieje wiele badań poświęconych wyszukiwaniu trendów w tym obszarze. Celem pracy jest analiza badań w obszarze zarządzania łańcuchem dostaw biznesu opartego na fanczyzie.

Metody: Wykonano analizę danych z prac opublikowanych w WOS (Web of Science) oraz bazie Scopus w okresie 2000 do 2020, używając w tym celu metody PRISMA (Preferred Reporting Items for Systematics Review and Meta Analyzes).

Wyniki: Finalnie zostało wyselekcjonowanych 41 prac, które zostały poddane szczegółowej analizie w celu określenia wzorów cytowań prac, wcześniejszych badań w stosunku do prezentowanych w badanych pracach oraz obszarów badań. Ustalono 10 tematów obszarów badawczych, a mianowicie: zarządzanie kanałami, koordynacja łańcucha dostaw, strategie korporacyjne, zależności sieciowe, logistyka, produkcja, pętla łańcucha dostaw, kanały dystrybucji, zarządzanie przemysłowe i inne.

Wnioski: Stworzono kilka rekomendacji, które powinny być wytycznymi dla dalszych badań dla naukowców zajmujących się zarządzaniem łańcuchem dostaw dla biznesu opartego na fanczyzie.

Słowa kluczowe: analiza systematyczna, łańcuch dostaw, franczyza

Nurul Ashykin Abd Aziz ORCID ID: https://orcid.org/0000-0001-9753-3257
Universiti Malaysia Kelantan, Malaysia
Faculty of Entrepreneurship and Business
Locked Bag 36, Pengkalan Chepa,
16100, Kota Bahru, Kelantan, **Malaysia**
e-mail: ashykin.a@umk.edu.my

Mohd Hizam Hanafiah ORCID ID: https://orcid.org/0000-0002-1053-6488
Universiti Kebangsaan Malaysia
Faculty of Economics and Management
43600 UKM, Bangi, Selangor, **Malaysia**
e-mail: mhhh@ukm.edu.my

Mohd Nasrulddin Abd Latif ORCID ID: https://orcid.org/0000-0003-4227-0570
Department of Information Technology and Communication,
Politeknik Mukah Sarawak Km 7.5, Jalan Oya, 96400,
Mukah, Sarawak, **Malaysia**
email: nasrulddin@pmu.edu.my

LogForum
> Scientific Journal of Logistics <
2020, 16 (4), 535-547
http://doi.org/10.17270/J.LOG.2020.512
http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X
ORIGINAL PAPER

INVENTORY MANAGEMENT AND LOGISTICS OPTIMIZATION: A DATA MINING PRACTICAL APPROACH

Rafael Granillo-Macías

Autonomous University of Hidalgo State, Hidalgo, **México**

ABSTRACT. **Background:** In the current economic scenarios, characterized by high competitiveness and disruption in supply chains, the latent need to optimize costs and customer service has been promoted, placing inventories as a critical area with high potential to implement improvements in companies. Appropriate inventory management leads to positive effects on logistics performance indices. In economic terms, about 15% of logistics costs are attributed to warehousing operations. With a practical approach, using a case study in a company in the food sector, this article proposes an inventory classification method with qualitative and quantitative variables, using data mining techniques, categorizing the materials using variables such as picking frequency, consumption rates and qualitative characteristics regarding their handling in the warehouse. The proposed model also integrates the classification of materials with techniques for locating facilities, to support decision-making on inventory management and storage operations.

Methods: This article uses a method based on the Partitioning Around Medoids algorithm that includes, in an innovative way, the application of a strategy for the location of the optimal picking point based on the cluster classification considering the qualitative and quantitative factors that represent the most significant impact or priority for inventory management in the company.

Results: The results obtained with this model, improve the routes of distributed materials based on the identification of their characteristics such as the frequency of collection and handling of materials, allowing to reorganize and increase the storage capacity of the different SKUs, passing from a classification by families to a cluster classification. Furthermore, the results support decision-making on storage capacity, allowing the space required by the materials that make up the different clusters to be identified.

Conclusions: This article provides an approach to improving decision-making for inventory management, showing a proposal for a warehouse distribution design with data mining techniques, which use indicators and key attributes for operational performance for a case study in a company. The use of data mining techniques such as PAM clustering makes it possible to group the inventory into different clusters considering both qualitative and quantitative factors. The clustering proposal with PAM offers a more realistic approach to the problem of inventory management, where factors as diverse as time and capacities must be considered, to the types and handling that must be had with the materials inside the warehouse.

Key words: cluster, Partitioning Around Medoids, facility location, supply chain.

INTRODUCTION

The environment of high global competition and the increase in demand for products and services by customers have driven the search for options to improve efficiency in companies' operations. For many organizations, internal logistics and warehousing are considered areas with high potential for the implementation of improvements, which can have a favorable impact on the operational efficiency of the business [Anđelković, Radosavljević 2018, Grosse, Glock 2015]. Warehousing operations are a key factor for the operational success of an organization, since they promote and support the fulfillment of the set of requirements and expectations of customers, throughout the supply chain. Proper inventory

Citation: Granillo-Macías R., 2020. Inventory management and logistics optimization: A Data Mining practical approach. LogForum 16 (4), 535-547, http://doi.org/10.17270/J.LOG.2020.512
Received: 24.06.2020, Accepted: 06.08.2020, on-line: 18.09.2020.

management has an important effect on logistics performance indices, mainly in those organizations that seek to reduce their costs and improve efficiency in their product preparation and delivery processes [Zhang et al. 2019]. In economic terms, warehouses represent about 15% of total logistics costs in developed countries [Guo et al. 2016].

A warehouse is an intermediary facility between suppliers and customers, whose utility is to dampen demand considering time and cost variables, seeking to reduce the gap between the production and consumption of goods [Aqlan 2017]. Operations carried out in a warehouse are generally divided into reception, storage, order picking, sorting, and shipping [Zhang et al. 2019, Çelik, Süral 2019], with order picking operations consuming the most time and work. Order picking is the most expensive operation, constituting around 55% of a warehouse's operating costs [Bottani et al. 2019, Çelik, Süral 2019, Grosse, Glock 2015], this being the main reason for which the preparation of orders is considered as an area of study opportunity to achieve the improvement of productivity in the company. In logistics, order picking refers to the process of selecting a set of Stock Keeping Units (SKUs), retrieving them from their various storage locations, and transporting them for review, packaging, and shipping for fulfillment of customer orders. internal or external. Order picking activities are also the most time consuming, in the case of manual operations, caused by heavy work and repetitive activities carried out in the warehouse. In manual operations where the labor force intervenes, the cost of harvesting is mainly related to the time used to transport products within the warehouse. According to studies carried out by [Bottani et al. 2019], the collection cost represents approximately 50% of the total order picking time.

Transportation time is related to the distance that must be traveled to collect the items requested in a customer's order. Therefore, minimizing the distance and the collection time is an essential objective to achieve efficiency and competitiveness in the warehouse [Faia Pinto, Nagano 2019]. In planning for order picking, several decisions need to be made at the tactical and operational levels [Çelik, Süral 2019, Bottani et al. 2019]. Decisions at the tactical level include: (1) the allocation of products to storage areas, which describes the rules for determining the assignments of SKUs to storage locations, and (2) the zoning of storage areas. collection, which is a means through which policies are decided on how to divide the order picking area into zones and determine the locations of the order picking areas [van Gils et al. 2018]. Operation-al decisions are influenced by: (1) order batch processing, based on rules that define the mix of customer orders in a single selection round, and (2) routing policies, which define the sequence of storage locations that must be visited to collect all the SKUs necessary for the formation of an order. Current trends in supply chain management promote the optimization of inventories, as a support to storage operations, through the use of different technologies [Aqlan 2017]. Technological tools based on data analysis, such as Warehouse Management Systems (WMS), are becoming increasingly sophisticated. WMSs are designed to provide efficient information for making decisions about storage, inventory, and SKU movements. In the Big Data era, analytical techniques such as data mining and business intelligence are being used in inventory management to provide accurate and up-to-date information to make better decisions [Xindong Wu et al. 2014]. Specifically, data mining analysis techniques are considered as the fundamental basis for Big Data.

Data mining is the process of extracting information from a data set, its main strengths are combining statistical models and autonomous learning, offering versatility to treat different types of data. Choi et al. [2018], Arora and Chana [2014], Tsai et al. [2015] point out that the areas focused on Big Data analysis in data mining include: (1) grouping techniques, (2) distributed and parallel processing, and (3) processing multimedia. Grouping techniques divide a data set into different groups. The grouping process consists of assigning a large number of data points to a smaller number of groups, so that the data points in the same group share the same properties, while the data of other groups are different. Grouping consists of classifying the input data based on certain values or attributes

[Aqlan 2017]. Clustering is used in different areas, including artificial intelligence, marketing, scientific analysis, and engineering [Xindong Wu et al. 2014]. The analysis through cluster grouping allows inventories to group SKUs according to certain characteristics. Specifically, this study presents an approach to inventory management, using cluster grouping based on variables related to the frequency of collection, storage, and warehouse returns. Using data mining techniques based on the Partitioning Around Medoids (PAM) algorithm, a case study is analyzed in a company in the food sector. The objective is to propose a method for inventory management, using clustering techniques and optimal picking point, categorizing materials through variables such as collection frequency, consumption rates, and qualitative characteristics regarding their handling in the warehouse.

The hypothesis was that using cluster grouping techniques it is possible to manage inventory, distribution, and storage logistics in a company, including both qualitative and quantitative variables. This article begins by identifying recent contributions to inventory management, order picking, and picking. Subsequently, the proposed approach based on data mining techniques is presented. Using data collected from a company in the food sector, the proposal is analyzed through a case study. Afterward, the results obtained are discussed, highlighting the variables that have the greatest contribution to storage logistics operations. Finally, the conclusions and future works for this study are presented.

LITERATURE REVIEW

The planning and control of materials and products, which support production functions, maintenance activities, and customer service, is carried out and coordinated through inventory management. The latent need to optimize costs and customer service has placed inventories as a fundamental area for improvement in companies, due to the high level of cost that they can reach in an organization. According to the extensive literature review carried out by Gu et al. [2007], the problems for inventory management are classified according to storage (reception, storage, order preparation, and shipping). Among the traditional and most widely used techniques by organizations for inventory management is ABC analysis. Class-based storage according to the ABC demand curve, divides stored items considering policies such as inventory turnover or cost [Guo et al. 2016]. Grosse and Glock [2015] develop an analytical model that helps predict performance on certain elements of the order picking system. With a quantitative approach, Jemelka et al. [2017] present a variant of the ABC analysis for the determination of inventories using a recursive model that considers the rates of return of materials and the redistribution of the sections for the location of SKUs within from a warehouse.

To distinguish themselves from the competition, reducing the time of preparation of orders, van Gils et al. [2017] propose the forecast of the workload in a warehouse con-text with emphasis on collection areas. Exploring the performance of different tools for order picking, de Vries et al. [2016] suggests that the human factor plays an important role for order picking within the warehouse. In the research by van Gils et al. [2018] statistically analyze and test the relationships between storage, order processing, batching, zoning, and routing by a full factorial Analysis of Variance (ANOVA). These authors conclude that significant benefits can be achieved in inventory management, while simultaneously considering storage, order processing, zone selection, and routing policies. Zhang et al. [2019] present the concept of Demand Correlation Pattern (DCP), to describe the correlation between SKU's, based on which they show a model to address the Storage Location Assignment Problem (SLAP). With the DCP proposal, Zhang et al. [2019] conclude that the class-based storage strategy, which divides SKUs into several classes and as-signs each class to a storage area, is one of the strategy of the inventory management most commonly adopted in practice.

Designing a multi-criteria inventory classification approach, Lolli et al. [2014] presents a method based on a hybrid model that combines the K-means algorithm and

Analytic Hierarchy Process (AHP). Analyzing multi-zone storage systems within the configuration of a WMS, Yuan et al. [2018] explore decisions on zones stowage, to determine the best distribution of products that arrive through multiple storage areas. In the research of Anđelković and Radosavljević [2018] use cluster analysis to identify which are the inventory management processes that can achieve the most significant benefits for the implementation of the WMS, as a result, these authors point out that the order processing operations are the most appropriate to implement information technologies based on the WMS. Examining the order picking problem (OPP), Çelik and Süral [2019] makes use of the properties of graph theory, integrating a model based on a heuristic approach, to determine the route that minimizes the times of transfer required for storage operations. A proposal on the minimization of the transfer times for collection is presented by Matthews and Visagie [2019], to reach an adequate arrangement for the collection operations of SKUs in a warehouse. Faia Pinto and Nagano [2019] propose a computational tool called GA-OPS, which is formulated based on two genetic algorithms, to minimize the number of picking trips, meeting the requirements requested in the different production orders.

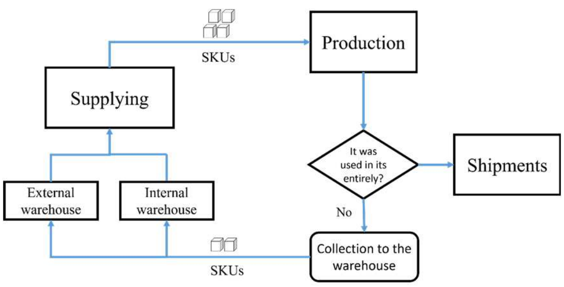
Djatna and Hadi [2017] through a multi-objective mathematical model, they present the order preparation problem in the warehouse of a beverage company with a drive-in rack system. Djatna and Hadi [2017] concludes that the integration between order picking (warehousing allocation, routing, batch processing, zoning and warehouse design) and other aspects (queue, operational and material handling aspects), is a current challenge for the order picking research area. Combining cluster analysis and simulated annealing algorithm to search for optimal classification in a warehouse, the authors Liu et al. [2016] presents a methodology that builds hierarchies of similar inventory groups, and then applies a simulated annealing algorithm to optimize inventory classifications on different hierarchy levels. Kusrini [2015] present a study that supports the process to determine the minimum stock and profit margin, using a model that groups the SKUs into categories of "fast movement" and "slow movement", using the grouping method from k-means.

Using data mining techniques, Aqlan [2017] categorizes inventories with cluster grouping, based on variables of collection frequency, time in storage, price, and sensitivity of products to transport. [Hong 2019] analyzing the elements involved in inventory management, he proposes the variables of flow time, work in process, and throughput in terms of pick probability. Considering that the classification and categorization of inventories require using multiple criteria to control different functions of inventory management, in the approach of Aktepe et al. [2018] an algorithm called functional-normal-and small (FNS) is analyzed, the FNS combines ABC analysis with variables of handling frequency, lead time, contract manufacturing process and specialty, which are used as input criteria for this model. In general, most of the literature on inventory management is focused on aspects related to the optimization of time, transfer distances, and use of resources, these being a reference to quantify improvements in warehousing operations in a company. Inventory analysis, proposed by various authors based on categories, is a predominant element that contributes to the improvement of storage operations. Specifically, the collection and preparation of orders are variables that are recognized as important factors that need to be considered to achieve effectiveness in inventory management.

Regarding classification methods, the k-means method is the most frequently used data mining technique, however, in this research, the cluster method is proposed through the PAM algorithm using quantitative variables such as (1) collection frequency, (2) average quantity per order, (3) daily rate of consumption, (4) daily rate of returns, (5) the average amount of returns per order and (6) frequency of return and related qualitative variables in the form of storage.

METHODOLOGY

The proposed approach to inventory management in this research is based on cluster grouping, to identify common elements among the different SKU´s that are located in a warehouse. Each cluster is integrated considering variables with particular characteristics, making them different from the other clusters formed. For this research, an international company in the food sector was used as a case study, which focuses on the production of food and beverages, specifically analyzing the problems of a business unit located in Mexico. This business unit with operations in Mexico, specializes in the preparation and bottling of beverages. The inventory management of the said company is carried out through internal warehouses (inside the facilities) and external warehouses (located outside the facilities), in a make to order environment. Figure 1 shows the logistics carried out in the warehouse, with the production department as an internal customer.



Source: own work

Fig. 1. Logistics in warehouse

The company has the particularity of SKU's return operations, due to the certain formulation and mixing processes, so the materials in a production order are not consumed in their entirety and are returned from the production area to the warehouse. High inventory levels, storage capacity, lack of storage spaces, and frequent variations in demand are some of the problems present in the management of company inventories. With this background, the proposed methodology has as a first step the identification of SKUs found in the warehouse. This stage includes selecting the methods and tools to ensure the identification, location, and location of the different materials and products used by the company in its supply chain, present throughout the different production processes. By locating barcodes on the various materials and using reports from the Computer System for Resource Planning (SAP), 203 SKUs were identified that entered the warehouse, during a production period of one year. The materials are determined by families, which are: chemicals, powders, liquid concentrates, lids, pallets, packaging, labels, PET lids, and cardboard. Once the different SKUs that make up the warehouse have been described, the factors that present the most significant impact or priority for inventory management were subsequently selected. In this case, the following were chosen for exits from the warehouse: daily consumption rate (DRC) (1), average quantity per order (AQO) (2) and pick frequency (PF) (3); Regarding the factors with the greatest impact on returns, the company considered: daily rate of return (DRR) (4), the average number of returns per order (ARO) (5) and frequency of return (RF) (6). The PF determines the frequency with which the materials are required by the production department [Aqlan 2017], while the RF indicates the frequency with which these are returned from the production department to the warehouse.

The following equations were used to calculate each of these factors :

$$DRC = \frac{Q_n^p}{t} \tag{1}$$

$$AQO = \frac{Q_n^p}{f_n^p} \tag{2}$$

$$PF = \frac{DRC}{AOQ} \tag{3}$$

In the case of returns, the equations are:

$$DRR = \frac{B_n^p}{t} \tag{4}$$

$$ARO = \frac{B_n^p}{r_n^p} \tag{5}$$

$$RF = \frac{DRR}{ARO} \tag{6}$$

where:

Q_n^p: demand quantity Q of SKU p in period n
B_n^p: quantity B of SKU p in period n returning to the warehouse
t: period in days

f_n^p: SKU request frequency p during period n

r_n^p : frequency of returns of SKU p during period n

Due to the characteristics of some materials, which require occupying positions in "rack" and "floor" locations, the company added this qualitative factor for inventory management, also including the unit of measure factor in which the materials are accounted (kilograms, pieces, or gallons). A location on the floor indicates that the material does not require special storage conditions, while a location on racks is that location where materials such as chemicals, powdered ingredients, and concentrates are stored, which requires a storage system using racks and in some instances under controlled temperature conditions, to preserve the materials they protect in optimal conditions. After calculating these factors, the next step was classification using the cluster grouping technique. In a cluster analysis, a set of data, in this case, the SKUs, are grouped by similarity in the input variables, for this study six quantitative factors (continuous) and two categories, to identify groups that are internally as homogeneous as possible but differ from each other as much as possible. Producing a reasonable grouping and classified in a more similar series is one of the main advantages of cluster analysis [Akay and Yüksel 2018]. The clustering methods are also designed for applications where the data varies over time.

The clustering algorithm used in this study was Partitioning Around Medoids (PAM). The PAM algorithm minimizes the sum of the differences of each observation for its medoid. Since in the operations of the company some SKUs record atypical consumption and storage under consignment (customer property), the PAM algorithm was used using k-medoids. A medoid refers to the element of a cluster whose average distance (difference) between it and all other items in the same cluster is the shortest possible. Using medoids instead of centroids makes the PAM method more robust, being less affected by outliers or noise, compared to algorithms like k-means [Akay and Yüksel 2018, Kaufman and Rousseeuw 2005]. The PAM algorithm is developed with the following steps: (1) select k random observations as initial medoids, (2) calculate the distance matrix between all observations, (3) assign each observation to its closest medoid, (4) to each cluster created, check if selecting another observation as medoid reduces the distance of the cluster and (5) check if at least one medoid has changed, otherwise, the process ends. For the dataset, the Gower distance metric was used, which is not possible with other algorithms, for example, k-means, which only allows Euclidean or Manhattan distances. Gower distance metric is a powerful method proposed by Gower [1971] and extended by Kaufman and Rousseeuw [2005], applied to databases with continuous, ordinal or categorical variables at the same time. Gower distance is based on Gower´s General Similarity Coefficient Sij, comparing two cases i and j, defined as:

$$\boldsymbol{S_{ij}} = \frac{\sum_k^n \boldsymbol{w_{ijk} S_{ijk}}}{\sum_k^n \boldsymbol{w_{ijk}}} \tag{7}$$

where:

S_{ijk} : indicates the contribution provided by the k-th variable.

w_{ijk} : it is usually 1 or 0 depending on whether the comparison is valid for the k-th variable.

Through the cluster grouping, the SKU's classification is obtained according to the proposed factors. Finally, with the classification obtained through PAM, the inventory analysis is performed, proposing a redistribution of materials in the warehouse. In this case, the optimal picking point was identified as an additional strategy for inventory management. The optimal picking point location strategy based on the redistribution of materials was a suggestion from the company to determine the location of the collection point that minimizes the transfer distances. Through the facility location problem, points a^1, … a^m ∈ R^2 was minimized where a represents a location within the warehouse. Using the Euclidean distances between points, the calculation for the location of the picking point was performed with equations (8) and (9).

$$\boldsymbol{d_2^2(x, a^i) := (x_1 - a_1^i)^2 + (x_2 - a_2^i)^2} \tag{8}$$

for all $(x_1, x_2) \in R^2$

and $a^i := (a_1^i, a_2^i), i = 1, \dots, m$

$$\sum_{i=1}^{m} v_i \cdot d_2^2(x, a^i) = \sum_{i=1}^{m} v_i \cdot ((x_1 - a_1^i)^2 + (x_2 - a_2^i)^2) \tag{9}$$

where $v_1, \dots, v_m \in R$ are weights assigned to the materials, according to the cluster classification obtained in the previous step.

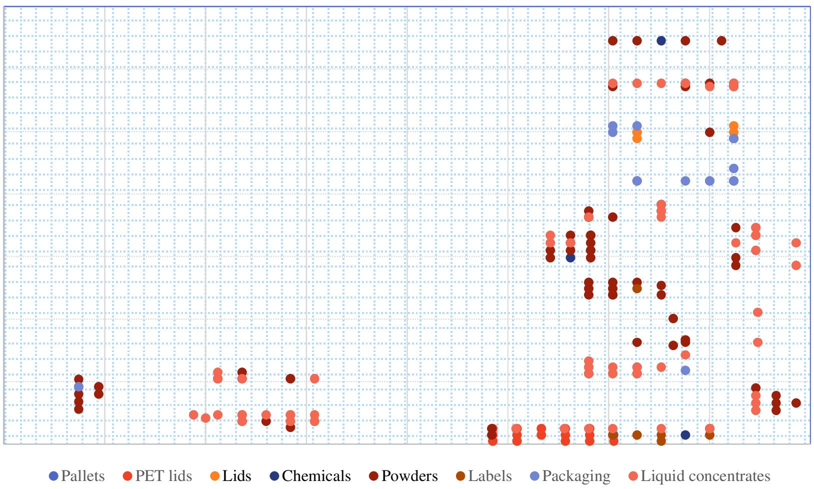
RESULTS

The data on the SKUs were obtained through the SAP system and processed in spreadsheets, identifying the inputs and outputs during a production period of one year. With the information from the SAP system, the frequencies and quantities of materials required by the production area were also calculated, in addition to the volume occupied and its location of each SKU. Table 1 shows the identification, location, quantity, and volume occupied of the SKUs present in the warehouse.

Table 1. Inventory and characteristics

Identification (family)	Number of SKUs	Location		Volume (in m^3)
		Internal	Internal/External	
Chemicals	6	x		12.32
Powders	65		x	519.29
Liquid concentrates	67		x	317.53
Lids	5		x	1.97
Pallets	1		x	1,169
Packaging	15	x		2.64
Labels	24	x		373.93
PET lids	9		x	0.53
Cardboard	11		x	641.71

Source: own work

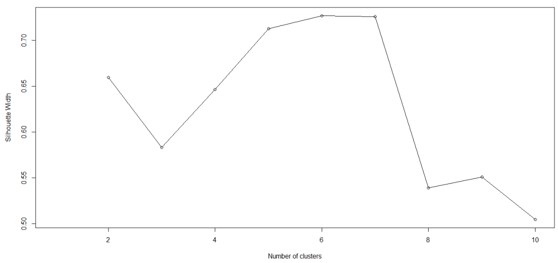


Source: own work

Fig. 2. Locations of the SKUs

Internal / external warehouse locations were considered those in which an SKU can be found, either in an internal warehouse, or in an external warehouse, mainly due to capacity and space constraints. Figure 2 presents the current locations of the SKUs in the internal warehouse.

Using the PAM clustering method, the SKUs were grouped based on the factors of DRC, AQO, PF, DRR, ARO, and RF, including two qualitative factors related to location (racks and floor) and the management unit (kilograms, pieces or gallons). Using the R studio software, modeling was performed with PAM, determining the number of clusters. By analyzing the similarity in the dataset and implementing the Gower distance, a similarity matrix was created. Establishing a similarity criterion allows the similarity of the elements to be related to each other; therefore, the proximity of an element is determined employing a similarity measure.



Source: own work

Fig. 3. Silhouette analysis

Subsequently, using the similarity matrix, with silhouette analysis, the size of the cluster was defined. With six clusters an average silhouette width of 0.73 was achieved, this being the highest result for the number of clusters (Figure 3).

Examining the context of each cluster, the solution with six clusters was the one that best adjusted to the diversity of data and requirements for warehouse administration. With the PAM clustering approach, the SKUs of the warehouse were grouped into six clusters as shown in Table 2.

Table 2. Quantitative factors

	Cluster					
	1	**2**	**3**	**4**	**5**	**6**
DRC	15.21	2.44	133.76	65 502.20	7 168.41	93 90.80
AQO	107.54	15.11	668.61	233 365.76	39 902.60	64 417.42
PF	0.14	0.15	0.18	0.28	0.25	0.09
DRR	1.72	0.2	17.6	12 428.9	828.2	1769.6
ARO	35.57	3.50	417.23	176 160.45	16 162.93	31 891.31
RF	0.04	0.05	0.04	0.08	0.05	0.04
# SKU´s	117	11	21	14	24	16
%	58	5	10	7	12	8
Volume (m^3)	616	33.65	841.08	23.64	1392	132.09
Average volume (m^3)	5.26	3.05	40.0	1.68	58.0	8.0

Source: own work

The SKUs were distributed as follows: 58% in Cluster 1, 5% in Cluster 2, 10% in Cluster 3, 7% in Cluster 4, 12% in Cluster 5 and 8% in Cluster 6. The factors with high values in PF and RF were clusters 4 and 5, which correspond to the families of labels, covers, and packaging materials. Cluster 6 includes families of label and packaging materials with the lowest PF. The DRC, AQO and DRR values are considerably higher in clusters 4, 5 and 6 because it corresponds to SKUs such as labels, can lids and packaging, which are used in large quantities during production. Cluster 5 includes, in addition to labels and packaging, the pallet family, so the volume occupied is greater than in other clusters. Without considering the family of pallets in cluster 5, cluster 3 is the one with the highest volume occupied in the warehouse. Cluster 1 is the one that contains the highest number of SKUs with 117, represented by materials from the families of chemicals, powders, and liquid concentrates.

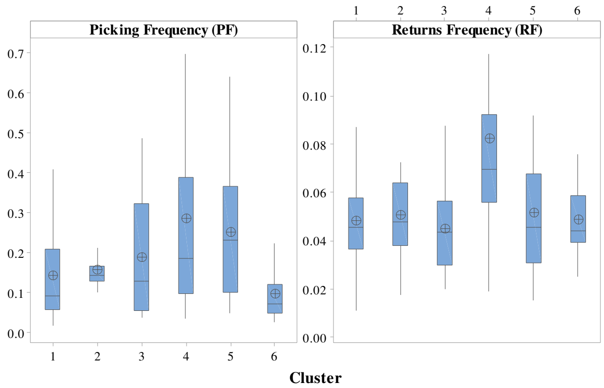
For qualitative factors, with the PAM grouping method, the results shown in Table 3 were obtained.

Table 3. Qualitative factors

		Location		Unit of measure		
		Floor	Rack	Kilograms	Pieces	Gallons
Cluster	1		x	x		
	2		x			x
	3	x		x		
	4	x			x	
	5	x			x	
	6		x		x	

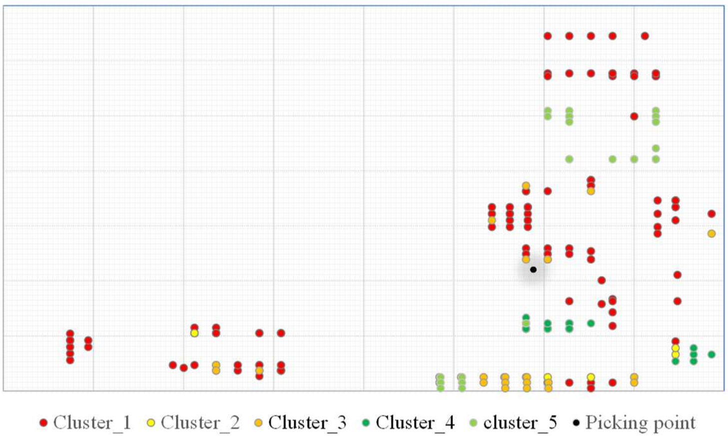
Source: own work

For example, for Cluster 2, the SKUs that form a group, belonging to families of liquid and chemical concentrates, that are in racks and identified as gallon material handling units. Also, these qualitative factors shown through the different clusters, allow the company to relate the characteristics of the materials and movement requirements with the systems and capacities of the equipment for the handling of materials. Based on the features that make up each of the grouped groups, for the location of the optimal collection point, and applying the Pareto principle, a weight is assigned to each of the factors. The weights give relevance to those factors that affect with a higher score towards the achievement of the different performance indicators, these weights are applied through equation (9) taking values of vi to reduce the variable d. In this case, the picking frequency and return frequency factors were determined by the company, as the main factors that favor efficiency in order processing. Eliminating outliers, as shown in Figure 4, clusters 4 and 5 were the main ones to consider for the PF and RF factors.



Source: own work

Fig. 4. Main factors



Source: own work

Fig. 5. Proposed warehouse layout

The company ranked clusters 4 and 5 with the highest weights, followed by clusters 2 and 3, and with the lowest weight to cluster 1. Regarding cluster 6, the company considered sending these materials to an external warehouse, such as the effect of low PF levels, a situation that favors the capacity of the internal warehouse. Applying equations (8) and (9), using the Facility Location Optimizer module of MATLAB software, the location of the optimal picking point was calculated. Graphically the solution is shown in Figure 5.

With this layout proposal, the calculated picking point was based on the weights of the clusters, with relevance in the picking frequency and warehouse returns, giving priority to these factors. This location is the point that minimizes the transfer distance for the preparation of the different SKUs, a situation that supports the improvement of logistics performance within the warehouse. With this distribution, the development of materials favors clusters 4 and 5, combining a policy of cluster collection and picking point, it is also possible to determine the volume required for the operation. The proposed picking point minimizes the routes of materials from clusters 4 and 5, with an average volume capacity of 60 m3. The configuration in Figure 5 also shows the distribution of the clusters throughout the warehouse, assisting in making decisions about planning the necessary space, depending on the volume occupied by each SKU that makes up the clusters. Compared to the current distribution of the company, this distribution proposal based on a cluster allows a reorganization of the SKUs increasing the storage capacity by 8%, in addition to avoiding the dispersed distribution of materials, going from a classification by families to a cluster classification.

CONCLUSIONS

The warehouse is an important component in the supply chain, due to reasons that include, among others, the fluctuations of demand and value-added service to the customer. Space, time, and costs are pillars for measuring storage efficiency. By optimizing inventory management, costs and time are minimized. With this proposal, it was possible to implement a methodology for the optimal identification and location of materials, without the need for expensive information systems, with a focus on the characteristics and factors that affect order preparation operations. The use of data mining techniques such as PAM clustering makes it possible to group the inventory into different clusters considering both qualitative and quantitative factors.

This article demonstrated how the variables of daily consumption rate, average quantity per order, picking frequency, the daily rate of return, the average number of returns per order, and frequency of return could be integrated into a distribution design, also including attributes related to the handling of materials within the warehouse.

The clustering proposal with PAM offers a more realistic approach to the problem of inventory management, where factors as diverse as time and capacities must be considered, to the types and handling that must be had with the materials inside the warehouse. The traditional approach to storage design issues for inventory management ignores the dynamic nature of customer demand. With this proposal, decision-makers in the company can analyze the dynamic environment of orders using factors such as picking frequency and return frequency. Also, with this analysis, the characteristics and qualities of the inventories can be periodically reviewed and the locations of the SKUs can be modified to benefit the improvement in supply logistics.

The inventory supply and administration process, through PAM, allows adapting the material selection environment, increasing the collection speed, and reducing the distance traveled. Furthermore, the results support decision-making on storage capacity, allowing the space required by the materials that make up the different clusters to be identified.

By combining the optimization of the picking point, a considerable benefit was achieved for the company, not only in streamlining the order preparation process but also in reducing the costs related to inventory management. By minimizing the transfer distances and using the identification of the materials, it is possible to fulfill orders faster and with high levels of satisfaction for different customers. Warehouse design decisions are another element that should be considered in inventory management, as it affects various aspects related to performance, including material handling, space cost, and capacity. As additional proposals, this study could be extended to the optimization of the warehouse design considering other factors, such as the routing for the collection, the delivery dates of the orders, the definition of picking areas, and the policies for the storage of materials.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This research was supported by PRODEP [grant number UAEH-EXB-152] and CONACYT.

REFERENCES

Akay Ö., Yüksel G., 2018. Clustering the mixed panel dataset using Gower's distance and k-prototypes algorithms, Communications in Statistics - Simulation and Computation, 47(10), 3031–3041. http://doi.org/10.1080/03610918.2017.1367806.

Aktepe A., Ersoz S., Turker A., Barisci N., Dalgic A, 2018. An Inventory classification approach combining expert systems, clustering, and fuzzy logic with the Abc method, And An Application, South African Journal of Industrial Engineering, http://doi.org/10.7166/29-1-1784.

Anđelković A., Radosavljević M, 2018. Improving the order-picking process through the implementation of warehouse management system, Strategic Management, 23(2), 3–10, http://doi.org/10.5937/StraMan1801003A.

Aqlan F, 2017. Dynamic clustering of inventtory parts to enhance warehouse management, European J. of Industrial Engineering, 11(4), 469, http://doi.org/10.1504/EJIE.2017.086184.

Arora S., Chana I, 2014. A survey of clustering techniques for big data analysis. 2014 5th International Conference - Confluence The Next Generation Information Technology Summit (Confluence), 59–65, http://doi.org/10.1109/CONFLUENCE.2014.6949256.

Bottani E., Volpi A., Montanari R., 2019. Design and optimization of order picking systems: An integrated procedure and two case studies, Computers & Industrial Engineering, 137, http://doi.org/10.1016/j.cie.2019.106035.

Çelik M., Süral H, 2019. Order picking in parallel-aisle warehouses with multiple blocks: complexity and a graph theory-based heuristic, International Journal of Production Research, 57(3), 888–906, http://doi.org/10.1080/00207543.2018.1489154.

Choi T.-M., Wallace S.W., Wang Y, 2018. Big Data Analytics in Operations Management, Production and Operations Management, 27(10), 1868–1883, http://doi.org/10.1111/poms.12838.

de Vries J., de Koster R., Stam D, 2016. Exploring the role of picker personality in predicting picking performance with pick by voice, pick to light and RF-terminal picking, International Journal of Production Research, 54(8), 2260–2274. http://doi.org/10.1080/00207543.2015.1064184

Djatna T., Hadi M. Z, 2017. Implementation of an ant colony approach to solve multi objective order picking problem in beverage warehousing with drive-in rack system, 2017 International Conference on Advanced Computer Science and Information Systems (ICACSIS), 137–142, http://doi.org/10.1109/ICACSIS.2017.8355024

Faia Pinto A.R., Nagano M.S, 2019. An approach for the solution to order batching and sequencing in picking systems, Production Engineering-Research and Development, 13(3–4), 325–341, http://doi.org/10.1007/s11740-019-00904-4

Gower J.C, 1971. A General Coefficient of Similarity and Some of Its Properties. Biometrics, 27(4), 857, http://doi.org/10.2307/2528823

Grosse E.H., Glock C.H, 2015. The effect of worker learning on manual order picking processes, International Journal of Production Economics, 170, 882–890, http://doi.org/10.1016/j.ijpe.2014.12.018.

Gu J., Goetschalckx M., McGinnis L.F, 2007. Research on warehouse operation: A comprehensive review, European Journal of Operational Research, 177(1), 1–21, http://doi.org/10.1016/j.ejor.2006.02.025.

Guo X., Yu Y., De Koster R.B.M, 2016. Impact of required storage space on storage policy performance in a unit load warehouse, International Journal of

Production Research, 54(8), 2405–2418, http://doi.org/10.1080/00207543.2015.1083624.

Hong S, 2019. A performance evaluation of bucket brigade order picking systems: Analytical and simulation approaches, Computers & Industrial Engineering, 135, 120–131, http://doi.org/10.1016/j.cie.2019.05.037.

Jemelka M., Chramcov B., Kriz P., Bata T, 2017. ABC analyses with recursive method for warehouse, 2017 4th International Conference on Control, Decision and Information Technologies (CoDIT), 0960–0963, http://doi.org/10.1109/CoDIT.2017.8102722.

Kaufman L., Rousseeuw P, 2005. Introduction. In Finding Groups in Data: An Introduction to Cluster Analysis, (pp. 1–67), John Wiley, Hoboken, http://doi.org/10.1002/9780470316801.ch1.

Kusrini K, 2015. Grouping of Retail Items by Using K-Means Clustering, Procedia Computer Science, 72, 495–502, http://doi.org/10.1016/j.procs.2015.12.131.

Liu J., Liao X., Zhao W., Yang N, 2016. A classification approach based on the outranking model for multiple criteria ABC analysis, Omega, 61, 19–34, http://doi.org/10.1016/j.omega.2015.07.004.

Lolli F., Ishizaka A., Gamberini R, 2014, New AHP-based approaches for multi-criteria inventory classification, International Journal of Production Economics, 156, 62–74. http://doi.org/10.1016/j.ijpe.2014.05.015.

Matthews J., Visagie S.E, 2019 SKU arrangement on a unidirectional picking line. International Transactions in Operational Research, 26(1), 100–130, http://doi.org/10.1111/itor.12550.

Tsai C.-W., Lai C.-F., Chao H.-C., Vasilakos, A. V, 2015, Big data analytics: a survey. Journal of Big Data, 2(1), 21, http://doi.org/10.1186/s40537-015-0030-3.

van Gils T., Ramaekers K., Braekers K., Depaire B., Caris A, 2018. Increasing order picking efficiency by integrating storage, batching, zone picking, and routing policy decisions, International Journal of Production Economics, 197, 243–261, http://doi.org/10.1016/j.ijpe.2017.11.021.

van Gils T., Ramaekers K., Caris A., Cools M, 2017. The use of time series forecasting in zone order picking systems to predict order pickers' workload, International Journal of Production Research, 55(21), 6380–6393, http://doi.org/10.1080/00207543.2016.1216659.

van Gils T., Ramaekers K., Caris A., de Koster R.B.M., 2018. Designing efficient order picking systems by combining planning problems: State of the art classification and review, EUROPEAN JOURNAL OF OPERATIONAL RESEARCH, 267(1), 1–15, http://doi.org/10.1016/j.ejor.2017.09.002.

Xindong Wu, Xingquan Zhu, Gong-Qing Wu, Wei Ding, 2014. Data mining with big data, IEEE Transactions on Knowledge and Data Engineering, 26(1), 97–107, http://doi.org/10.1109/TKDE.2013.109.

Yuan R., Cezik T., Graves S.C, 2018. Stowage decisions in multi-zone storage systems, International Journal of Production Research, 333–343, http://doi.org/10.1080/00207543.2017.1398428.

Zhang R.-Q., Wang M., Pan X, 2019. New model of the storage location assignment problem considering demand correlation pattern, COMPUTERS & INDUSTRIAL ENGINEERING, 129, 210–219, http://doi.org/10.1016/j.cie.2019.01.027.

ZARZĄDZANIE ZAPASEM ORAZ OPTYMALIZACJA LOGISTYKI - PODEJŚCIE OPARTE NA EKSPLORACJI DANYCH

STRESZCZENIE. **Wstęp:** W obecnych warunkach ekonomicznych, charakteryzujących się wysoką konkurencyjności i nieprzewidywalności działalności w obrębie łańcucha dostaw, istotne jest dążenia do optymalizacji kosztów i poprawy poziomu obsługi klientów, poprzez prawidłowe zarządzanie zapasem, jako czynnikiem kluczowym. Właściwe zarządzanie zapasami prowadzi do pozytywnych wpływów na wyniki logistyczne. W ujęciu ekonomicznym, około 15% kosztów logistycznych jest związane z operacjami magazynowymi. Poprzez zastosowanie studium przypadku z branży spożywczej, w pracy proponowana jest metoda klasyfikacji zapasów z zmiennymi jakościowymi i ilościowymi, przy zastosowaniu technik eksploracji danych, kategoryzując materiały przy użyciu zmiennych takich jak częstotliwość pobrań, poziom konsumpcji, jak i charakterystyki jakościowe związane z operacjami magazynowymi. Proponowany model łączy klasyfikację materiałową z technikami lokalizacyjnymi w celu ułatwienia procesu decyzyjnego w obszarze zarządzania zapasem oraz operacji magazynowych.

Metody: Zastosowana metoda opiera się na algorytmie Partitioning Around Medoids, który w innowacyjny sposób, stosuje strategię lokalizacji optymalnego punktu poboru w oparciu o klasyfikację klastrową, uwzględniając jakościowe jak i ilościowe czynniki, mające duży wpływ na określanie priorytetów w zarządzaniu zapasem w przedsiębiorstwie.

Wyniki: Uzyskane wyniki poprawiają marszruty dystrybuowanych materiałów w oparciu o identyfikację ich charakterystyk takich jak częstotliwość pobrań i handlingu, pozwalając na reorganizację i wzrost pojemności magazynowej różnych indeksów materiałowych, przechodząc z klasyfikacji na podstawie rodzin do klasyfikacji opartej na klusterze. Dodatkowo, wyniki wspomagają proces decyzyjny związany ze zdolnościami magazynowymi, umożliwiając identyfikację na najniższym poziomie miejsca magazynowego.

Wnioski: Praca prezentuje podejście do poprawy procesu decyzyjnego w zarządzaniu zapasem poprzez propozycję projektu magazynu w oparciu o techniki eksploracji danych, które stosują mierniki i wskaźniki działań operacyjnych. Zastosowanie technik eksploracji danych takich jak klustrowanie PAM umożliwia grupowanie zapasów przy uwzględnieniu różnych czynników jakościowych i ilościowych. Proponowana metod PAM umożliwia bardziej realistyczne podejście do problemów zarządzania zapasem, gdzie muszą być uwzględnione tak różne czynniki jak czas czy zdolności oraz typu operacji magazynowych.

Słowa kluczowe: Cluster, Partitioning Around Medoids, lokalizacja zasobów, łańcuch dostaw

Rafael Granillo-Macías ORCID ID: https://orcid.org/0000-0002-1015-667X
Autonomous University of Hidalgo State, UAEH
Campus Sahagun
Department of Industrial Engineering
Corredor Industrial, Ciudad Sahagun, Hidalgo, **México**
e-mail: rafaelgm@uaeh.edu.mx

LogForum

> Scientific Journal of Logistics <

2020, 16 (4), 549-559

http://doi.org/10.17270/J.LOG.2020.504

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

THE ASSESSMENT OF THE LOGISTICS PERFORMANCE INDEX OF CEE COUNTRIES WITH THE NEW COMBINATION OF SV AND MABAC METHODS

Ozcan Isik, Yuksel Aydin, S. Merve Kosaroglu

Sivas Cumhuriyet University, Sivas, **Turkey**

ABSTRACT. **Background:** The increase in global trade has caused logistics activities to be an important tool in providing strategic competitive advantage on a global scale. The logistics industry, which helps to facilitate the activities related to the movement of goods in the supply chain, is one of the fastest-growing sectors and has important effects on the economic performance of the countries. Measuring and evaluating the logistics performance of countries can enable them to reach their goals of achieving sustainable competitive advantage by revealing the strengths and weaknesses of logistics services in the entire supply chain. In this regard, the purpose of this study is to analyze and rank logistics performance in terms of selected 11 Central and Eastern European Countries (CEECs).

Methods: In this study, the SV (Statistical Variance) and the MABAC (Multi-Attributive Border Approximation area Comparison) methods are used to form a decision-making model in evaluating the logistic performance. In logistics performance evaluation, the SV method is used to weight the selected performance criteria, whereas the MABAC method is employed to evaluate and rank the logistics performance of CEECs.

Results: The results obtained from the SV method demonstrates that timeliness and infrastructure are the most and least significant performance criteria, respectively. According to the performance ranking of the countries by the MABAC method, the countries in the top three rankings are the Czech Republic, Poland and Hungary, respectively.

Conclusions: The fact that the ranking of the proposed hybrid model is the same as the original logistics performance index (LPI) ranking of the selected countries suggests that the proposed model is consistent.

Key words: SV, MABAC, Logistics Performance, CEECs, Multi Criteria Decision Making.

INTRODUCTION

Factors such as globalization, technological developments, the widespread use of the internet, changing consumption habits, urbanization have led to increased competition among countries. Today, as a result of increasing competition on a global scale, gaining competitive advantage is of great importance for countries to come to the forefront in international trade.

Logistics, which facilitates the mobility of goods as well as providing cost savings, comprises an important service network both within and across the countries and plays a key role in achieving competitive advantage in international markets. Moreover, logistic activities, which have significant effects on the country's foreign trade balance, have become the driving force for the growth and development of the country's economies [Erkan, 2014]. Under these conditions, countries' efforts to seek competitive advantage have raised the importance of logistics activities, which is one of the most significant factors of trade.

Effective logistics activities in international trade contribute not only to the increase of the reliability of the supply chain of countries, but

Citation: *Işik Ö., Aydin Y., Koşaroğlu Ş., 2020. The assessment of the logistics performance index of CEE countries with the new combination of SV and MABAC methods. LogForum 16 (4), 549-559,* http://doi.org/10.17270/J.LOG.2020.504

Received: 05.06.2020, Accepted: 05.08.2020, on-line: 18.09.2020.

also to the development of trade relations between countries, which can help countries to compete globally [Rashidi and Cullinane 2019]. Nevertheless, inefficient logistics services can damage the foreign trade balance of the countries and cause disruption of the activities of all sectors in the economy. This may mean increased operational costs and disrupted relations in the supply chain for companies as well as countries [Marti et al. 2014].

Countries should check the logistics performance index (LPI) to evaluate their performance and set their objectives in the logistics industry. The goal of the LPI data developed by the World Bank is to reveal the differences in logistics activities between countries. The LPI consisting of 6 indicators such as customs, infrastructure, international shipments, logistics quality and competence, tracking and tracing, and timeliness ranks the countries in terms of their logistics performance and guides countries aiming at improving their logistics performance. Analyzing the LPI scores in detail, countries can determine challenges and opportunities in their logistics supply chain and improve their performance.

The objective of this study is to propose a hybrid performance evaluation model based on LPI data published by World Bank for selected CEECs whose importance in world trade increases day by day.

As a result of the collapse of the Berlin-Wall in 1989, planned economies have transformed into free-market economies and the concept of transition economy has taken its place in the literature. Among the transition economies, the old planned economies in Europe are called the CEECs. CEECs have shown different development performances in the process until today. When the economic indicators are evaluated, different levels of development between these countries are clearly seen. There are also countries that have become important economies of the European Union in parallel with the increase in welfare level among CEECs. The development of CEECs can be attributed to the improvement of various economic variables, especially the increase in production. Nevertheless, it is seen that these countries' place in the world economy has become evident with their growing foreign trade volumes. Accordingly, the CEECs are distinguished from other transition economies by their stable and strong economic performance [Mıhçı 2011].

This study makes three contributions to the existing literature. Firstly, to the best of our knowledge, it is the first study that evaluates the logistics performance of selected CEECs. Secondly, this study also proposes a new combined multi-criteria decision making (MCDM) model including the SV and MABAC methods. Finally, the ranking results of the proposed hybrid model are compared with the existing LPI rankings of the countries and the consistency of the model is checked. Additionally, the findings of this study make some significant recommendations to the CEECs to improve their logistics performance.

The rest of the study is organized as follows: Section 2 presents literature review of the prior studies regarding logistics performance of the countries. Section 3 explains the proposed hybrid methodology. Section 4 gives the application results of proposed model and finally Section 5 concludes the study.

REVIEW OF THE LITERATURE

The literature review section is in threefold: (1) The Applications of the MCDM in the Logistics Performance Assessment of the Countries, (2) The Application Areas of the SV Method, (3) The Application Areas of MABAC Method.

The Applications of the MCDM in the Logistics Performance Assessment of the Countries

In the existing literature, the MCDM models are frequently used by many authors in the study of the performance evaluation. Recently, inter-country logistics performance evaluation, which is one of the dominant streams in the literature, has become the focus of attention for many researchers and academics. Recent studies in this area are summarized as follows.

Among the studies that have been focused on OECD countries, many MCDM methods such as CRITIC, SAW, TOPSIS, VIKOR and Peters' fuzzy regression methods [Çakır 2017], Fuzzy AHP and ARAS-G [Yildirim and Mercangoz 2020], Fuzzy AHP and GRA methods [Candan 2019] have been proposed to evaluate and rank logistics performance. Nevertheless, using CRITIC, SWARA, combined weighting method, and PIV method, Ulutaş and Karaköy [2019] have compared the logistics performance of the European Union (EU) countries. Based on the integrated AHP and VIKOR methods, [Bayır and Yılmaz 2017] have also evaluated logistic performance of EU countries. Similarly, Mercangöz et al. [2020] have proposed an integrated model based on the Fuzzy AHP and COPRAS-G to analyze the LPI data of 28 EU and 5 EU candidate countries from 2010 to 2018. Moreover, Marti et al. [2017] have applied a multiplier DEA input model to the LPI data set of a group of 141 countries to examine their logistics performance.

The Application Areas of the SV Method

The SV method has been employed to determine the objective weights of criteria in different MCDM problems, such as material selection [Rao and Patel 2010, Liu et al. 2013], industrial robot selection [Rao et al. 2011], risk-ranking model [Liu et al. 2016], benchmarking of product recovery alternatives in reverse logistics [Sharma et al. 2016], green supplier selection problem and strategic project selection problem [Krishankumar et al. 2019] and financial development based performance assessment [Gülençer and Türkoğlu, 2020].

The Application Areas of MABAC Method

There are many studies that use the MABAC method in the different fields. For example, Pamučar and Ćirović [2015] have used fuzzy DEMATEL and MABAC methods to rank the forklift alternatives for a logistics company. Božanić et al. [2016] have proposed fuzzy AHP-MABAC model to rank potential locations for the development of laying-up positions. Using FUCOM and MABAC methods, Nunic [2018] has evaluated and selected the PVC carpentry manufacturers among Five potential alternatives. Milosavljević et al. [2018] have used various MCDM techniques, including the MABAC method, to solve the railroad container terminal location problem. Pamučar et al. [2018] have constructed a hybrid model based on interval rough numbers consisting of AHP and MABAC for assessing university web pages. Sharma et al. [2018] have proposed a hybrid model and integrate AHP and MABAC methods in rough environment for prioritizing railway stations. Biswas and Das [2019] have developed a hybrid model for selection of electric vehicle employing the integration of fuzzy AHP and MABAC. Wei et al. [2019] have presented a hybrid method of CRITIC and MABAC under probabilistic linguistic sets to choose medical consumption product supplier. Luo and Xing [2019] have proposed a hybrid model consisting of the combination of extended BWM, PROMETHEE II and MABAC methods to solve personnel selection problem for an IT company. Muravev and Mijic [2020] have integrated BWM method and MABAC method to evaluate the providers of spare parts for transport vehicles. Rahim et al. [2020] have employed a combination of bipolar neutrosophic set and the MABAC method for sustainable energy selection problem.

As can be understood from the brief literature summary, there is no study focusing on logistics performance assessment of CEECs in the literature. This study aims to fill this gap.

PROPOSED METHODOLOGY

Based on the hybrid model, this study combines the SV and the MABAC methods to assess inter-country logistics performance. In this section the steps of allocation of these two methods are described below.

SV Method

The variance weighting as a type of objective technique is proposed by Rao and

Patel [2010]. Statistical variance is a measure that gives important information about the distribution of the data. In this study, the variance weighting technique is employed to obtain the weight coefficients of the selected criteria. The calculation procedure of this method is as follows [Rao and Patel 2010]:

Step 1. The decision matrix A is formed as shown in the Eq. (1):

$$A = [a_{ij}]_{m*n} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

$i = 1,2, \ldots \ldots m;$
$j = 1,2, \ldots n$ (1)

In the above matrix, a_{ij} is the assessment value of i-th alternative according to j-th criterion.

Step 2. Because of different units employed in the measurement of the attributes, the decision matrix must be standardized to make the attributes comparable. Hence, decision matrix is normalized employing the following equation:

$$a_{ij}^* = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij};} i = 1,2, \ldots m; \; j = 1,2, \ldots n \quad (2)$$

a_{ij}^* is the normalized value of a_{ij}.

Step 3. Variance value for each criterion is calculated as:

$$\mathbf{V_j} = \left(\frac{1}{n}\right) \sum_{i=1}^{n} \left(\mathbf{a_{ij}^*} - (\mathbf{a_{ij}^*})_{\mathbf{mean}}\right)^2 \quad (3)$$

In Eq. (3), V_j is the variance of the data corresponding to the j-th criterion.

Step 4. Weight coefficient of each criterion is computed via Eq. (4).

$$w_j = \frac{V_J}{\sum_{i=1}^{m} V_j} \quad (4)$$

In which, w_j represents the objective weight with respect to the j-th criterion.

MABAC Method

MABAC method is used to identify the logistics performance of CEECs. This method, which has been introduced to the literature by Pamučar and Ćirović [2015], is based on defining the distance of the alternatives from the border approximation area [Pamučar and Ćirović 2015]. In the following the application steps of MABAC method are given:

Step 1. The initial decision matrix A is constructed. This matrix is presented in Eq. (1).

Step 2. The decision matrix A is normalized. Eqs. (5.1) and (5.2) are employed to normalize the benefit (positive) and cost (negative) criteria, respectively.

$$a_{ij}^* = \frac{a_{ij} - \min(a_{ij})}{\text{mak}(a_{ij}) - \min(a_{ij})};$$

$i = 1,2, \ldots \ldots m;$

$j = 1,2, \ldots n$ (5.1)

$$a_{ij}^* = \frac{a_{ij} - \text{mak}(a_{ij})}{\min(a_{ij}) - \text{mak}(a_{ij})};$$

$i = 1,2, \ldots \ldots m; \; j = 1,2, \ldots n$ (5.2)

In which, a_{ij}^* is the normalized value of a_{ij}.

Step 3. Weighted normalized decision matrix is determined as:

$\hat{a}ij = w_j + w_j \times a_{ij}^*;$

$i = 1,2, \ldots \ldots m; \; j = 1,2, \ldots n$ (6)

where, w_j is the weight coefficients of the attributes.

Step 4. The values of the border approximation area for each attribute are computed according to Eq. (7).

$$g_j = (\textstyle\prod_{i=1}^{m} \hat{a}ij)^{1/m}; \; j = 1,2, \ldots n \quad (7)$$

where, m is the total number of alternative.

Step 5. The distance of the alternatives from the border approximation area (q_{ij}) is computed as in Eq. (8)

$$q_{ij} = \hat{a}ij - g_j;$$

$$i = 1,2, \dots \dots m; \;\; j = 1,2, \dots n \qquad (8)$$

Step 6. The total distance of each alternative from the border approximate area is calculated as:

$$S_i = \sum_{j=1}^{n} q_{ij} \; ; \; i = 1,2, \dots \dots m \qquad (9)$$

Here, the alternative with the highest S_i value is considered to be the best alternative in terms of the selected evaluation criteria.

APPLICATION OF THE PROPOSED HYBRID MODEL FOR THE EVALUATION OF LOGISTICS PERFORMANCE

In this section, the proposed hybrid SV-MABAC model is applied to the sample consisting of the 2018 LPI data of CEECs. The 2018 LPI data for CCE countries are retrieved from World Bank. The criteria set regarding LPI data used in the evaluation process consists of 6 criteria such as Customs(C1), Infrastructure(C2), International Shipments (C3), Logistics Competence (C4), Tracking & Tracing (C5), and Timeliness (C6). These criteria have recently been used by researchers to determine the logistics performance of one country compared to that of other countries.

Determination of Criteria Weights with SV

The initial decision matrix, which takes into account the 2018 LPI data of CEECs in calculating the objective weights of the performance criteria, is presented in Table 1.

Table 1. Decision Matrix

	C1	C2	C3	C4	C5	C6
Bulgaria	2.937588	2.762986	3.233723	2.881315	3.015289	3.313491
Croatia	2.978555	3.012820	2.929487	3.096154	3.012820	3.593939
Czech Republic	3.286673	3.464600	3.746009	3.715632	3.703427	4.133620
Estonia	3.322037	3.098638	3.262154	3.147851	3.206675	3.798684
Hungary	3.354866	3.270945	3.221880	3.213207	3.670508	3.785941
Latvia	2.796570	2.983000	2.744904	2.692550	2.787563	2.878851
Lithuania	2.846491	2.729618	2.789990	2.955624	3.123323	3.646595
Poland	3.253458	3.208902	3.678499	3.580044	3.505663	3.954262
Romania	2.580718	2.906903	3.176497	3.073653	3.264727	3.681887
Slovak Republic	2.789011	3.000000	3.101099	3.139194	2.985348	3.139194
Slovenia	3.418681	3.261905	3.187912	3.052381	3.266667	3.695238

Table 2. Normalized Decision Matrix

	C1	C2	C3	C4	C5	C6
Bulgaria	0.087520	0.081987	0.092202	0.083401	0.084837	0.083628
Croatia	0.088741	0.089400	0.083527	0.089620	0.084768	0.090706
Czech Republic	0.097921	0.102806	0.106809	0.107551	0.104199	0.104327
Estonia	0.098974	0.091947	0.093013	0.091116	0.090222	0.095874
Hungary	0.099952	0.097060	0.091864	0.093008	0.103272	0.095552
Latvia	0.083319	0.088515	0.078264	0.077937	0.078430	0.072658
Lithuania	0.084806	0.080997	0.079550	0.085552	0.087877	0.092035
Poland	0.096931	0.095219	0.104884	0.103626	0.098634	0.099800
Romania	0.076888	0.086257	0.090570	0.088969	0.091855	0.092926
Slovak Republic	0.083094	0.089020	0.088421	0.090866	0.083995	0.079229
Slovenia	0.101854	0.096792	0.090896	0.088353	0.091910	0.093263

As shown in Table 2, the Initial decision matrix is normalized employing Eq. (2).

After forming the normalized decision matrix, variance and weight values for each criterion are calculated according to Eqs. (3) and (4). The results for these calculations are presented in Table 3. The order of criteria with respect to priority weights is C6>C3>C1>C4>C5<C2. Hence, the results reported in Table 3 indicate that Timeliness (C6) and Infrastructure (C2) are the most and least significant performance criteria, respectively.

Table 3. The Variance and Weight of the Criterion

	C1	C2	C3	C4	C5	C6
Variance	0.000066	0.000040	0.000073	0.000064	0.000062	0.000076
Weight	0.171761	0.105975	0.191793	0.168824	0.161768	0.199880

Ranking of the LPI-Performance of CEECs with MABAC

In the second stage of the proposed model, we perform a ranking of the countries with respect to logistics performance through the application of the MABAC method. Firstly, Eq. (5.1) is applied to the decision matrix shown in Table 1 because of the fact that we have only benefit type criteria. Thus, a normalized decision matrix is formed for the MABAC method. This matrix is indicated in Table 4.

Table 4. Normalized Decision Matrix

	C1	C2	C3	C4	C5	C6
Bulgaria	0.425878	0.045400	0.488279	0.184506	0.248646	0.346390
Croatia	0.474767	0.385318	0.184379	0.394498	0.245950	0.569896
Czech Republic	0.842466	1.000000	1.000000	1.000000	1.000000	1.000000
Estonia	0.884668	0.502080	0.516679	0.445029	0.457614	0.733070
Hungary	0.923845	0.736517	0.476450	0.508910	0.964057	0.722914
Latvia	0.257591	0.344746	0.000000	0.000000	0.000000	0.000000
Lithuania	0.317166	0.000000	0.045036	0.257139	0.366605	0.611861
Poland	0.802828	0.652103	0.932565	0.867471	0.784068	0.857059
Romania	0.000000	0.241210	0.431117	0.372505	0.520999	0.639987
Slovak Republic	0.248571	0.367876	0.355802	0.436567	0.215955	0.207483
Slovenia	1.000000	0.724218	0.442519	0.351713	0.523117	0.650627

Table 5. Weighted normalized decision matrix

	C1	C2	C3	C4	C5	C6
Bulgaria	0.244910	0.110786	0.285441	0.199973	0.201991	0.269117
Croatia	0.253307	0.146808	0.227155	0.235425	0.201555	0.313791
Czech Republic	0.316464	0.211949	0.383585	0.337648	0.323536	0.399760
Estonia	0.323713	0.159182	0.290888	0.243956	0.235795	0.346406
Hungary	0.330442	0.184027	0.283172	0.254740	0.317721	0.344376
Latvia	0.216005	0.142509	0.191793	0.168824	0.161768	0.199880
Lithuania	0.226238	0.105975	0.200430	0.212235	0.221073	0.322179
Poland	0.309656	0.175081	0.370651	0.315274	0.288605	0.371189
Romania	0.171761	0.131537	0.274477	0.231712	0.246049	0.327801
Slovak Republic	0.214456	0.144960	0.260033	0.242527	0.196702	0.241352
Slovenia	0.343522	0.182723	0.276664	0.228202	0.246391	0.329927

Weighted normalized decision matrix is formed using Eq. (6) and presented in Table 5.

The next step within the MABAC method is to compute the values of border approximation area matrix using Eq. (7). Table 6 indicates the results related to these calculations.

Table 6. Border approximation area matrix

	C1	C2	C3	C4	C5	C6
g_j	0.262167	0.150996	0.270890	0.238664	0.235131	0.309686

Table 7. The distance from the border approximate area

	C1	C2	C3	C4	C5	C6
Bulgaria	-0.017257	-0.040210	0.014551	-0.038691	-0.033141	-0.040570
Croatia	-0.008860	-0.004187	-0.043735	-0.003240	-0.033577	0.004105
Czech Republic	0.054297	0.060953	0.112695	0.098984	0.088404	0.090074
Estonia	0.061546	0.008187	0.019998	0.005291	0.000664	0.036720
Hungary	0.068275	0.033031	0.012282	0.016076	0.082590	0.034690
Latvia	-0.046162	-0.008487	-0.079098	-0.069840	-0.073363	-0.109806
Lithuania	-0.035929	-0.045021	-0.070460	-0.026429	-0.014059	0.012493
Poland	0.047489	0.024085	0.099761	0.076610	0.053474	0.061503
Romania	-0.090406	-0.019459	0.003587	-0.006953	0.010917	0.018115
Slovak Republic	-0.047711	-0.006036	-0.010857	0.003863	-0.038429	-0.068334
Slovenia	0.081355	0.031727	0.005774	-0.010463	0.011260	0.020241

After computing the value g_j of each criterion, we obtain the values of the distance of the alternatives from the border approximation area via Eq. (8).

The last step within the MABAC approach is to identify the total distance of each alternative from the border approximate area. These calculations are carried out through Eq. (7) and the results are indicated in Table 8. The rankings of CEECs are as follows; Czech Republic, Poland, Hungary, Slovenia, Estonia, Romania, Croatia, Bulgaria, Slovak Republic, Lithuania and Latvia according to the S_ivalues from the Table 8. So, among the CEECs, the most successful country in terms of logistics performance is the Czech Republic.

As seen in the last column of Table 8, the order of the proposed model is the same as the original order. The fact that both rankings give the same results reveals that the proposed model is consistent.

Table 8. The Results of the Proposed Model

	S_i Values	Ranking of the proposed model	Original ranking among CEECs	Original ranking among all countries
Bulgaria	-0.155317	8	8	52
Croatia	-0.089493	7	7	49
Czech Republic	0.505407	1	1	22
Estonia	0.132405	5	5	36
Hungary	0.246943	3	3	31
Latvia	-0.386756	11	11	70
Lithuania	-0.179406	10	10	54
Poland	0.362921	2	2	28
Romania	-0.084198	6	6	48
Slovak Republic	-0.167505	9	9	53
Slovenia	0.139895	4	4	35

CONCLUSIONS

Given today's global competitive business environment, it is possible to state that the success of the supply chain considerably depends on the effectiveness of logistics activities. Playing a leading role in delivering the goods safely to the final customers, the logistics sector supports various activities that generate the supply chain and contributes to the growth and improvement of national economies. In this context, countries can determine their competitive positions in the global market in terms of logistics services by comparing their logistics performance with those of other economies.

The objective of this study as mentioned above is to propose a new combined model forming from SV and MABAC methods to evaluate the logistics performance of selected 11 transition economies in 2018. According to the results based on the SV weighting method, the order of the criteria is as follows: Timeliness, International Shipments, Customs, Logistics Competence, Tracking & Tracing, and Infrastructure. This result showing that timeliness is the most significant component of LPI is similar to that of Bayır and Yılmaz [2017] but different from those of Rezaei et al. [2018], Yildirim and Mercangoz [2019] and Ulutaş and Karaköy [2019]. The possible reason for this may be attributed to the subjective weighting methods used in these studies.

The ranking of the countries by MABAC method taking into account the weights found in the previous step is as follows: Czech Republic, Poland, Hungary, Slovenia, Estonia, Romania, Croatia, Bulgaria, Slovak Republic, Lithuania and Latvia. Thus, the results show that the countries in the top three rankings are the Czech Republic, Poland and Hungary, respectively. So the countries that fall outside the top three in logistics performance assessment should both strengthen the supply chain and take into account the order of importance of LPI criteria when determining their competitive strategies. More clearly, they should increase their investments that will facilitate logistics operations by focusing more on logistics processes to achieve the level of success of the top three countries and to have a larger share from world trade.

Even though this study presents a new model to the literature in performance evaluation, it has some limitations. Firstly, the results of this study should be interpreted only in terms of CEECs and should not be generalized in terms of other transition economies. Secondly, using only LPI data in 2018 is another limitation of this study. In future studies, researchers can expand the analysis by using methods involving fuzzy or gray numbers in logistics performance evaluation. In addition, the proposed performance evaluation model of this study may be applied to other companies or sectors in future studies.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The authors received no financial support for the research, authorship, and/or publication of this article.

REFERENCES

Bayır T., Yılmaz Z., 2017. Assesment of Logistic Performance Indexes of EU Countries by AHP and VIKOR Methods. Middle East Journal of Education, 3(2), 73-92.

Biswas T.K., Das M.C., 2019. Selection of commercially available electric vehicle using fuzzy AHP-MABAC. Journal of The Institution of Engineers (India): Series C, 100(3), 531-537, http://doi.org/10.1007/s40032-018-0481-3

Božanić D.A., Pamučar D.S., Karović S.M., 2016. Use of the fuzzy AHP–MABAC hybrid model in ranking potential locations for preparing laying-up positions, Vojnotehnički Glasnik/Military Technical Courier, 64(3), 705-729, http://doi.org/10.5937/vojtehg64-9261

Çakır S., 2017. Measuring logistics performance of OECD countries via fuzzy linear regression. Journal of Multi-Criteria Decision Analysis, 24(3-4), 177-186, http://doi.org/10.1002/mcda.1601

Candan G., 2019. Lojistik Performans Değerlendirmesi İçin Bulanık AHP ve Gri İlişkisel Analiz Yöntemleri İle Bütünleşik Bir Yaklaşım/Integrated Approach of Fuzzy AHP and Grey Relational Analysis for Logistic Performance Evaluation. Anemon Muş Alparslan Üniversitesi Sosyal Bilimler Dergisi/Journal of Social Sciences of Mus Alparslan University, 7(5), 277-286, http://doi.org/10.18506/anemon.506769

Erkan B., 2014. The importance and determinants of logistics performance of selected countries. Journal of Emerging Issues in Economics, Finance and Banking, 3(6), 1237-1254.

Gülençer İ., Türkoğlu S.P., 2020, Gelişmekte Olan Asya ve Avrupa Ülkelerinin Finansal Gelişmişlik Performansının İstatistiksel Varyans Prosedürü Temelli Ocra Yöntemiyle Analizi/Analysis of Financial Development Performance of Developing Asian and European Countries Using OCRA Method Based Statistical Variance Procedure, Üçüncü Sektör Sosyal Ekonomi Dergisi/Third Sector Social Economic Review, 55(2), 1330-1344, http://doi.org/10.15659/3.sektor-sosyal-ekonomi.20.06.1375

Krishankumar R., Saranya R., Nethra R.P., Ravichandran K.S., Kar S., 2019. A decision-making framework under probabilistic linguistic term set for multi-criteria group decision-making problem. Journal of Intelligent & Fuzzy Systems, 36(6), 5783-5795, http://doi.org/doi.org/10.3233/JIFS-181633

Liu H.C., Liu L., Wu J., 2013. Material selection using an interval 2-tuple linguistic VIKOR method considering subjective and objective weights. Materials & Design (1980-2015), 52, 158-167, http://doi.org/10.1016/j.matdes.2013.05.054

Liu H.C., You J.X., Chen S., Chen Y.Z., 2016, An integrated failure mode and effect analysis approach for accurate risk assessment under uncertainty. IIE Transactions, 48(11), 1027-1042, http://doi.org/10.1080/0740817X.2016.1172742

Luo S.Z., Xing L. N., 2019. A Hybrid Decision Making Framework for Personnel Selection Using BWM, MABAC and PROMETHEE. International Journal of Fuzzy Systems, 21(8), 2421-2434, http://doi.org/10.1007/s40815-019-00745-4

Marti L., Martin J.C., Puertas R., 2017. A DEA-logistics performance index. Journal of Applied Economics, 20(1), 169-192, http://doi.org/10.1016/S1514-0326(17)30008-9

Marti L., Puertas R., Garcia L., 2014, The importance of the Logistics Performance Index in international trade. Applied Economics, 46(24), 2982-2992, http://doi.org/10.1080/00036846.2014.916394

Mercangoz B.A., Yildirim B., Yildirim S.K., 2020. Time Period Based COPRAS-G Method: Application on the Logistics Performance Index. LogForum, 16 (2), 239-250, http://doi.org/10.17270/J.LOG.2020.432

Mıhçı H., 2011. Human Development Performance of Transition Economies in the Post-Cold War Period, Hacettepe Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 29(1), 21-42.

Milosavljević M., Bursać M., Tričković G., 2018. Selection of the railroad container terminal in Serbia based on multi criteria decision making methods. Decision Making: Applications in Management and Engineering, 1(2), 1-15, http://doi.org/10.31181/dmame1802001m

Muravev D., Mijic N., 2020. A Novel Integrated Provider Selection Multicriteria Model: The BWM-MABAC Model. Decision Making: Applications in Management and Engineering, 3(1), 60-78, http://doi.org/10.31181/dmame2003078m

Nunic Z., 2018. Evaluation and selection of manufacturer PVC carpentry using FUCOM-MABAC model. Operational Research in Engineering Sciences: Theory and Applications, 1(1), 13–28, http://doi.org/10.31181/oresta19012010113n

Pamučar D., Ćirović G., 2015. The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC). Expert systems with applications, 42(6), 3016-3028, http://doi.org/10.1016/j.eswa.2014.11.057

Pamučar D., Stević Ž., Zavadskas E.K., 2018. Integration of interval rough AHP and interval rough MABAC methods for evaluating university web pages. Applied Soft Computing, 67, 141-163, http://doi.org/10.1016/j.asoc.2018.02.057

Rahim N., Abdullah L., Yusoff B., 2020. A Border Approximation Area Approach Considering Bipolar Neutrosophic Linguistic Variable for Sustainable Energy Selection. Sustainability, 12(10), 3971, http://doi.org/10.3390/su12103971

Rao R.V., Patel B.K., 2010. A Subjective and Objective Integrated Multiple Attribute Decision Making Method for Material Selection. Materials & Design, 31(10), 4738-4747, http://doi.org/10.1016/j.matdes.2010.05.014

Rao R.V., Patel B.K., Parnichkun M., 2011. Industrial Robot Selection Using a Novel Decision Making Method Considering Objective and Subjective Preferences. Robotics and Autonomous Systems, 59(6), 367-375, http://doi.org/10.1016/j.robot.2011.01.005

Rashidi K., Cullinane K., 2019. Evaluating the sustainability of national logistics performance using Data Envelopment Analysis. Transport Policy, 74, 35-46, http://doi.org/10.1016/j.tranpol.2018.11.014

Rezaei J., van Roekel W.S., Tavasszy L., 2018. Measuring the relative importance of the logistics performance index indicators using Best Worst Method. Transport Policy, 68, 158-169, http://doi.org/10.1016/j.tranpol.2018.05.007

Sharma H.K., Roy J., Kar S., Prentkovskis O., 2018. Multi criteria evaluation framework for prioritizing indian railway stations using modified rough AHP-MABAC method. Transport and telecommunication journal, 19(2), 113-127, http://doi.org/10.2478/ttj-2018-0010

Sharma S.K., Mahapatra S.S., Parappagoudar M.B., 2016. Benchmarking of product recovery alternatives in reverse logistics. Benchmarking: An International Journal, 23(2), 406-424, http://doi.org/10.1108/BIJ-01-2014-0002

Ulutaş A., Karaköy Ç., 2019. An analysis of the logistics performance index of EU countries with an integrated MCDM model. Economics and Business Review, 5(4), 49-69, http://doi.org/10.18559/ebr.2019.4.3

Wei G., Wei C., Wu J., Wang H., 2019. Supplier selection of medical consumption products with a probabilistic linguistic MABAC method. International Journal of Environmental Research and Public Health, 16(24), 5082, http://doi.org/10.3390/ijerph16245082

Yildirim B.F., Mercangoz B.A., 2020, Evaluating the logistics performance of OECD countries by using fuzzy AHP and ARAS-G. Eurasian Economic Review, 10(1), 27-45, http://doi.org/10.1007/s40822-019-00131-3

OSZACOWANIE WSPÓŁCZYNNIKA DZIAŁALNOŚCI LOGISTYCZENJ KRAJÓW EUROPY ŚRODKOWO-WSCHODNIEJ ZA POMOCĄ NOWEJ KOMBINACJI METOD SV ORAZ MABAC

STRESZCZENIE. **Wstęp:** Wzrost globalnego handlu jest przyczyną wzrostu ważności działalności logistycznej jako narzędzia służącego do uzyskiwania przewagi konkurencyjnej na globalną skalę. Branża logistyczna, która wspomaga wszelkie czynności związane z przepływem towarów w obrębie łańcucha dostaw, jest jednym z najszybciej rosnących sektorów i ma istotny wpływ na ekonomiczne wyniki krajów. Pomiar oraz ocena sprawności logistycznej krajów umożliwia im osiągnięcie postawionych celów w uzyskaniu zrównoważonej przewagi konkurencyjnej poprzez ujawnienie słabych i mocnych stron swoich usług logistycznych w obrębie całego łańcucha dostaw.
Celem pracy jest analiza i stworzenie rankingu działalności logistycznej wybranych 11 krajów Europy Środkowo-Wschodniej.

Metody: W pracy zastosowano metody SV (Statistical Variance) oraz MABAC (Multi-Attributive Border Approximation area Comparison) dla zbudowania modelu podejmowania decyzji odnośnie oceny działalności logistycznej. Dla oceny działalności logistycznej, metoda SV została zastosowana do wyznaczenia wagi poszczególnych kryteriów oceny, podczas gdy metoda MABAC została używana do oceny i tworzenia rankingu działalności logisty stycznej krajów Europy Środkowo-Wschodniej.
Wyniki: Wyniki uzyskane przy użyciu metody SV pokazują, że terminowość oraz infrastruktura jest najważniejszymi kryteriami oceny działalności. Zgodnie ze stworzonym rankingiem przy pomocy metody MABAC, najwyżej ocenionymi krajami były: Czechy, Polska i Węgry.
Wnioski: Ranking uzyskany za pomocą opracowanej metody jest taki sam jak przy użyciu oryginalnego współczynnika działalności logistycznej (LPI), co dowodzi poprawności wypracowanego modelu.

Słowa kluczowe: SV, MABAC, działalność logistyczna, kraje Europy Środkowo-Wschodniej, wielokryterialne podejmowanie decyzji

Ozcan Isik ORCID ID: https://orcid.org/0000-0003-2230-8738
Sivas Cumhuriyet University,
Zara Veysel Dursun School of Applied Sciences
Department of Banking and Finance
Sivas 58700, **Turkey**
e-mail: ozcan@live.com

Yuksel Aydin ORCID ID: https://orcid.org/0000-0001-8966-7781
Sivas Cumhuriyet University,
Faculty of Economics and Administrative Sciences
Department of Business Administration
Sivas 58140, **Turkey**
e-mail: yaydin@cumhuriyet.edu.tr

Serife Merve Kosaroglu ORCID ID: https://orcid.org/0000-0002-2563-5753
Sivas Cumhuriyet University,
Cumhuriyet Social Sciences Vocational School
Department of Finance, Banking and Insurance
Sivas 58140, **Turkey**
e-mail: mervekosaroglu@gmail.com

LogForum

> Scientific Journal of Logistics <

2020, 16 (4), 561-571

http://doi.org/10.17270/J.LOG.2020.507

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

LOGISTICS MATURITY OF THE POLISH SERVICE SECTOR - RESEARCH RESULTS

Karolina Werner-Lewandowska

Poznan Universtity of Technology, Poznań, **Poland**

ABSTRACT. **Background:** The aim of the article is to demonstrate new methods for investigation of logistics maturity in service enterprises. The research assumes that logistic processes are implemented in service enterprises, which implies the possibility of developing a logistics maturity model for service enterprises in a theoretical aspect and the postulate that in economic practice there are different levels of logistics maturity of service enterprises and it is possible to identify them.

The originality of the presented research results from two aspects. The first aspect is of a methodical nature and concerns the logistics model used - LMM4SI, which is a proprietary tool that allows to assess the logistics maturity of a service enterprise. The second aspect is of a cognitive nature and is the scope and object of research, which are underrepresented in the literature. Some research concerns the development of a logistics maturity model and its application in the fashion industry. In Poland, similar studies are not being carried out, which a research gap is partially eliminated by the presented research. The results of the presented research concerned logistic maturity, defined as the organizational level of the enterprise, indicating the degree of use of logistics engineering in the areas of service enterprise operation.

Methods: The research methods used in the presented research are surveys that allowed to obtain primary data from 2,000 Polish service enterprises, mathematical analysis to determine the level of logistics maturity, and statistical analysis to make conclusions about the logistics maturity of the Polish service sector.

Results: As a result of conducted research an original logistics maturity model for the service industry (called LMM4SI) and the evaluation procedure carried out with its use. Realizing the cognitive aim of the article, the results of research on the logistics maturity of Polish service providers were presented.

Conclusions: The research results showed that service enterprises do not achieve high levels of logistics maturity. It was found that the developed methods allow for an effective assessment of the logistic maturity of enterprises.

Key words: logistics maturity, service sector.

INTRODUCTION

The number of service enterprises is increasing in Poland. According to data from the Central Statistical Office in Poland, in 2018 service enterprises constituted 54% of all enter-prises. Amongst them, enterprises categorized as SMEs (micro, small and medium enterprises) dominate. In 2017, they constituted 99.8% of all Polish enterprises, with micro enterprises being the largest group (96%; 2 million).

According to the World Bank, in 2018 the service sector had more than 65% share in GDP. For this reason, service enterprises may be the object of scientific research in the area of their business activities, which most often relate to marketing, customer service and human resource management. However, research on the logistics activity of service providers is rare. This is primarily due to the difficulty of implementing logistics activities by service enterprises as the features of the service such as: Lack of ownership, Intangibility, Inseparability, Variability,

Citation: Werner-Lewandowska K., 2020. Logistics maturity of the Polish service sector - research results. LogForum 16 (4), 561-571, http://doi.org/10.17270/J.LOG.2020.507

Received: 17.06.2020, Accepted: 24.08.2020, on-line: 18.09.2020.

Perishability, User participation make service as a product not susceptible to logistics activities.

Despite this, service enterprises implement logistics processes, storing stocks of materials needed to perform services and transporting them to the place of service, cooperate within supply chains and use IT solutions associated with logistics.

The above elements are a motivation for undertaking research on logistics in the service sector.

The subject of the presented research is the logistics maturity of service enterprises. Maturity in management is defined as a measurement of the ability of an organization for continuous improvement in a particular discipline (as defined in O-ISM3) [Vicente 2017]. The higher the maturity, the higher will be the chances that incidents or errors will lead to improvements either in the quality or in the use of the resources of the discipline as implemented by the organization. Maturity can be assessed by means of Maturity Models (hereinafter referred to as MMs). In enterprise management, they allow to improve the planning of activities that should lead to expected results, i.e. to achieve the desired state or level of maturity. For enterprise management, they are a simple but effective way to measure processes. The concept of maturity models stems from software engineering and their application is spreading to other fields at an ever faster pace [Poeppelbuss et al. 2011]. In addition, these models strengthen companies by providing them with the necessary operational conditions to manage organizational changes [Serna 2012]. MMs are regarded as tools for gradual and systematic demonstration of the development and/or improvement of general skills, processes, organizational structures and operating conditions [Blondiau et al. 2016]. MMs are used because in many cases the best way to modify the process is not that obvious. This type of model can be used as a multi-stage planning tool to identify which improvements in an organization should be made and when. The area that needs to be improved is assessed on the basis of MMs. Next, the evaluation result is used to determine which improvements should be introduced to increase the level of maturity [Helgesson et al. 2012]. Although the MM approach began in computer science and software engineering, its application has spread to other areas such as the medical sector [McCarthy et al. 2014], supply chain management [Lockamy et al. 2014], education [Zhou 2012, Marshall 2011, Egberongbe et al. 2017], IT outsourcing [Gottschalk et al. 2006], e-governance [Misra and Dhingra 2002], project management [Kwak and Ibbs 2002, Grant and Pennypacker 2006], knowledge management [Serenko et al. 2016], business process management [Tarhan et al. 2016, Van Looy et al. 2011], enterprise interoperability [Campos et al., 2013] and MMs for Industry 4.0 [Schumacher et al., 2016, Ellefsen et al. 2019], Logistics 4,0 [Werner-Lewandowska and Kosacka-Olejnik 2019c] or in aspects of sustainable development [Golińska et al. 2015, Odważny et el. 2019]. According to the literature review [Kosacka-Olejnik, 2020], research in the field of logistics maturity and the development of a logistics maturity model is being conducted by Italian scientists: C. Battista, MM Schiraldi [Battista and Schiraldi 2013].

The object of the presented research was the Polish service sector. The service industry is currently the dominant source of GDP in the EU-28. According to Eurostat data [Eurostat 2020], the share of services in the total gross value added for the EU-28 amounted to 73.2% in 2018 compared to 72.2% in 2008. According to the quoted Eurostat data, the relative importance of services was particularly high in Luxembourg, Malta, Cyprus, France, the United Kingdom, Greece, the Netherlands, Belgium, Portugal and Denmark. In Ireland, Slovakia and the Czech Republic, the share of services in GDP averages around 60%. An increase in the number of service enterprises is observed in Poland, which brings the Polish economy closer to the Western markets model. According to data from the Central Statistical Office in Poland, in 2018 service enterprises constituted 54% of all enterprises, among which enterprises categorized as SMEs (micro, small and medium enterprises) dominate. In 2017, they constituted 99.8% of all Polish enterprises, and among them the largest group (96%; 2 million) were micro-enterprises [Zakrzewski and Skowrońska (ed.) 2019].

Polish SMEs run their business mainly in the service sector (52.3%), including 13.5% providing services in the area of professional, scientific and technical activities, 8.8% in the area of health care and social welfare, 7.5% in the area of transport and warehouse management.

The analysis of the share of Polish enterprises in the creation of GDP in terms of the economy sector showed that in the case of SMEs the service sector is the most important. Its share in the creation of GDP in 2016 amounted to 43.1%, compared with 29.2% for large companies. [Zakrzewski and Skowrońska (ed.) 2019].

In terms of the number of employees in Polish enterprises in 2017, enterprises from the service sector also dominated. When analyzing data concerning the average gross monthly salary (in PLN) per one employee according to PKD sections (Polish Classification of Economic Activities), it is concluded that the highest one is in the section assigned to the service sector, i.e. Information and communications. It is worth noting, however, that the lowest salary is in the section: Other economic activity.

The above statistical data on the Polish service sector prove that this is an area of the economy with high developmental potential, which is worth researching.

In 2018, the Polish service sector was dominated by professional, scientific and technical activities (19%), transport and warehouse management activities (12%) and other service activities (12%) [CSO 2019].

The presented summaries indicate a high degree of competitiveness in the service sector. The growing importance of services in the European economy is the result of technological progress, changes in the level of relative prices, outsourcing and globalization.

Justifying the undertaking of research on the logistics maturity of service enterprises, attention should be drawn to the relationship between these enterprises and logistics. Reflections on the current state of knowledge about logistics maturity in service enterprises should begin with indicating the features of services, such as:

- Intangibility,
- Volatility - associated with volatile aesthetic and cultural sensations unable to be captured in time and space and which result from the uniqueness of services rendered even by the organizational unit itself [Gołembska and Tyc - Szmil 2008]. In logistics terms, volatility is complementary to the intangibility of services.
- Lack of storage possibility,
- Simultaneous production and consumption.
- All the listed features of services are assigned to them, regardless of the scope or type of services [Gołembska and Tyc - Szmil 2008].

The provision of services, regardless of their type, is accompanied by logistics processes that are carried out in parallel. As Gołembska and others point out, logistics processes accompanying the provision of the service should be managed in such a way that both the process of providing the service and the accompanying logistics processes create added value in time and space. The basic logistics processes in the sphere of services include: Supplies, including ordering raw materials, selection of suppliers, Warehousing (storage) of material resources used for the production of services, Inventory management, Transport, Packaging management, Order acceptance and service, Sales and customer service [Biesok 2013].

Logistics maturity in service enterprises should be evaluated because an intangible service requires tangible logistics support, without which it cannot be performed.

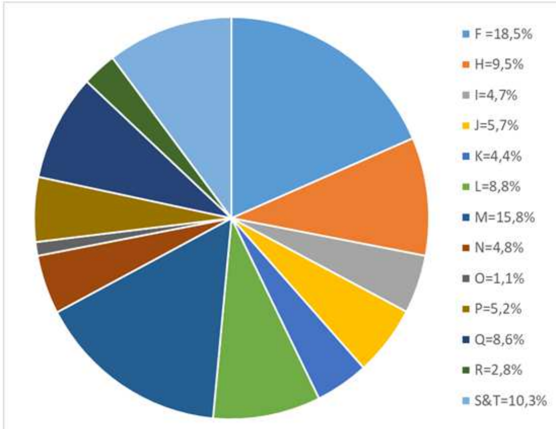
LOGISTICS MATURITY MODEL FOR SERVICE INDUSTRY - LMM4SI

In response to the need to assess logistics maturity in the service sector, the Logistics Maturity Model for Service Industry (LMM4SI) was developed. The model assumes 6 maturity levels LMLm, $m \in \{1,2,3,4,5,6\}$ (hereinafter: LMLm), which correspond to particular stages of logistics development in the economy, from the fragmentation phase to the Logistics 4.0 phase and are proposed in research carried out by R.H. Ballou [2007]. The level of maturity is deter-mined in 5 areas of logistics activity (hereinafter: LA) undertaken by service enterprises such as: Warehouse management (WM for short), Transport management (TM for short), Sup-ply and inventory management (SIM for short), Cooperation within supply chains and distribution (SCD for short) and in the field of IT solutions supporting logistics in the service sector (IT for short). The model assumes that the level of logistics maturity achieved by the enterprise is determined by logistics tools used in the enterprise, while the impact of individual tools on the levels of maturity can be different, which was expressed in the strength of impact [Werner-Lewandowska, Kosacka-Olejnik 2018]. 65 such tools were defined. Unacquaintance with more than 50% of tools indicates that the enterprise is not logistically mature (LML0).

RESEARCH OBJECT

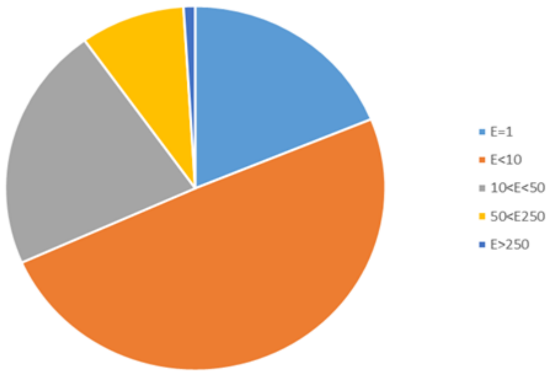
The research covered 2,000 Polish service enterprises from 12 sections according to PKD (Polish Classification of Economic Activities). The characteristics of the studied population by the type of service according to NACE (French Nomenclature statistique des Activités économiques dans la Communauté Européenne, Statistical Classification of Economic Activities in the European Union) are presented in Figure 1. In Figure 1, the individual letters are codes of service activity sectors, meaning in turn: F- construction, H- transportation and storage, I- accommodation and food service activities, J - information and communication, K-financial and insurance activities, L- real estate activities, M- professional, scientific and technical activities, N- administrative and support service activities, O- public administration and defense; compulsory social security, P- education, Q- human health and social work activities, R-arts, entertainment and recreation, S&T- other service activities and activities of households as employers; undifferentiated goods- and services-producing activities of households for one's own use.

The structure of the surveyed population included both micro, small, medium and large enterprises - Figure 2.



Source: own elaboration

Fig. 1. Structure of the surveyed population by industries according to NACE Rev.2.

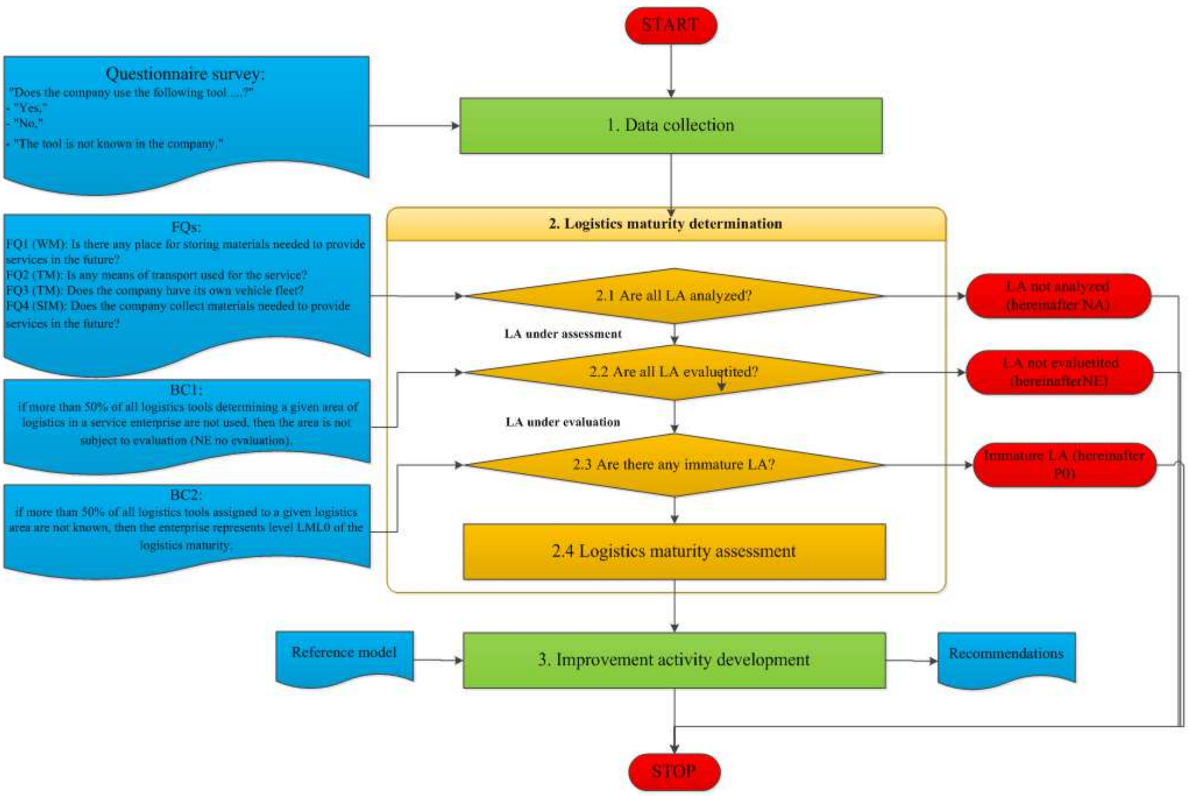


Source: own elaboration

Fig. 2. Structure of the surveyed population by employment level (E)

RESEARCH METHODOLOGY

The assessment of logistics maturity according to the LMM4SI is carried out according to the procedure presented in Figure 3. The procedure consists of 3 steps. The detailed description of this model can be found in research studies by Werner-Lewandowska and Kosacka-Olejnik [Werner-Lewandowska and Kosacka-Olejnik 2018, Werner-Lewandowska and Kosacka-Olejnik 2019a, Werner-Lewandowska and Kosacka-Olejnik 2019b, Werner-Lewandowska and Kosacka-Olejnik 2019c, Werner-Lewandowska 2019].



Source: own elaboration based on [Werner-Lewandowska and Kosacka-Olejnik 2019b]

Fig. 3. Stages in logistics maturity assessment with the use of the LMM4SI.

The research results presented in the article relate to Stage 2 of the procedure, i.e. they indicate the results regarding the determination of the level of logistics maturity of service enter-prises.

The logistics maturity model – LMM4SI - developed in the research cycle, assumes that a service enterprise can achieve 1 out of 6 levels of logistics maturity in 5 areas of logistics activity. The determinant of a given level is the degree of use of logistics tools identical with a given area. In accordance with the procedure for determining the level of maturity according to the LMM4SI, the enterprise is not subject to evaluation in a given area of logistics activity in two cases:

– The area of logistics activity is not undertaken in the enterprise.
  It was assumed that this applies to areas such as: Warehouse management, Transport management and Inventory and supply management. These are areas of logistics activity that may not be present in a service enterprise. This, however, does not have to have a negative impact on the provision of services. A service enterprise may not maintain stocks of materials needed to perform services in the future or supply is carried out in a system, e.g. item for item. This results in not earmarking any space in the enterprise for storage. A service enterprise may also provide services without using internal means of transport.
  The identification of areas not evaluated for logistics maturity was planned in stage 1 in the survey questionnaire, which contained filtering questions (FQs in Fig.3). On the basis of answers to filtering questions in stage 2, it was determined whether a given area of logistics activity is subject to further analysis (in Fig.3 as NA-Not Analyzed).
– The BC1 condition is met, which means that the enterprise does not use more than 50% of logistics tools in a given area of logistics activity. Then the given area is not

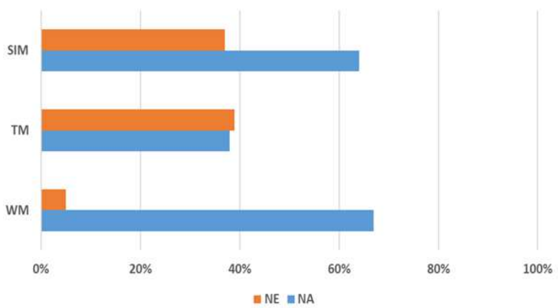
subject to evaluation (in Fig.3 as NE-Not Evaluated).

Based on surveys, it is also possible to indicate that a given enterprise does not know 50% or more of tools in a given area of logistics activity, which implies level 0 indicating logistics immaturity in a given area (in Fig.3, marked L0).

RESEARCH RESULTS

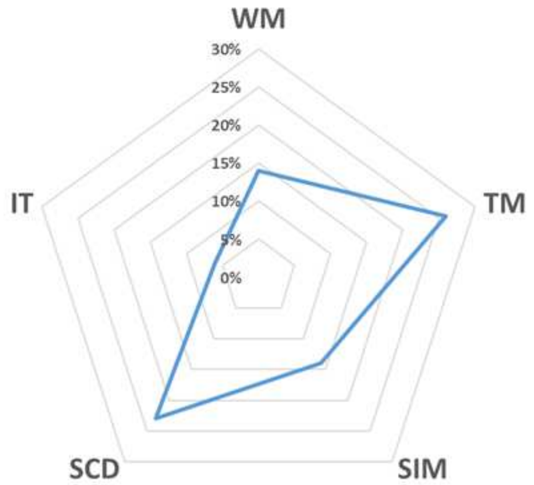
The conducted research indicates that in service enterprises, regardless of the service section, activities are carried out in the areas of storage, transport, supply and warehouse management, distribution and cooperation within supply chains. Their implementation is supported by IT solutions. However, as confirmed by the research (Figure 4), 67% of Polish enterprises do not have a designated area for storing inventories, i.e. the storage process is not carried out in the planned space or is not undertaken at all due to the lack of inventory of materials for future services, which is declared by 64% of the surveyed enterprises. Almost every fourth Polish service enterprise (38%) does not use external transport to provide services.

The conducted research showed that the Polish service sector is primarily immature in the area of Transport management. Nearly 30% of the surveyed enterprises do not know more than 50% of tools related to the management of means of transport (Figure 5).



Source: own elaboration

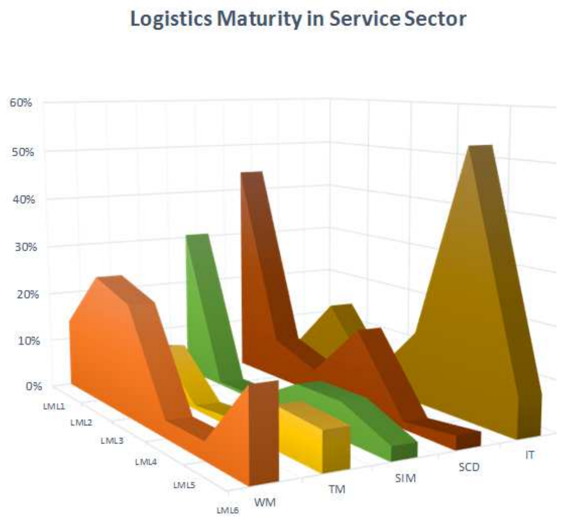
Fig. 4. Areas not analyzed or not evaluated in the study



Source: own elaboration

Fig. 5. Logistics immaturity of Polish service enterprises

Analyzing logistics maturity levels achieved by enterprises in individual areas (Figure 6), it can be stated that in the area of Warehouse management, the LML3 dominates, achieved on average by 20% of the surveyed population. In the area of Transport management, on average 34% of the surveyed population of service enterprises are logistically immature. In the area of Supply and inventory management, the LML1 dominates, achieved on average by 33% of the surveyed enterprises. Similarly, the LML1 is the most common level (44%) of logistics maturity in the area of Cooperation within the supply chain and distribution. The LML5 dominates in the area related to IT solutions in logistics, which was achieved on average by 48% of the surveyed enterprises. The highest level - LML6 - does not dominate in any of the analyzed areas, but is more often achieved in the area of Warehouse management due to the use of outsourcing in the area of storage space and transport management.



Source: own elaboration

Fig. 6. Logistics maturity of Polish service enterprises

As part of the undertaken research cycle, the correlation between the level of logistics maturity and the size of the enterprise and industry was examined. The presented results refer to the assumption that a minimum of 75% of the surveyed enterprises in a given service section or a minimum of 75% of enterprises of a given size, expressed by an employment level, reach one of six levels of logistics maturity or are immature in this respect. The summary of the results of the correlation analysis are presented in Table 1.

As can be concluded from the conducted research, taking into account the percentage of enterprises (minimum 75%) that achieve a given level of logistics maturity in range of the highest LML6, there is no clear correlation with the service sector. This level is achieved by all enterprises in sections J, L, O and Q, N, M and P. The relationship resulting from the size of the enterprise is also not observed (measured by the level of employment).

As it results from the presented data, the LML6 is mainly achieved by micro enterprises (employing fewer than 10 employees or self-employed). This applies to areas related to Ware-house management, Supply and inventory management and IT solutions.

Table 1. Maturity levels of Polish service enterprises, including sections and employment levels

LA		F	H	I	J	K	L	M	N	O	P	R	Q	SiT
WM	E=1													
	E<10					LML2	LML6			LML6	LML5			
	10<E<50											LML3		
	50<E250								LML3	LML3				
	E>250	LML2		LML2		LML2				LML3				
TM	E=1													
	E<10									LML1	LML5			
	10<E<50													
	50<E250								LML6					
	E>250		LML1								LML6			
SIM	E=1							LML1		LML1			LML1	
	E<10				LML6									
	10<E<50						LML5	LML2	LML1	LML1				
	50<E250							LML1	LML1					
	E>250	LML1		LML1		LM1				LML2			LML1	
SCD	E=1						LML1						LML1	
	E<10													
	10<E<50									LML2				
	50<E250					LML2	LML1			LML1		LML2	LML1	
	E>250	LML1		LML1	LML1	LML1		LML6		LML4	LML1		LML1	
IT	E=1		LML5	LML5				LML5					LML6	
	E<10				LML5						LML5			
	10<E<50				LML5	LML4		LML5						
	50<E250			LML5		LML4			LML5					
	E>250			LML4	LML5			LML5			LML3		LML4	

Medium-sized enterprises achieve the LML6 in the range of Transport management and large enterprises additionally in the area related to Cooperation within the supply and distribution chain.

The logistics maturity level 5 (LML5) in the area of WM, TM, and IT is achieved primarily by micro enterprises belonging to section P, which shows that enterprises providing Education services employing fewer than 10 employees achieve a high level of logistics maturity in the area of Warehouse management, Transport management and IT solutions. Micro enterprises from section P achieve the LML5 in 3 out of 5 areas.

The LML5 in terms of IT solutions used is achieved by most enterprises in sections J and M, regardless of their size, which makes these sectors susceptible to modern technologies used in business practice.

At the same time, it can be observed that the LML5 in the area of IT solutions is mainly achieved by micro enterprises.

As regards the LML4, no correlation between the service section and the size of the enterprise can be seen based on the research and results obtained.

The LML3 was achieved by the surveyed population of Polish service enterprises only in the area related to Warehouse management - small enterprises from section R (100%), medium enterprises from sections N (100%) and O (100%), and large enterprises from section O (100%). In addition, this level was achieved by 100% of large enterprises belonging to section P.

The LML2, in the area of warehouse management, is typical for large enterprises from sections F (75%), I (75%), K (75%) and in the area of transport from section O (100%). The LML2 also characterizes the logistics maturity of medium-sized enterprises in the field of Cooperation within supply and distribution chains from sections K (100%) and R (100%).

Service sections, according to PKD (Polish Classification of Economic Activities), which are characterized by the LML2 of logistics maturity are K, O, R, which achieve this level in 2 out of 5 examined areas of logistics activity.

The LML1 of logistics maturity is the most typical for section O - it is achieved in 3 of 5 areas of economic activity, such as: Transport management, Supply and inventory management and Cooperation within supply and distribution chains. The LML1 is achieved mainly by large enterprises employing over 250 employees.

Logistics immaturity, referred to in the model as the LML0, characterizes sections I and O - they show immaturity in 3 out of 5 examined areas. In terms of the size of the enterprise, logistics immaturity is primarily demonstrated by micro enterprises.

CONCLUSIVE REMARKS

The subject of the article was the presentation of the results of research on the logistics maturity of Polish service enterprises. The article presents the research background and the adopted methodology for assessing logistics maturity. An original logistics maturity model for the service sector – LMM4SI - was presented.

The conclusion resulting from the study indicates that Polish service enterprises do not achieve high levels of logistics maturity. The statistical data presented in the Introduction indicate a high degree of competitiveness in the service sector. This means that, as in the case of the industry and trade sector, regardless of their size, enterprises should strive to improve their functioning in order to become competitive in the market and increase profits. Logistics, considered by many to be a key success factor or a key competence, should also be viewed as an area for improvement. Separating logistics from the service sector, due to its intangible nature and volatility, does not seem to be the right direction in managing a service enterprise. It should be remembered that the provision of intangible services requires physical resources - materials that must be purchased, stored and transported. In addition, service providers are links in logistics chains. This role should result in taking actions by service providers to increase the effectiveness and efficiency of activities in individual areas of logistics activity, which will have a positive impact on the operation of the entire logistics chain. It is postulated that the diagnosis of the level of logistics maturity of a service enterprise, made with the use of the LMM4SI procedure, should be the starting point for corrective and improving actions.

As directions for further research, the authors indicate sustainable logistics management in the service sector. In this area, they observe a cognitive and methodological gap.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

This paper refers to the research financed by the National Since Center, Poland, project "Research on logistics maturity in service enterprises", grant no. 2016/21/D/HS4/02116.

REFERENCES

Ballou R.H., 2017. The evolution and future of logistics and supply chain management, European Business Review 19(4). http://doi.org/10.1108/09555340710760152

Battista, C., Schiraldi, M., 2013. The logistic maturity model: Application to a fashion company, International Journal of Engineering Business Management 5, 1-11, http://doi.org/10.5772/56838.

Biesok G. (Ed.), 2013. Logistics of services, CeDeWu, Warsaw.

Blondiau A., Mettler T., Winter R., 2016. Designing and implementing maturity models in hospitals: An experience report from 5 years of research, Health Informatics Journal 22 (3), 758–67. http://doi.org/10.1177/1460458215590249

Ellefsen A.P.T., Oleśków-Szłapka J., Pawłowski G., Toboła A., 2019. Striving for excellence in AI implementation: AI Maturity Model framework and preliminary researchresults, LogForum 15 (3), 363-376, http://doi.org/10.17270/J.LOG.2019.354.

Eutostat (2020). https://ec.europa.eu/eurostat/statisticsxplained/index.php?title=National_accounts_and_GDP#Gross_value_added_in_the_EU_by_economic_activity [accsess: 23rd January 2020].

Central Statistical Office, 2019. GDP quarterly accounts 2014-2018. Warsaw, Central Statistical Office, from http://stat.gov.pl

Golinska P, Kosacka M, Mierzwiak R, Werner-Lewandowska K., 2015. Grey decision making as atool for the classification of the sustainability level of remanufacturing companies", Journal of Clean Production 105, 28–40. http://doi.org/10.1016/j.jclepro.2014.11.040

Gołembska E, Tyc-Szmil K., Brauer J., 2008. Logistics in service, Polish Scientific Publishers PWN, Warsaw.

Gottschalk, P., Solli-Saether H. 2006. Maturity model for IT outsourcing relationships, Industrial Management and Data Systems 106 (1–2), 200–12. http://doi.org/10.1108/02635570610649853

Grant K.P., Pennypacker J.S., 2006. Project Management Maturity: An Assessment of Project Management Capabilities among and between Selected Industries, IEEE Transac-tions on Engineering Management 53 (1), 59–68. http://doi.org/10.1109/TEM.2005.861802.

Poeppelbuss J., Niehaves B., Simons A., Becker J., 2011. Maturity models in information systems research: literature search and analysis, Communications of the Association for Information Systems 29 (27), 505–532, http://doi.org/10.17705/1CAIS.02927.

Helgesson Y.Y.L., Host M., Weyns K., 2012. A review of methods for evaluation of maturity models for process improvement, Journal of Software-Evolution and Process 24 (4), 436–54. http://doi.org/10.1002/smr.560.

Kosacka-Olejnik M., 2020. Logistics maturity model in the service industry: State of art and research implications, LogForum 16 (2), 261-269, http://doi.org/10.17270/J.LOG.2020.401.

Kwak Y.H., Ibbs C.W., 2002, Project management process maturity (PM)(2) model. Journal of Management in Engineering 18 (3), 150–5.

http://doi.org/10.1061/(ASCE)0742-597X(2002)18:3(150).

Lockamy III A.,, McCormack K., 2004, The Development of a Supply Chain Management Process Maturity Model Using the Concepts of Business Process Orientation, Supply Chain Management: An International Journal 9 (4), 272–278. http://doi.org/10.1108/13598540410550019

Marshall S., 2011. Improving the Quality of E-Learning: Lessons from the eMM, Journal of Computer Assisted Learning 28 (1), 65–78. http://doi.org/10.1111/j.1365-2729.2011.00443.x.

McCarthy C.F.,. Kelley M.A, Verani A.R., Louis M.E.S., Riley P.L., 2014. Development of a Framework to Measure Health Profession Regulation Strengthening, Evalua-tion and Program Planning 46, 17–24. http://doi.org/10.1016/j.evalprogplan.2014.W z04.008. http://doi.org/

Misra, D.C., Dhingra A., 2002. E-Governance Maturity Model, Electronics Information and Planning 29 (6/7), 269–275.

Odważny F., Wojtkowiak D., Cyplik P., Adamczak M., 2019. Concept for measuring organizational maturity supporting sustainable development goals, LogForum 15 (2), 237-247, http://doi.org/10.17270/J.LOG.2019.321.

Schumacher, A., Erol S., Sihn W., 2016. A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises, Procedia CIRP 52, 161–166. http://doi.org/10.1016/j.cub.2017.05.064.

Serenko A., Bontis N., Hull E., 2016. An Application of the Knowledge Management Ma-turity Model: The Case of Credit Unions, Knowledge Management Research & Practice 14 (3), 338–352. http://doi.org/10.1057/kmrp.2014.37.

Serna E., 2012. Maturity Model of Knowledge Management in the Interpretativist Perspective. International Journal of Information Management 32 (4), 365–371. http://doi.org/10.1016/j.ijinfomgt.2011.12.001.

Tarhan A., Turetken O., Reijers H.A., 2016. Business Process Maturity Models: A Systematic Literature Review, Information and Software Technology 75, 122–134. http://doi.org/10.1016/j.infsof.2016.01.010.

Van Looy A., De Backer M., Poels G., 2011. Defining business process maturity. A journey towards excellence, Total Quality Management and Business Excellence 22 (11),1119–37. http://doi.org/10.1080/14783363.2011.624779.

Vicente A., 2011. Open Information Security Maturity Model, The Open Group, United Kingdom.

Werner-Lewandowska K., Kosacka-Olejnik M., 2018, Logistics maturity model for service company – theoretical background, Procedia Manufacturing, 17, 91-802. http://doi.org/10.1016/j.promfg.2018.10.130.

Werner-Lewandowska K., Kosacka-Olejnik M., 2019a, Logistics Maturity Model for Engi-neering Management – Method Proposal, Management Systems in Production Engineering, 27(1), 33-39. http://doi.org/10.1515/mspe-2019-0006.

Werner-Lewandowska K., Kosacka-Olejnik M., 2019b, Logistics engineering application in the logistic maturity model for the service enterprises, Proceeding of The 14th Interna-tional Conference of Logistics and SCD System, Chinese Martime Institute.

Werner-Lewandowska K., Kosacka-Olejnik M., 2019c, Logistics 4.0 Maturity in Service Industry: Empirical Research Results, Procedia Manufacturing, 38: 1058-1065. http://doi.org/10.1016/j.promfg.2020.01.192.

Werner-Lewandowska K., 2019. Logistics maturity of the 3pl providers - empirical research results, article going through the publishing process, in: Brzeziński Ł. et al.(Eds.), Mod-ern solutions in production and warehousing, Spatium, Radom. http://doi.org/10.17270/B.M.978-83-66017-87-0.2.

Zakrzewski R., Skowrońska A. (Eds.), 2019. Raport o stanie sektora małych i średnich przedsiębiorstw w Polsce. Warszawa, Polska Agencja Rozwoju Przedsiębiorczości.

Zhou Y., 2012. Towards Capability Maturity Model of E-Learning Process, Intelligent In-formation Management 4 (04), 95. http://doi.org/10.4236/iim.2012.44015.

DOJRZAŁOŚĆ LOGISTYCZNA POLSKIEGO SEKTORA USŁUG - WYNIKI BADAŃ

STRESZCZENIE. **Wstęp:** Celem artykułu jest przedstawienie nowych metod badania dojrzałości logistycznej przedsiębiorstw usługowych. W badaniach założono, że procesy logistyczne są realizowane w przedsiębiorstwach usługowych, co implikuje teoretycznie możliwość opracowania modelu dojrzałości logistycznej przedsiębiorstw usługowych oraz postulat, że w praktyce gospodarczej istnieją różne poziomy dojrzałości logistycznej przedsiębiorstw usługowych i jest możne je zidentyfikować.

Oryginalność przedstawionych badań wynika z dwóch aspektów. Pierwszy aspekt ma charakter metodyczny i dotyczy zastosowanego modelu logistycznego - LMM4SI, który jest autorskim narzędziem pozwalającym ocenić dojrzałość logistyczną przedsiębiorstwa usługowego. Drugi aspekt ma charakter poznawczy w zakresie przedmiotu i obiektu badań, które są słabo reprezentowane w literaturze. Prowadzone dotychczas badania dotyczyły opracowania modelu dojrzałości logistycznej i jego zastosowania w branży modowej. W Polsce nie prowadzi się podobnych badań, przez co prezentowane badania częściowo eliminują tę lukę badawczą. Wyniki prezentowanych badań dotyczą dojrzałości logistycznej, rozumianej jako poziom organizacyjny przedsiębiorstwa, wskazujący na stopień wykorzystania inżynierii logistycznej w obszarach funkcjonowania przedsiębiorstwa usługowego.

Metody: Metodami badawczymi wykorzystanymi w prezentowanych badaniach są badania ankietowe, które pozwoliły na pozyskanie danych pierwotnych z 2000 polskich przedsiębiorstw usługowych, analiza matematyczna wykorzystana w celu określenia poziomu dojrzałości logistycznej oraz analiza statystyczna zastosowana na etapie wnioskowania o dojrzałości logistycznej polskiego sektor usług.

Wyniki: W wyniku przeprowadzonych badań powstał autorski model dojrzałości logistycznej dla branży usługowej (zwany LMM4SI) i przeprowadzona z jego wykorzystaniem procedura oceny. Realizując poznawczy cel artykułu, przedstawiono wyniki badań dojrzałości logistycznej polskich usługodawców.

Wnioski: Wyniki badań wykazały, że przedsiębiorstwa usługowe nie osiągają wysokiego poziomu dojrzałości logistycznej. Stwierdzono, że opracowane metody pozwalają na skuteczną ocenę dojrzałości logistycznej przedsiębiorstw.

Słowa kluczowe: dojrzałość logistyczna, sektor usług

Karolina Werner-Lewandowska ORCID ID: https://orcid.org/0000-0002-9549-4511
Poznan Universtity of Technology
2 J. Rychlewskiego Str. 60-965 Poznan, **Poland**
e-mail: karolina.werner@put.poznan.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (4), 573-592

http://doi.org/10.17270/J.LOG.2020.518

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

EXCLUSIONARY CONSTRAINTS IN TRANSPORT – RESULTS OF QUANTITATIVE RESEARCH

Marcin Anholcer[1], Arkadiusz Kawa[2]

1) Poznań University of Economics and Business, Poznań, **Poland**, 2) Łukasiewicz Research Network, Institute of Logistics and Warehousing, Poznań, **Poland**

ABSTRACT. **Background**: Among all the processes in the supply chain, transport is one of the most complex and most expensive. While planning the transportation process, one needs to consider various factors, among others the exclusionary constraints imposed on selected suppliers, products or mean of transport. Although several papers can be found where the authors discuss the problem of exclusionary constraints, it is very difficult to find one concerning the empirical research in this area. Our work tries to fill this gap. The main goal and contribution of this article is the analysis of significance and importance of various exclusions in transport present in the real life.

Methods: We present the results of a quantitative research performed on a random sample of 300 logistics services providers in Poland, concerning the exclusionary constraints in transportation.

Results: The research confirmes that the exclusion factors are an important part of activity of the companies transporting goods. Although the distributions of the frequencies are different, depending on the factor, one may observe that every factor was noticed by a significant fraction of companies. The analysis of the potential dependencies between the variables show that the importance and frequency of the factors is rather independent from the company's features. Our study contributes to the theories and practices of logistics enterprises.

Conclusions: This study extends earlier research on exclusionary constraints with using empirical studies. In the future work we will use the results of the quantitative research to develop mathematical models of the transportation problems and we want to prepare more effective methods of planning the deliveries.

Key words: transportation, exclusionary constraints, quantitative research, logistics.

INTRODUCTION

Supply chain configuration consists of building a structure in an enterprise network, within which a flow of things and information takes place. Such a structure is made of individual actors (a producer, an assembler, a distributor, a retailer, etc.). A supply chain may embrace all flows starting from the purchase of raw materials and finishing with the delivery to the final customer.

One of the challenges related with the supply chains is price pressure which forces supply chain leaders into constant efforts to decrease product prices, even when the competitive strategy is primarily focused on such characteristics as quality or delivery time. Globalization and internationalization of enterprises have also contributed to the fact that a large number of companies produce or commission production in various countries around the world [Anholcer, Kawa 2012].

What is closely connected with the flow of goods among the nodes of an enterprise network is transport, which is considered one of the most important elements of a logistic system and requires careful planning and control.

Transportation costs can be a significant part of a company's overall logistics spending

Citation: Anholcer M., Kawa A.,2020. Exclusionary constraints in transport – results of quantitative research. LogForum 16 (4), 573-592, http://doi.org/10.17270/J.LOG.2020.518

Received: 09.07.2020, Accepted: 28.08.2020, on-line: 18.09.2020.

[Murray 2014]. According to various estimates, transportation constitutes one-third of the logistics costs [see e.g. Tseng et al. 2005]. All the costs are transferred to the customer by increasing prices. This shows why decreasing transportation costs is one of the companies' major targets. Various transportation strategies may be applied by management to improve the performance [Murray 2014]. The issue of transportation cost optimization is treated as one of the most difficult and most complex problems which transport enterprises deal with.

In many cases it is necessary to impose some exclusionary constraints on the transportation process. In particular, it can be the case when some types of goods cannot be transported by the same mean of transport (like livestock and frozen fruits and vegetables). Another situation where such constraints have to be imposed is when some suppliers do not want their products to be delivered to the same customer (e.g. because of some reasons concerning marketing strategy of the company).

Various transportation and, more generally, network problems with exclusionary constraints were studied e.g. by Cao [1992], Cao and Uebe [1995], Darmann et al. [2011], Glover et al. [1978], Goossens and Spieksma [2009], Klingman and Russel [1975], Öncan, Zhang and Punnen [2013], Pferschy and Schauer [2013], Sun [2002], Thompson and Setbi [1986], Vancroonenburg et al. [2014], Zhang et al. [2011]. All the mentioned papers represent, however a theoretic approach: the authors consider models and algorithms, but do not analyze the real life data. We decided to fill this gap. For that reason we performed a quantitative research, presented in this article.

Based on several articles and market reports we distinguished several factors that can imply the necessity of exclusions. It turned out that sample possible causes of exclusions may be: sensitivity for humidity [Kurmanov et al. 2015, Brenner et al. 2014], sensitivity for temperature [Kurmanov et al. 2015, Blake et al. 2010, Butzke et al. 2012, Brenner et al. 2014, Lu et al. 2013], sensitivity for light [Blake et al. 2010], over-sized loads [Goldstein 2010], high-value goods [Goldstein 2010], duration of transportation [Lu et al. 2013] and chosen types of transported goods, like perishable products [Lu et al. 2013], dangerous products [Muncke et al. 2017] or livestock [Broom 2008].

Based on this knowledge, we performed a qualitative research: Focus Group Interview (FGI) and Individual In-Depth Interview (IDI) in order to prepare a longer list of possible causes [see Anholcer, Kawa 2015, Anholcer, Kawa 2017]. The main goal of the present article was to perform a research among the logistics companies in order to find out which causes of exclusions are the most significant and the most frequent in real life.

EMPIRICAL RESEARCH DESCRIPTION

In order to collect the empirical data, Polish logistics firms were asked to fill a questionnaire. The questions concerned the exclusionary constraints (in the context of products), and possible losses in transportation, as well as in storage. Most of them were closed. More specifically, the respondents were allowed to choose one out of 5 answers (1 meaning "not significant" or something similar, and 5 – "very significant", or similar). In addition, several questions about the firm were posed, e.g. about size, employment, exact kind of performed activity (transportation / storage / logistics etc.). The research was performed with the use of the Computer-Assisted Web Interview (CAWI) and Computer-Assisted Telephone Interview (CATI). The objective of the research was to analyze the significance and frequency of various possible causes of exclusions in transportation. The collection method was direct structured individual interview using questionnaires, performed among the respondents being managers responsible for transportation. General population consisted of Polish companies involved in logistic operations and in order to choose the final group of respondents, we used random sampling with sample size equal to 300. The questionnaire was first tested in a pilot designed for 7 respondents, chosen from among the representatives of the logistics services industry, experts and researchers operating in the area of logistics [Kawa and Anholcer 2018].

According to Eurostat [2016] approximatively 140 thousand transport and warehousing companies were operating in Poland in 2014. After removing firms involved in pipeline and passenger transport, which are not part of logistics services industry, the number of firms in our target population tops 94 000. In order to perform random sampling, we collected the data about the companies using the Regon database hold by the Central Statistical Office in Poland, as well as commercial databases (in order to get the contact information). Initially, about 23 thousand managers obtained the survey and 58 questionnaires returned. Then out of about 30 thousand persons 248 were interviewed by telephone. After excluding few questionnaires with incomplete information and errors, 300 of them were qualified for further analyzes. These gives the measurement error of 5.6%, assuming the confidence level of 95%. Also according to literature, 300 observations are enough for concluding about the population of about 94 000 [Bazarnik et al. 1992].

Table 1. Sample characteristics

Characteristics	Share in the sample
Employment	
0-9 employees	49.7%
10-49 employees	36.7%
50+ employees	11.7%
N/A	2.0%
Legal form	
Sole-trader	54.3%
Limited liability company	25.3%
Civil law partnership	7.7%
Others	10.7%
N/A	2.0%
Serviced industries	
Construction	41.7%
Food	29.0%
Chemical	15.3%
Furniture	15.3%
Logistic	14.0%
Agricultural	13.7%
Paper	13.3%
Electric	13.0%
Textile	8.0%
Medical	6.3%
Telecommunications	4.0%
Financial	1.3%

Source: own computations

The basic sample statistics have been presented in Table 1. The respondents who completed the questionnaire represented usually micro (49.7%) and small (36.7%) enterprises having usually the legal form of sole-traders (54.3%), limited liability companies (25.3%) and civil law partnership (7.7%) The majority of the surveyed companies provided services for customers from the construction (41,7%) and food (29%) industry.

In this article we focus on two groups of questions, concerning the exclusionary constraints in transportation. Question 2 was: “Below some causes are listed, because of which it is impossible to transport selected goods jointly; please describe their significance for your company, by choosing one of the numbers from 1 (completely not significant) to 5 (very significant)”. This question consisted of 17 sub-questions corresponding with selected possible reasons of exclusions. These were:

p2.1. Sensitivity for duration of transport.
p2.2. Sensitivity for transportation conditions (fragile goods).
p2.3. Sensitivity for temperature.
p2.4. Sensitivity for humidity.
p2.5. Sensitivity for light.
p2.6. Sensitivity for fragrances.
p2.7. High-value goods.
p2.8. Perishable goods.
p2.9. Dangerous product (e.g. ADR).
p2.10. Livestock.
p2.11. Competitive goods (products of competitive companies).
p2.12. Loads of above-standard sizes.
p2.13. Time windows of deliveries.
p2.14. Exclusive transport contract.
p2.15. Large distances between supply and destination points.
p2.16. Legal restrictions (e.g. summer and weekend prohibitions).
p2.17. Others.

Similarly, the question 3 was “please describe the frequency of the following causes of exclusions in your company, by choosing one of the numbers from 1 (does not occur at all) to 5 (very often)”. It also consisted of 17 sub-questions, corresponding with the questions p2.1-p2.17, this time numbered by p3.1-p3.17, respectively. In the following section we presented the results of quantitative research performed on the described questions.

EMPIRICAL RESEARCH RESULTS

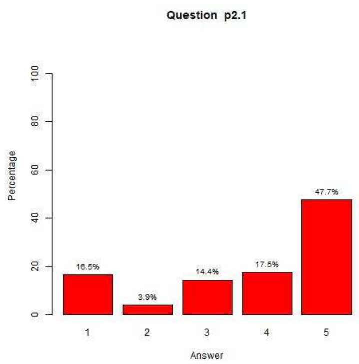
Let us start with the basic statistics of the questions they are collected in table 2. Although the answers are not numeric, the mean and median give some insight into which causes are significant or frequent and which are not. As we can see, most of the respondents answered almost all the questions, the only exceptions are questions p2.17 and p3.17 (about the other possible causes of exclusions). This means that the list of possible causes of exclusions prepared by the authors was rather complete and it omitted only few possible causes.

Table 2. Basic statistics

Question	#Answers	Mean	Median	Question	#Answers	Mean	Median
p2.1	285 (95.00%)	3.761	4	p3.1	282 (94.00%)	2.89	3
p2.2	286 (95.33%)	3.416	4	p3.2	284 (94.67%)	2.669	3
p2.3	284 (94.67%)	2.863	3	p3.3	284 (94.67%)	2.391	2
p2.4	285 (95.00%)	2.432	2	p3.4	284 (94.67%)	1.979	1
p2.5	283 (94.33%)	1.968	1	p3.5	283 (94.33%)	1.597	1
p2.6	284 (94.67%)	2.511	2	p3.6	283 (94.33%)	1.975	1
p2.7	286 (95.33%)	3.476	4	p3.7	283 (94.33%)	2.661	3
p2.8	282 (94.00%)	2.681	2	p3.8	283 (94.33%)	2.014	1
p2.9	283 (94.33%)	2.58	1	p3.9	282 (94.00%)	2.018	1
p2.10	280 (93.33%)	1.893	1	p3.10	278 (92.67%)	1.45	1
p2.11	279 (93.00%)	2.315	2	p3.11	280 (93.33%)	2.193	2
p2.12	283 (94.33%)	2.364	1	p3.12	283 (94.33%)	1.933	1
p2.13	285 (95.00%)	3.488	4	p3.13	283 (94.33%)	3.074	3
p2.14	281 (93.67%)	3.142	3	p3.14	285 (95.00%)	2.418	2
p2.15	284 (94.67%)	3.468	4	p3.15	282 (94.00%)	3.028	3
p2.16	286 (95.33%)	3.455	4	p3.16	286 (95.33%)	2.664	3
p2.17	41 (13.67%)	2.488	1	p3.17	46 (15.33%)	2.261	1

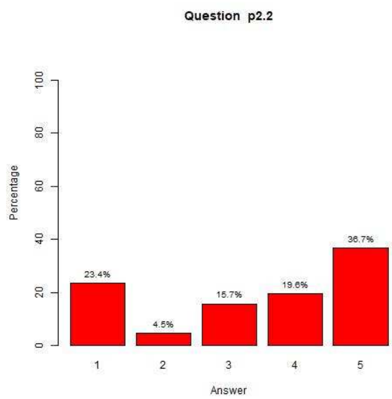
Source: own computations

Now, let us present the analysis of the answers' frequencies. The results are presented on figures 1–34.



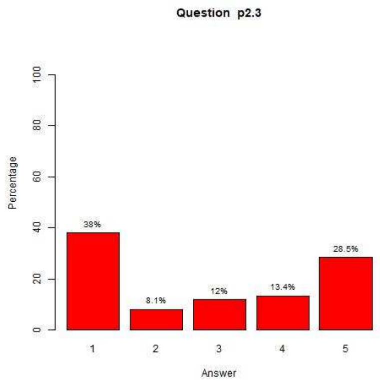
Source: own computations

Fig. 1. Frequencies of answers for question p2.1 – significance of the factor: Sensitivity for duration of transport.



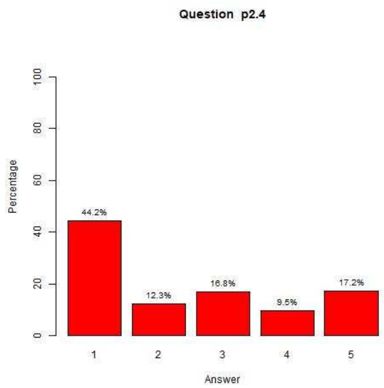
Source: own computations

Fig. 2. Frequencies of answers for question p2.2 – significance of the factor: Sensitivity for transportation conditions (fragile goods)



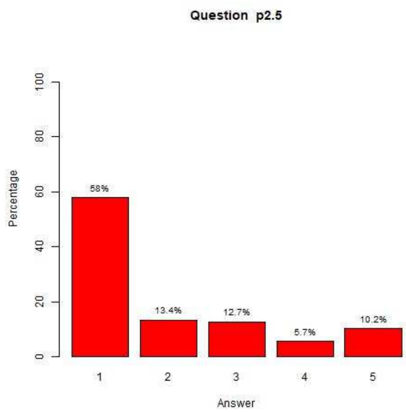
Source: own computations

Fig. 3. Frequencies of answers for question p2.3 – significance of the factor: Sensitivity for temperature



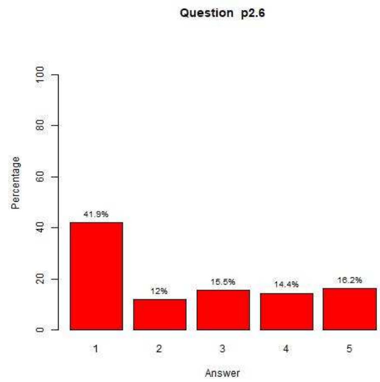
Source: own computations

Fig. 4. Frequencies of answers for question p2.4 – significance of the factor: Sensitivity for humidity



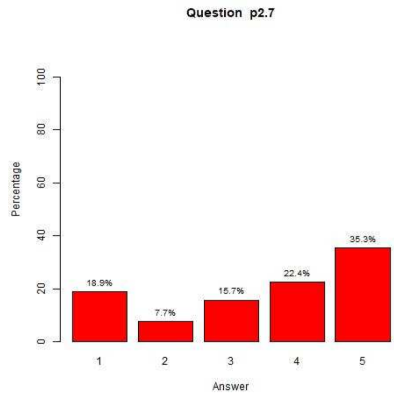
Source: own computations

Fig. 5. Frequencies of answers for question p2.5 – significance of the factor: Sensitivity for light



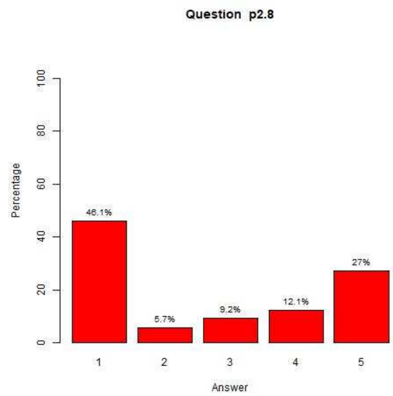
Source: own computations

Fig. 6. Frequencies of answers for question p2.6 – significance of the factor: Sensitivity for fragrances



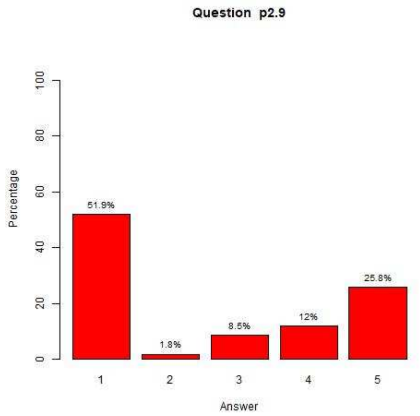
Source: own computations

Fig. 7. Frequencies of answers for question p2.7 – significance of the factor: High-value goods



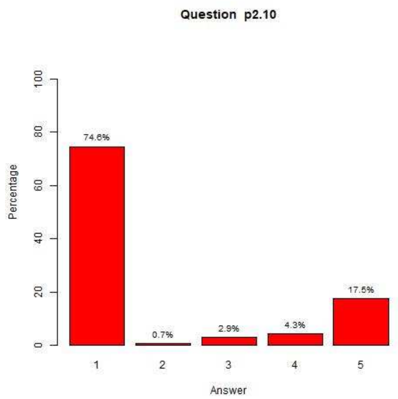
Source: own computations

Fig. 8. Frequencies of answers for question p2.8 – significance of the factor: Perishable goods



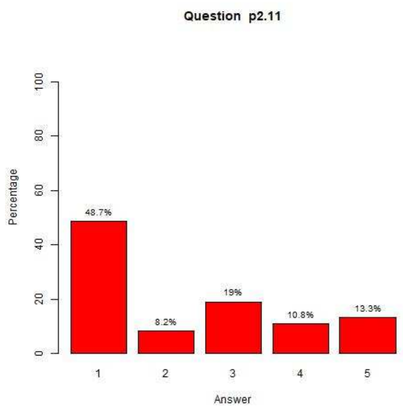
Source: own computations

Fig. 9. Frequencies of answers for question p2.9 – significance of the factor: Dangerous product (e.g. ADR)



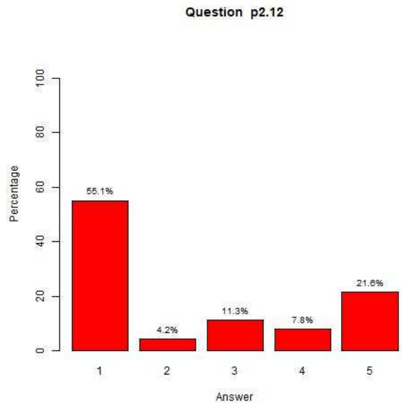
Source: own computations

Fig. 10. Frequencies of answers for question p2.10 – significance of the factor: Livestock



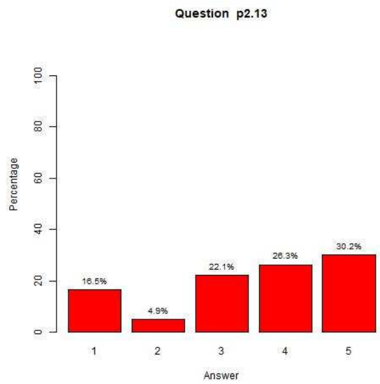
Source: own computations

Fig. 11. Frequencies of answers for question p2.11 – significance of the factor: Competitive goods (products of competitive companies)



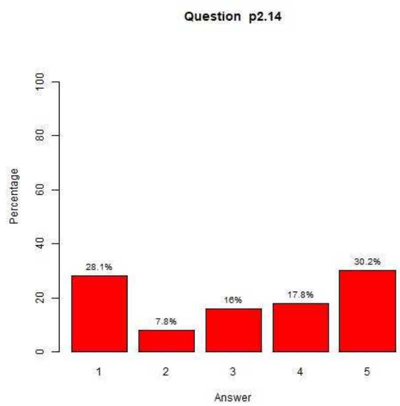
Source: own computations

Fig. 12. Frequencies of answers for question p2.12 – significance of the factor: Loads of above-standard sizes



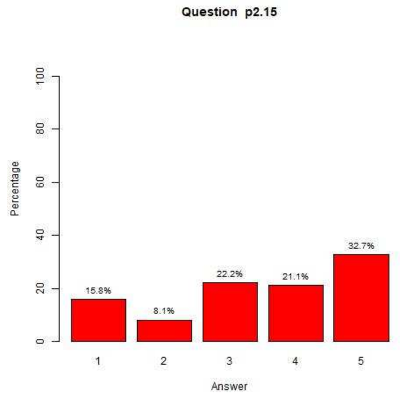
Source: own computations

Fig. 13. Frequencies of answers for question p2.13 – significance of the factor: Time windows of deliveries



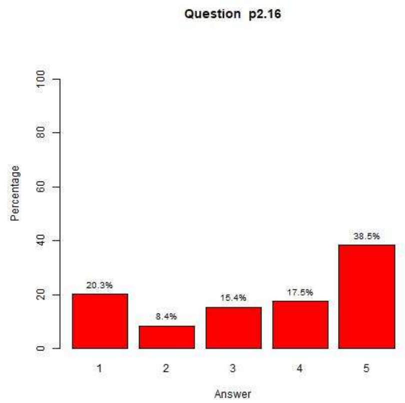
Source: own computations

Fig. 14. Frequencies of answers for question p2.14 – significance of the factor: Exclusive transport contract



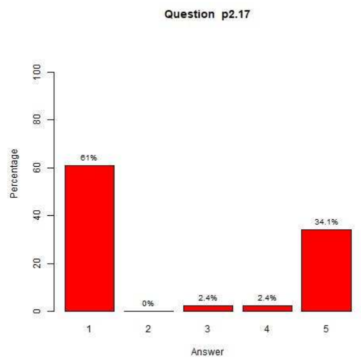
Source: own computations

Fig. 15. Frequencies of answers for question p2.15 – significance of the factor: Large distances between supply and destination points



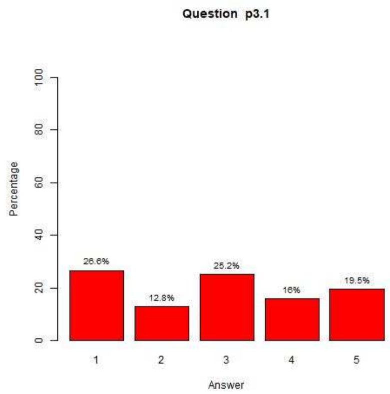
Source: own computations

Fig. 16. Frequencies of answers for question p2.16 – significance of the factor: Legal restrictions (e.g. summer and weekend prohibitions)



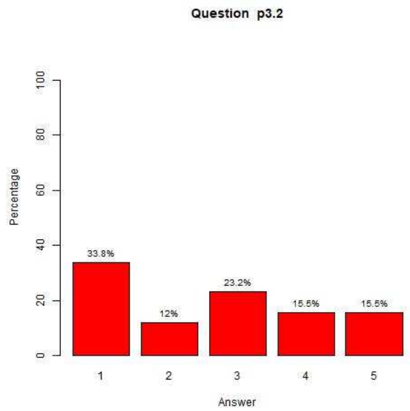
Source: own computations

Fig. 17. Frequencies of answers for question p2.17 – significance of the factor: Others



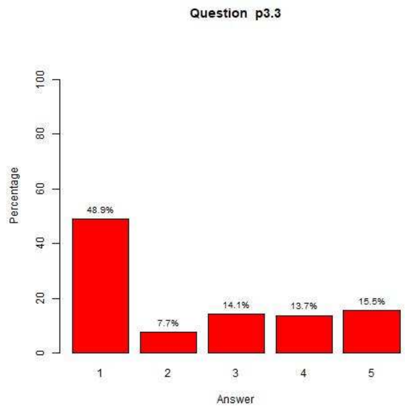
Source: own computations

Fig. 18. Frequencies of answers for question p3.1 – frequency of the factor: Sensitivity for duration of transport



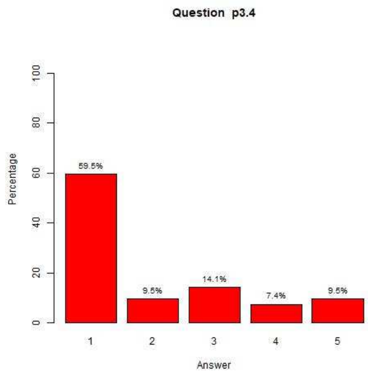
Source: own computations

Fig. 19. Frequencies of answers for question p3.2 – frequency of the factor: Sensitivity for transportation conditions (fragile goods)



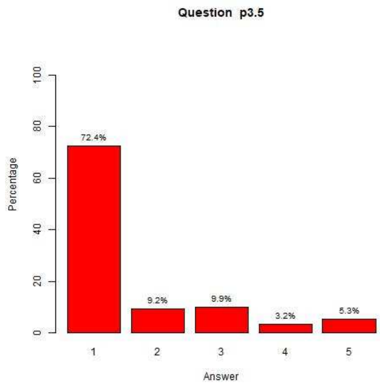
Source: own computations

Fig. 20. Frequencies of answers for question p3.3 – frequency of the factor: Sensitivity for temperature



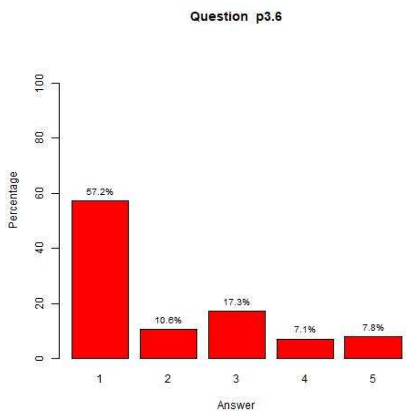
Source: own computations

Fig. 21. Frequencies of answers for question p3.4 – frequency of the factor: Sensitivity for humidity



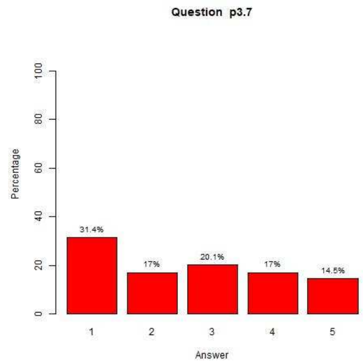
Source: own computations

Fig. 22. Frequencies of answers for question p3.5 – frequency of the factor: Sensitivity for light



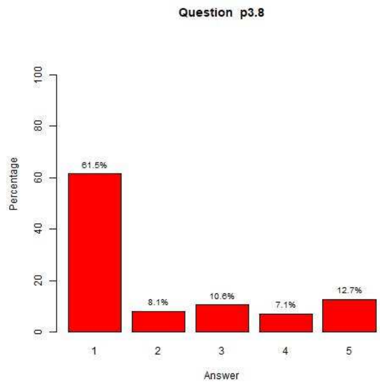
Source: own computations

Fig. 23. Frequencies of answers for question p3.6 – frequency of the factor: Sensitivity for fragrances



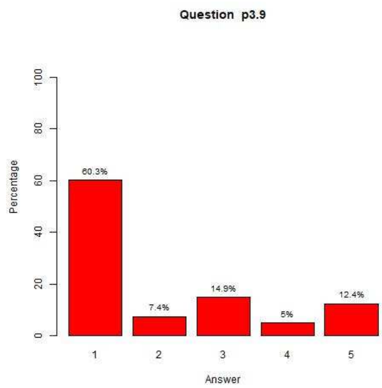
Source: own computations

Fig. 24. Frequencies of answers for question p3.7 – frequency of the factor: High-value goods



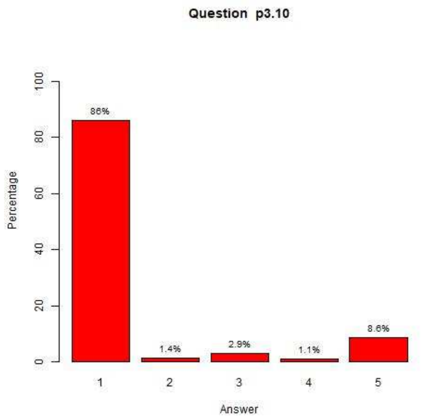
Source: own computations

Fig. 25. Frequencies of answers for question p3.8 – frequency of the factor: Perishable goods



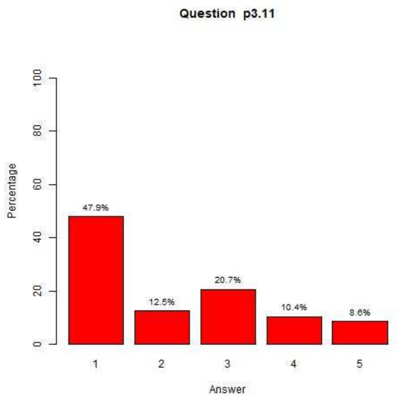
Source: own computations

Fig. 26. Frequencies of answers for question p3.9 – frequency of the factor: Dangerous product (e.g. ADR)



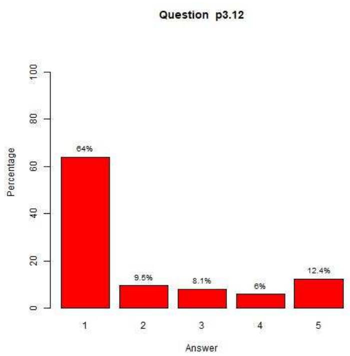
Source: own computations

Fig. 27. Frequencies of answers for question p3.10 – frequency of the factor: Livestock



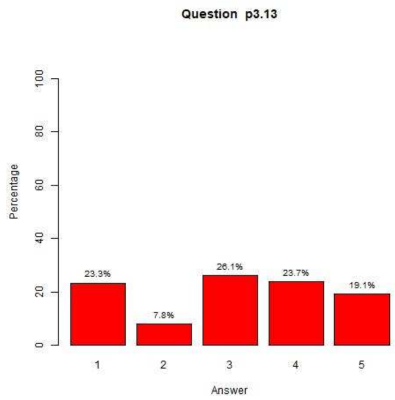
Source: own computations

Fig. 28. Frequencies of answers for question p3.11 – frequency of the factor: Competitive goods (products of competitive companies)



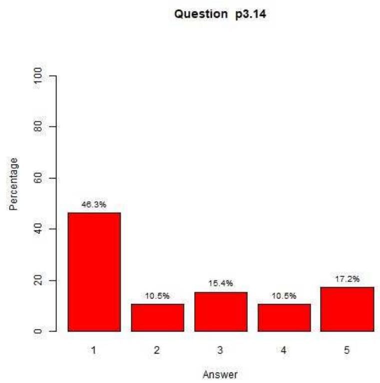
Source: own computations

Fig. 29. Frequencies of answers for question p3.12 – frequency of the factor: Loads of above-standard sizes



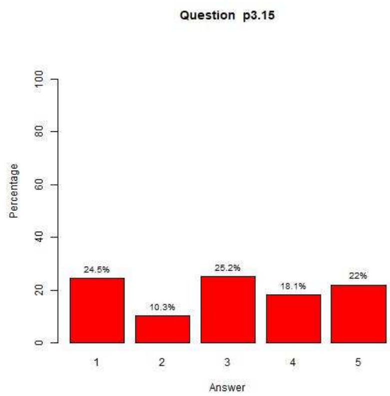
Source: own computations

Fig. 30. Frequencies of answers for question p3.13 – frequency of the factor: Time windows of deliveries



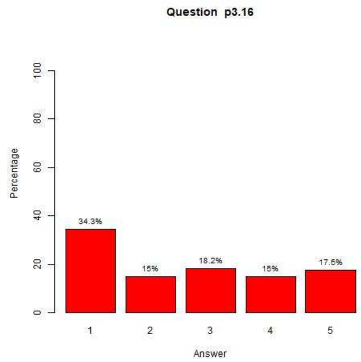
Source: own computations

Fig. 31. Frequencies of answers for question p3.14 – frequency of the factor: Exclusive transport contract



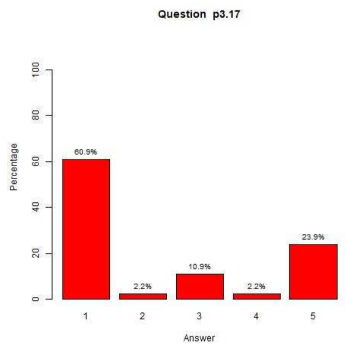
Source: own computations

Fig. 32. Frequencies of answers for question p3.15 – frequency of the factor: Large distances between supply and destination points



Source: own computations

Fig. 33. Frequencies of answers for question p3.16 – frequency of the factor: Legal restrictions (e.g. summer and weekend prohibitions)



Source: own computations

Fig. 34. Frequencies of answers for question p3.17 – frequency of the factor: Others

As we can see, in the case of first three factors (sensitivity for duration of transport, transportation conditions and temperature), the distribution of answers is very similar: for relatively many respondents the chosen factors were either very important or completely not significant. Moreover, only in the case of sensitivity for temperature, "not significant" was the most common answer. In two remaining cases it was the second answer.

The situation with the next three factors is different than before: many respondents marked the sensitivity for humidity, sensitivity for light and sensitivity for fragrances as completely not significant (over 44%, 56% and almost 42%, respectively). The other answers gained similar numbers of answers (between 10% and 20%, with few exceptions).

In the case of high-value goods, one may observe that relatively many firms (over 35%) consider this factor as very significant. The distribution of answers is very similar to the ones of the answers to questions p2.1-p2.3.

As shown on figures 8-12, many respondents (usually more than a half) consider as completely not significant factors the perishable or dangerous products, livestock, over-sized commodities and the situation when the competitive good are supposed to be transported. What is worth mentioning, if someone considers some of the factors as significant, then in most cases it is considered as very important. This makes the distributions of the mentioned answers a little bit similar to the distributions of the answers to questions p2.1-p2.3.

This similarity is much more visible in the case of the answers to questions p.13-p.16. In fact, two extremal answers (1 and 5) were chosen the most frequently, but the distribution is much flatter in the case of time windows, exclusive transport contracts, long distances and legal restrictions.

The last distribution is very different from others. If the respondent answered to the question p2.17, they either described other (not listed above) factors as completely not important or very significant. One should expect such distribution of answers: if someone gives an example of new factor, not given before, it usually means that this factor is very important to them.

The list of potential other factors may be interesting. The respondents had opportunity to give some examples in a separate, open question. Unfortunately, only few of them decided to give some examples (we managed to collect only 14 answers and most of them were very similar to the pre-defined factors. Among others, the following factors were listed: transport price, weight of commodity, the spatial distribution of commodities and weather (unfortunately we do not have more detailed explanations for these factors).

Let us switch now to the questions about the frequencies of various exclusion factors.

As we can see, in case of duration and fragility, the distributions are rather flat, although the most common answer is “never”.

The figures 20 and 21 show that the sensitivity for temperature and humidity does not occur as the reason of exclusions in about half of the companies. The other answers were rather evenly distributed.

This situation is also visible in figures 22 and 23. Most firms did not notice any occurrence of the sensitivity for fragrances or light that would cause any exclusions.

The high value of goods as a case of exclusions is an exception – still “never” is the most common answer, but in this case almost 70% of firms met this problem and the distribution of the answers from 2 to 5 is very flat.

In the case of five next factors, presented on figures 25-29 (perishables, dangerous, competitive or over-sized goods and livestock), the distributions look like before: no occurrence in most firms (or at least 47,9%) and very few of them describe this factor as “very often”.

Time windows seem to be much more important factor: almost 80% of companies met this problem and almost 70% gave the answers between 3 and 5. Exclusive contracts (figure 31) were in turn not present in over 45% of companies.

Large distances and legal restrictions were visible in over 75% and over 65% of firms, respectively. The distributions of the answers 2-5 could be considered as flat again.

Finally, as in the case of significance, also the frequency of the factor “other” is either completely not present in the companies (over 60% of the answers) or is very high (almost 24%). Also, in this case, the respondents were able to give some specific examples of the other factors. Unfortunately, this time they did not give any specific examples.

In the remainder of our research, we focused on the possible dependencies between answers to various questions. For that reason, we prepared the contingency tables with the joint distribution of the answers to the questions p2.1-p2.17, p3.1-p3.17 and the questions about the company. The latter ones described, among others, company’s branch of activity (distribution, trade, production, transportation, shipping, logistics), type of deliveries (from groupage to full truck load), range (from local to worldwide), comparison of financial performance and resources of the company and main competitors, branches of the customers, region of Poland, where the main office of the company is registered, number of employees and legal form of the company. For each case where it was possible, the χ^2 independence test was performed at the significance level 0.05 i.e., we rejected the hypothesis about the variables’ independence when the ¬p–value was less than 0.05.

In the case of dependency between exclusion factors and company’s features, we decided to present the results of the test only in the cases when the null hypothesis was rejected (i.e., we can assume that the variables are dependent). The results are presented in tables 3-9.

Table 3. The results of χ^2 test: question m1 (main field of activity: distribution, trade, production, transportation, shipping, logistics, other)

Q1	Q2	Chi-sq	df	p-val
m1	p2.10	116.961	28	0.000
m1	p2.12	44.285	28	0.026
m1	p3.8	45.958	28	0.018
m1	p3.9	51.167	28	0.005
m1	p3.12	43.529	28	0.031

Source: own computations

As we can see in table 3, only in case of two exclusion factors, their significance may be considered as depending on the kind of firm’s activity. These are: livestock (p2.10) and over-sized loads (p2.12). If we consider the occurrence of the factors, it depends on the firm’s branch in three cases. These time these are: perishable (p3.8) and dangerous (p3.9) products and over-sized loads (p3.12). As we can see, in general the exclusions caused by the loads of above-standard size strongly depend on the firm’s area of activity.

Table 4. he results of χ^2 test: questions m2.1 (frequency of groupage loads), m2.2 (frequency of partial loads), m2.3 (frequency of full-truck loads)

Q1	Q2	Chi-sq	df	p-val
m2.1	p2.5	31.681	20	0.047
m2.1	p2.6	32.540	20	0.038
m2.1	p2.7	38.750	20	0.007
m2.1	p3.3	36.479	20	0.014
m2.1	p3.4	37.030	20	0.012
m2.1	p3.5	40.947	20	0.004
m2.1	p3.7	33.546	20	0.029
m2.1	p3.9	34.113	20	0.025
m2.1	p3.12	31.873	20	0.045
m2.2	p2.1	34.867	20	0.021
m2.2	p2.4	37.336	20	0.011
m2.2	p2.7	34.566	20	0.023
m2.2	p2.8	34.486	20	0.023
m2.2	p2.9	39.419	20	0.006
m2.2	p2.14	45.752	20	0.001
m2.2	p3.4	35.025	20	0.020
m2.2	p3.5	41.968	20	0.003
m2.2	p3.7	41.324	20	0.003
m2.2	p3.13	32.690	20	0.036
m2.2	p3.14	36.087	20	0.015
m2.3	p2.1	33.804	20	0.027
m2.3	p2.7	35.898	20	0.016
m2.3	p2.8	40.259	20	0.005
m2.3	p2.14	44.347	20	0.001
m2.3	p2.16	33.777	20	0.028
m2.3	p3.8	37.520	20	0.010

Source: own computations

Let us consider the kind of loads that firm delivers (table 4). In case of groupage loads, their frequency had influence on the importance of the factors such as sensitivity for light (p2.5) and fragrances (p2.6), and high-value goods (p2.7). It has also influence on the occurrence of the factors such as fragility on temperature (p3.3), humidity (p3.4) and light (p3.5), high-value goods (p3.7), dangerous (p3.9) and over-sized (p3.12) loads. The frequency of partial loads influences the significance of sensitivity for duration (p2.1) and humidity (p2.4), high-value (p2.7), perishable (p2.8) and dangerous (p2.9) products, and exclusive contracts (p2.14). It corresponds also with the frequency of the occurrence of the factors like sensitivity for humidity (p3.4) and light (p3.5), high-value goods (p3.7), time windows (p3.13) and exclusive contracts (p3.14). Finally, the frequency of full-truck loads has influence on the significance of sensitivity for duration (p2.1), high-value (p2.7) and perishable (p2.8) goods, exclusive contracts (p2.14) and legal restrictions (p2.16). Only the frequency of the occurrence of perishable products (p3.8) depends on the frequency of full-truck loads.

Now let us analyze the relation between the range of deliveries and the occurrence of the exclusion factors (table 5).

Table 5. The results of χ^2 test: questions m3.1 (frequency of local deliveries), m3.2 (frequency of regional deliveries), m3.3 (frequency of countrywide deliveries), m3.4 (international/worldwide deliveries)

Q1	Q2	Chi-sq	df	p-val
m3.1	p2.7	49.683	20	0.000
m3.1	p3.2	34.299	20	0.024
m3.2	p2.1	39.415	20	0.006
m3.2	p2.5	33.083	20	0.033
m3.2	p2.15	34.576	20	0.022
m3.2	p3.16	41.149	20	0.004
m3.3	p2.6	37.232	20	0.011
m3.3	p3.5	31.793	20	0.046
m3.3	p3.7	37.080	20	0.011
m3.3	p3.11	33.314	20	0.031
m3.4	p2.2	32.661	20	0.037
m3.4	p2.3	31.696	20	0.047
m3.4	p2.6	37.955	20	0.009
m3.4	p2.8	34.319	20	0.024
m3.4	p2.9	31.680	20	0.047
m3.4	p2.13	34.746	20	0.021
m3.4	p2.14	37.107	20	0.011
m3.4	p3.2	65.948	20	0.000
m3.4	p3.3	37.737	20	0.010
m3.4	p3.6	47.213	20	0.001
m3.4	p3.9	40.348	20	0.005
m3.4	p3.13	32.940	20	0.034

Source: own computations

The factors that depend on the frequency of local deliveries are high-valued goods (significance – p2.7) and fragility of commodities (frequency – p3.2). The frequency of regional deliveries influences the factors like: sensitivity for duration (importance – p2.1), sensitivity for light (importance – p2.5), distances from supply and destination points (importance – p2.15) and legal restrictions (frequency – p3.16). Countrywide deliveries influence the following exclusion factors: sensitivity for light (frequency – p3.5) and fragrances (importance – p2.6), high-value goods (frequency – p3.7) and competitive goods (frequency – p3.11). As we can see, the biggest influence on both importance and occurrence of the exclusion factors has the frequency of operating on international market. To be more specific, it influences the fragility of products (importance and frequency – p2.2 and p3.2), sensitivity for temperature (importance and frequency – p2.3 and p3.3), sensitivity for fragrances (importance and frequency – p2.6 and p3.6), perishable products (importance – p2.8), dangerous products (importance and frequency – p2.9 and p3.9), time windows (importance and frequency – p2.13 and p3.13) and exclusive contracts (importance – p2.14).

The questions m4 (average distance to customers) and m5 (number of customers) were open questions, skipped them in this analysis. Another question was about the comparison of the company's economic parameters to the parameters of the competitors (table 6). The respondents were asked to choose a number between 1 and 5 (1 – much worse, 5 – much better).

Table 6. The results of χ^2 test: questions m6.1 (market share: 1 – much worse that competitors' shares, 5 – much better), m6.2 (sales income), m6.3 (profit), m6.4 (ROI).

Q1	Q2	Chi-sq	df	p-val
m6.1	p3.7	36.795	20	0.012
m6.1	p3.9	37.230	20	0.011
m6.2	p3.7	36.701	20	0.013
m6.2	p3.9	39.230	20	0.006
m6.2	p3.10	31.435	20	0.050
m6.2	p3.12	32.225	20	0.041
m6.2	p3.14	34.093	20	0.026
m6.3	p3.8	32.975	20	0.034
m6.3	p3.9	35.360	20	0.018
m6.3	p3.10	33.457	20	0.030
m6.4	p2.2	33.242	20	0.032
m6.4	p2.10	38.371	20	0.008
m6.4	p2.15	32.125	20	0.042
m6.4	p2.16	35.197	20	0.019
m6.4	p3.5	32.548	20	0.038
m6.4	p3.8	42.174	20	0.003
m6.4	p3.9	38.640	20	0.007
m6.4	p3.15	32.915	20	0.034

Source: own computations

As we can see, the evaluation of the market share was connected with the exclusion factors like high-valued and dangerous products (in both cases some differences in frequency encountered – p3.7 and p3.9). Same connection was found in the context of the evaluation of sales income. Moreover, the latter one influenced also the frequencies of occurrence of factors like livestock (p3.10), oversized loads (p3.12) and exclusive contracts (p3.14). The evaluation of profit had in turn influence on the frequency of perishable (p3.8) and dangerous (p3.9) products and livestock (p3.10). The evaluation of ROI was the only one that differentiated somehow also the importance of the exclusion factors. To be more specific, it was related to fragility (importance – p2.2), sensitivity for light (frequency – p3.5), perishable goods (frequency – p3.8), dangerous products (frequency – p3.9), livestock (importance – p2.10), distance from supply and destination points (importance and frequency – p2.15 and p3.15) and legal restrictions (importance – p2.16).

Similarly, the respondents compared also the resources of the firm to the resources of the competitors (1 – much worse, 5 – much better). The results of tests are presented in table 7.

As we can see, the evaluation of know-how was related to the exclusion factors like sensitivity for duration (frequency – p3.1), fragility (importance and frequency – p2.2 and p3.2), perishable goods (importance – p2.8), dangerous products (frequency – p3.9) and distance from supply and destination points (importance – p2.16).

The organizational issues were related to sensitivity for duration (frequency – p3.1), fragility (frequency – p3.2), sensitivity for fragrances (importance – p2.6), high-valued goods (frequency – p3.7) and dangerous products (frequency – p3.9).

Management methods corresponded with fragility (frequency – p3.2), sensitivity for light (frequency – p3.5), high-value goods (frequency – p3.7) and perishable goods (importance – p2.8).

The evaluation of technology was connected with fragility (frequency – p3.2), high-value goods (frequency – p3.7) and perishable goods (importance – p2.8).

The experience in turn correlated with fragility (frequency – p3.2), perishable goods (importance – p2.8), dangerous and competitive products (frequency – p3.9 and p3.11).

The perception of brand correlated with duration (frequency – p3.1), fragility (frequency – p3.2), sensitivity for light (importance – p2.5), perishable goods (importance – p2.8), dangerous products (frequency – p3.9) and time windows (frequency – p3.13).

Table 7. The results of χ^2 test: questions m7.1 (know-how: 1 – much worse that competitors' know-how, 5 – much better), m7.2 (operations organization), m7.3 (management methods), m7.4 (technology), m7.5 (experience), m7.6 (brand), m7.7 (relations)

Q1	Q2	Chi-sq	df	p-val
m7.1	p2.2	31.670	20	0.047
m7.1	p2.8	37.511	20	0.010
m7.1	p2.15	37.609	20	0.010
m7.1	p3.1	53.088	20	0.000
m7.1	p3.2	38.585	20	0.008
m7.1	p3.9	32.972	20	0.034
m7.2	p2.6	31.901	20	0.044
m7.2	p3.1	41.096	20	0.004
m7.2	p3.2	43.783	20	0.002
m7.2	p3.7	37.752	20	0.009
m7.2	p3.9	37.185	20	0.011
m7.3	p2.8	33.210	20	0.032
m7.3	p3.2	33.289	20	0.031
m7.3	p3.5	33.282	20	0.031
m7.3	p3.7	41.002	20	0.004
m7.4	p2.8	39.709	20	0.005
m7.4	p3.2	39.178	20	0.006
m7.4	p3.7	31.632	20	0.047
m7.5	p2.8	34.721	20	0.022
m7.5	p3.2	37.001	20	0.012
m7.5	p3.9	32.881	20	0.035
m7.5	p3.11	31.493	20	0.049
m7.6	p2.5	32.896	20	0.035
m7.6	p2.8	37.436	20	0.010
m7.6	p3.1	31.916	20	0.044
m7.6	p3.2	36.038	20	0.015
m7.6	p3.9	35.899	20	0.016
m7.6	p3.13	31.959	20	0.044
m7.7	p2.8	37.722	20	0.010
m7.7	p2.10	36.746	20	0.013
m7.7	p2.14	36.070	20	0.015
m7.7	p3.2	34.536	20	0.023
m7.7	p3.5	39.774	20	0.005
m7.7	p3.7	32.299	20	0.040
m7.7	p3.8	32.374	20	0.039
m7.7	p3.13	37.464	20	0.010

Source: own computations

Finally, the perception of firm's relations was related to fragility (frequency – p3.2), sensitivity for light (frequency – p3.5), high-value goods (frequency – p3.7), perishable goods (importance and frequency – p2.8 and p3.8), livestock (importance – p2.10), time windows (frequency – p3.13) and exclusive contracts (importance – p2.14).

The analysis of the possible influence of the branch of economy in which the company operates was presented in tables 8a and 8b. Multiple choices were possible. First observation is that the questions m8.4 (textile industry), m8.8 (telecommunication), m8.11 (finance) and m8.12 (logistics) do not appear in the table. This means, that the occurrence and significance of the discussed exclusion factors are independent from operating (or not) in the four branches of economy listed above.

Operating (or not) in the food industry had influence on fragility (importance – p2.2), sensitivity for temperature (importance and frequency – p2.3 and p3.3), sensitivity for humidity (frequency – p3.4), sensitivity for fragrances (importance and frequency – p2.6 and p3.6), perishable products (importance and frequency – p2.8 and p3.8) and legal restrictions (importance and frequency – p2.16 and p3.16)

Presence at the energy market influenced only the importance and frequency of occurrence of high-value commodities (p2.7 and p3.7).

Being involved in the construction industry had influence on the exposition on factors like fragility (importance – p2.2), sensitivity for temperature (frequency – p3.3), high-value commodities (frequency – p3.7), perishable products (importance and frequency – p2.8 and p3.8), competitive products (frequency – p3.11), oversized loads (importance – p2.12), time windows (frequency – p3.13), distance from supply and destination points (frequency – p3.15) and legal restrictions (importance – p2.16).

Operating in paper industry influenced the occurrence of perishable products (importance – p2.8), livestock (frequency – p3.10) and exclusive contracts (importance – p2.14).

Activity in chemical industry correlated with the factors like fragility (importance – p2.2), sensitivity for temperature (frequency – p3.3), sensitivity for humidity (importance and frequency – p2.4 and p3.4), sensitivity for fragrances (frequency – p3.6), dangerous products (importance and frequency – p2.9 and p3.9) and the frequency of occurrence of oversized loads and restrictions on time windows (p3.12 and p3.13).

Operating (or not) in agriculture had influence on sensitivity for duration (frequency – p3.1), sensitivity for temperature (importance – p2.3), sensitivity for humidity (frequency – p3.4), sensitivity for light (frequency – p3.5), sensitivity for fragrances (frequency – p3.6) and perishable products (frequency – p3.8).

Table 8a. The results of χ^2 test: questions m8.1 (food industry: yes/no), m8.2 (energy: yes/no), m8.3 (construction: yes/no), m8.5 (paper industry: yes/no), m8.6 (chemical industry: yes/no), m8.7 (agriculture: yes/no), m8.9 (health: yes/no)

Q1	Q2	Chi-sq	df	p-val
m8.1	p2.2	20.772	4	0.000
m8.1	p2.3	26.972	4	0.000
m8.1	p2.6	19.892	4	0.001
m8.1	p2.8	24.867	4	0.000
m8.1	p2.16	12.760	4	0.013
m8.1	p3.3	31.163	4	0.000
m8.1	p3.4	10.943	4	0.027
m8.1	p3.6	29.671	4	0.000
m8.1	p3.8	38.458	4	0.000
m8.1	p3.16	16.202	4	0.003
m8.2	p2.7	13.671	4	0.008
m8.2	p3.7	26.418	4	0.000
m8.3	p2.2	11.897	4	0.018
m8.3	p2.8	13.580	4	0.009
m8.3	p2.12	13.670	4	0.008
m8.3	p2.16	9.562	4	0.048
m8.3	p3.3	9.505	4	0.050
m8.3	p3.7	9.526	4	0.049
m8.3	p3.8	11.739	4	0.019
m8.3	p3.11	9.612	4	0.047
m8.3	p3.13	11.262	4	0.024
m8.3	p3.15	10.545	4	0.032
m8.5	p2.8	9.720	4	0.045
m8.5	p2.14	10.772	4	0.029
m8.5	p3.10	12.316	4	0.015
m8.6	p2.2	13.513	4	0.009
m8.6	p2.4	13.029	4	0.011
m8.6	p2.9	16.202	4	0.003
m8.6	p3.3	12.299	4	0.015
m8.6	p3.4	11.916	4	0.018
m8.6	p3.6	13.339	4	0.010
m8.6	p3.9	18.210	4	0.001
m8.6	p3.12	18.489	4	0.001
m8.6	p3.13	12.011	4	0.017
m8.7	p2.3	10.054	4	0.040
m8.7	p3.1	9.818	4	0.044
m8.7	p3.4	10.517	4	0.033
m8.7	p3.5	14.904	4	0.005
m8.7	p3.6	13.734	4	0.008
m8.7	p3.8	15.578	4	0.004
m8.9	p2.5	23.183	4	0.000
m8.9	p3.2	18.236	4	0.001
m8.9	p3.4	10.621	4	0.031
m8.9	p3.8	12.407	4	0.015

Source: own computations

Table 8b. The results of χ^2 test: questions m8.10 (furniture industry: yes/no) and. m8.13 (other: yes/no)

Q1	Q2	Chi-sq	df	p-val
m8.10	p2.5	9.801	4	0.044
m8.10	p2.9	12.863	4	0.012
m8.10	p2.12	11.225	4	0.024
m8.10	p3.2	11.500	4	0.021
m8.10	p3.9	11.185	4	0.025
m8.10	p3.16	11.730	4	0.019
m8.13	p3.13	10.058	4	0.039

Source: own computations

Presence in the health industry influenced fragility (frequency – p3.2), sensitivity for humidity (frequency – p3.4), sensitivity for light (importance – p2.5) and the occurrence of perishable goods (frequency – p3.8).

Operating in furniture industry correlated with fragility (frequency – p3.2), sensitivity for light (importance – p2.5), occurrence of dangerous products (importance and frequency – p2.9 and p3.9) or oversized loads (importance – p2.12) and legal restrictions (frequency – p3.16).

Other industries do not influence the discussed factors. The only exception, where a relation was found, is the frequency of the occurrence of time windows (p3.13).

The region of Poland (m9), in which the firm has its headquarters, had no influence on the answers to any of the questions about the significance (p2.1-p2.17) or frequency of occurrence (p3.1-p3.17) of any of the discussed factors of exclusions. Same with the legal form of the enterprise (m11). Thus, the last analyzed group of possible dependencies were those concerning the company's size, measured with the size of the crew (table 9).

Table 9. The results of χ^2 test: question m10 (how many employees has the company: 0-9, 10-49, 50-249, 250-999, 1000-4999, 5000 and more)

Q1	Q2	Chi-sq	df	p-val
m10	p2.2	42.345	20	0.002
m10	p2.5	33.213	20	0.032
m10	p2.6	36.850	20	0.012
m10	p2.8	37.919	20	0.009
m10	p2.13	38.666	20	0.007
m10	p3.2	50.112	20	0.000
m10	p3.3	41.948	20	0.003
m10	p3.5	36.641	20	0.013
m10	p3.6	39.004	20	0.007
m10	p3.7	33.180	20	0.032
m10	p3.8	34.439	20	0.023
m10	p3.9	58.251	20	0.000
m10	p3.12	39.937	20	0.005
m10	p3.13	32.842	20	0.035
m10	p3.16	39.459	20	0.006

Source: own computations

The number of employees correlated with fragility of transported goods (importance and frequency – p2.2 and p3.2), sensitivity for temperature (frequency – p3.3), sensitivity for light (importance and frequency – p2.5 and p3.5), sensitivity for fragrances (importance and frequency – p2.6 and p3.6), occurrence of high-value products (frequency – p3.7), perishable goods (importance and frequency – p2.8 and p3.8) or dangerous products (frequency – p3.9), oversized loads (frequency – p3.12), time windows (importance and frequency – p2.13 and p3.13) and legal restrictions (frequency – p3.16).

Just to reassume this part of our analysis, let us note that the importance and significance of the exclusion factors rather rarely relies on company's features – usually various properties were correlated with only few factors. The extremal cases, like some kinds of industry, location and the legal form of the company do not influence neither the importance nor the occurrence of the factors at all i.e., their distribution does not depend of those features of the company.

Let us end this section with the analysis of the results of the independence tests for the questions about importance (p2.1-p2.17) or frequency of occurrence (p3.1-p3.17) of the exclusion factors. This time, because of the number of dependencies, we presented only the ¬p–values of the tests for all the pairs: among p2.1-p2.17 (table 10), between p2.1-p2.17 and p3.1-p3.17 (table 11) and among p3.1-p3.17 (table 12).

As we can see, in almost all the cases we must reject the independence hypothesis, which means that the importance and frequencies of occurrence of various exclusion factors are dependent. There are, of course, some exceptions (marked in red). One may observe that they are usually connected with question p2.17 or p3.17 ("other factors"). The remaining results show that the frequency and importance of various factors are related to each other. A very important information is that all the values on the diagonal of the table 11 are 0.000 (i.e., they are less than 0.0005). This means that in case of every exclusion factor, its importance is related with its occurrence.

Table 10. The results of χ^2 test: questions about the significance of factors (p2.1-p2.17) vs. themselves

p-val	p2.1	p2.2	p2.3	p2.4	p2.5	p2.6	p2.7	p2.8	p2.9	p2.10	p2.11	p2.12	p2.13	p2.14	p2.15	p2.16	p2.17
p2.1	0.000	0.000	0.000	0.001	0.041	0.000	0.000	0.000	0.003	0.006	0.005	0.006	0.000	0.000	0.000	0.000	0.114
p2.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.000	0.000	0.002	0.000	0.283
p2.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.051	0.000	0.002	0.005	0.026	0.002	0.250
p2.4	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.004	0.009	0.001	0.001	0.000	0.663
p2.5	0.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.306	0.009	0.028	0.002	0.602
p2.6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.047	0.002	0.000	0.017	0.000	0.288
p2.7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.229
p2.8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.010	0.000	0.403
p2.9	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.268	0.000	NA
p2.10	0.006	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.004	0.000	0.011	0.006	0.174	0.000	NA
p2.11	0.005	0.000	0.051	0.003	0.000	0.000	0.000	0.006	0.000	0.004	0.000	0.023	0.000	0.000	0.000	0.001	0.753
p2.12	0.006	0.029	0.000	0.004	0.000	0.047	0.000	0.000	0.000	0.000	0.023	0.000	0.001	0.391	0.104	0.000	0.109
p2.13	0.000	0.000	0.002	0.009	0.306	0.002	0.000	0.000	0.000	0.011	0.000	0.001	0.000	0.000	0.000	0.000	0.707
p2.14	0.000	0.000	0.005	0.001	0.009	0.000	0.000	0.000	0.000	0.006	0.000	0.391	0.000	0.000	0.000	0.000	0.094
p2.15	0.000	0.002	0.026	0.001	0.028	0.017	0.001	0.010	0.268	0.174	0.000	0.104	0.000	0.000	0.000	0.000	0.009
p2.16	0.000	0.000	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.041
p2.17	0.114	0.283	0.25	0.663	0.602	0.288	0.229	0.403	NA	NA	0.753	0.109	0.707	0.094	0.009	0.041	0.000

Source: own computations

Table 11. The results of χ^2 test: questions about the significance of factors (p2.1-p2.17) vs. questions about the frequency of factors (p3.1-p3.17)

p-val	p3.1	p3.2	p3.3	p3.4	p3.5	p3.6	p3.7	p3.8	p3.9	p3.10	p3.11	p3.12	p3.13	p3.14	p3.15	p3.16	p3.17
p2.1	0.000	0.062	0.029	0.308	0.256	0.074	0.007	0.000	0.029	0.001	0.002	0.531	0.000	0.000	0.002	0.014	0.617
p2.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.000	0.000	0.017	0.004	0.000	0.053	0.001	0.648
p2.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.009	0.055	0.000	0.115	0.322	0.205
p2.4	0.015	0.000	0.000	0.000	0.000	0.000	0.055	0.000	0.031	0.001	0.024	0.025	0.310	0.024	0.109	0.037	0.259
p2.5	0.038	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.205	0.017	0.110	0.013	0.107	0.545	0.125	0.018
p2.6	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.120	0.326	0.181	0.001	0.737	0.000	0.103
p2.7	0.000	0.000	0.088	0.003	0.000	0.001	0.000	0.000	0.000	0.014	0.000	0.000	0.008	0.009	0.039	0.001	0.156
p2.8	0.015	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.003	0.012	0.000	0.000	0.000	0.436
p2.9	0.217	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.052	0.017	0.033	0.036	NA
p2.10	0.138	0.062	0.009	0.002	0.002	0.000	0.542	0.000	0.000	0.000	0.000	0.000	0.096	0.020	0.053	0.377	NA
p2.11	0.000	0.002	0.176	0.013	0.006	0.001	0.001	0.641	0.020	0.106	0.000	0.073	0.000	0.000	0.000	0.002	0.809
p2.12	0.092	0.154	0.002	0.260	0.002	0.024	0.000	0.000	0.000	0.000	0.156	0.000	0.249	0.004	0.265	0.001	0.399
p2.13	0.003	0.001	0.035	0.170	0.071	0.012	0.002	0.001	0.020	0.482	0.492	0.013	0.000	0.000	0.000	0.000	0.622
p2.14	0.001	0.000	0.001	0.004	0.018	0.000	0.000	0.000	0.000	0.051	0.000	0.316	0.000	0.000	0.000	0.000	0.172
p2.15	0.000	0.006	0.189	0.042	0.031	0.311	0.063	0.016	0.014	0.427	0.024	0.083	0.000	0.000	0.000	0.000	0.456
p2.16	0.056	0.000	0.003	0.000	0.001	0.000	0.001	0.000	0.052	0.015	0.003	0.009	0.013	0.000	0.000	0.000	0.140
p2.17	0.800	0.442	0.200	0.906	NA	0.797	0.848	0.509	0.271	NA	0.928	0.761	0.319	0.070	0.137	0.011	0.000

Source: own computations

Table 12. The results of χ^2 test: questions about the frequency of factors (p3.1-p3.17) vs. themselves

p-val	p3.1	p3.2	p3.3	p3.4	p3.5	p3.6	p3.7	p3.8	p3.9	p3.10	p3.11	p3.12	p3.13	p3.14	p3.15	p3.16	p3.17
p3.1	0.000	0.000	0.000	0.000	0.018	0.000	0.000	0.000	0.007	0.028	0.000	0.285	0.000	0.000	0.000	0.000	0.421
p3.2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.000	0.006	0.000	0.000	0.000	0.000	0.089
p3.3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.285
p3.4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.719
p3.5	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	NA
p3.6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.087
p3.7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.974
p3.8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.121
p3.9	0.007	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.613
p3.10	0.028	0.018	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.111	0.000	0.003	0.059	NA
p3.11	0.000	0.000	0.017	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.073	0.000	0.000	0.000	0.000	0.841
p3.12	0.285	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.073	0.000	0.016	0.258	0.118	0.000	0.562
p3.13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.111	0.000	0.016	0.000	0.000	0.000	0.000	0.041
p3.14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.258	0.000	0.000	0.000	0.000	0.866
p3.15	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.003	0.000	0.118	0.000	0.000	0.000	0.000	0.150
p3.16	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.001	0.059	0.000	0.000	0.000	0.000	0.000	0.000	0.001
p3.17	0.421	0.089	0.285	0.719	NA	0.087	0.974	0.121	0.613	NA	0.841	0.562	0.041	0.866	0.150	0.001	0.000

Source: own computations

CONCLUSIONS

The research described in this article confirms that the exclusion factors are an important part of activity of the companies transporting goods. Although the distributions of the frequencies are different, depending on the factor, one may observe that every factor was noticed by a significant fraction of companies. This confirms also that the list of factors, prepared based upon the qualitative research [Anholcer, Kawa 2017], properly reflects the real situation.

The analysis of the potential dependencies between the variables show that the importance and occurrence of the factors is rather independent from the company's features. There are, however, some exceptions (usually between 5 and 10 factors per each feature). There are, however, also the features (like location of the headquarters and legal form) which have no influence on any of the exclusion factors.

This means that one should study all the existing dependencies – e.g. operating in some markets clearly increases or decreases the exposition on some exclusion factors (which cause, in turn, additional costs).

What is also interesting – the occurrence and importance of various factors are dependent (with few exceptions). It means that when being subject to some exclusion, one should expect that soon also other exclusions would appear.

Of course, we plan further research in this area, mostly based upon further exploration of the data collected with the questionnaire. First, we will use the results of the quantitative research to develop mathematical models of the transportation problems. We also collected data about the losses and defects that may occur during transportation or storage and we are in train of analyzing them. Finally, taking into account the results of the analyses, we plan to prepare more effective methods of planning the deliveries.

The limitation of the methodological nature of this study is the essence of a quantitative research, especially data collected with the questionnaire. This method is burdened with the risk of free interpretation of phenomena and concepts by both the respondents and the researchers, their subjectivity, variability of the examined environment, and evaluation.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The publication was financed from the funds of the National Science Center granted on the basis of decision number DEC-2014/13/B/HS4/01552.

REFERENCES

Anholcer M., Kawa A., 2012. Optimization of Supply Chain via Reduction of Complaints Ratio. In: Jezic G., Kusek M., Ngoc-Thanh Nguyen N.-T., Robert J., Howlett R.J., Lakhmi C., Jain L.C. (eds.), Agent and Multi-Agent Systems. Technologies and Applications. Lecture Notes in Computer Science, 2012, 7327/2012. http://doi.org/10.1007/978-3-642-30947-2_67

Anholcer M., Kawa A., 2017. Identyfikacja ograniczeń wykluczających w transporcie – wyniki badań przeprowadzonych metodą jakościową. Gospodarka Materiałowa i Logistyka 06/2017, 18–24. [Identification of Exclusionary Constraints in Transport - Research Results Conducted by Qualitative Method]

Anholcer, M., Kawa, A., 2015. Optimization of transportation decisions under exclusionary side constraints in food supply chain. In: Bruzzone A., Longo F., Mercadé-Prieto R., Vignali G. (eds.): Proceedings of the International Food Operations and Processing Simulation Workshop, DIME UNIVERSITA DI GENOVA, Genova, 28-33.

Bazarnik, J., Grabiński, T., Kąciak, E., Mynarski, S., Sagan A., 1992. Badania Marketingowe. Metody i Oprogramowanie Komputerowe [Marketing research. Computer methods and software]., Canadian Consortium of Management Schools, Warszawa – Kraków: Akademia Ekonomiczna w Krakowie

Blake A., Kotseridis Y., Brindle I.D., Inglis, D., Pickering, G.J., 2010. Effect of light and temperature on 3-alkyl-2-methoxypyrazine concentration and other impact odorants of Riesling and Cabernet Franc wine during bottle aging. Food Chemistry, 119 (3), 935–944. http://doi.org/10.1016/j.foodchem.2009.07.052

Brenner V., Hülsmann M., Cordes-Berszinn P., 2014. Improving Flexibility in Autonomous Cooperating Food Chains. In: Nandakumar M., Jharkharia S., Nair A. (eds) Organisational Flexibility and Competitiveness. Flexible Systems Management. Springer, New Delhi, http://doi.org/10.1007/978-81-322-1668-1_20

Broom D.M., 2008. The welfare of livestock during road transport. In: M. Appleby, V. Cussen, L. Garcés, L. Lambert and J. Turner (Editors) Long Distance Transport and the Welfare of Farm Animals 157-181. Wallingford: CABI.

Butzke C.E., Vogt E.E., Chacon-Rodriguez L.C., 2012. Effects of heat exposure on wine quality during transport and storage. Journal of Wine Research, 23 (1), 15–25. http://doi.org/10.1080/09571264.2011.646254

Cao B., 1992. Transportation problem with nonlinear side constraints a branch and bound approach. Mathematical Methods of Operations Research (ZOR) 36, 185–197. http://doi.org/10.1007/BF01417216

Cao B., Uebe G., 1995. Solving transportation problems with nonlinear side constraints with tabu search. Computers & Operations Research 22, 593–603. http://doi.org/10.1016/0305-0548(94)00055-D

Darmann A., Pferschy U., Schauer J., Woeginger G.J., 2011. Paths, trees and matchings under disjunctive constraints. Discrete Appl Math 159 (16):1726–1735. http://doi.org/10.1016/j.dam.2010.12.016

Eurostat 2016. Transportation and storage statistics – NACE Rev. 2, http://ec.europa.eu/eurostat/statistics-explained/.

Glover F., Karney D., Klingman D., Russel R., 1978. Solving singly constrained transshipment problems, Transportation Science 12, 277–297. http://doi.org/10.1287/trsc.12.4.277

Goldstein S., 2010. Pallet firms push global ops. Packaging News, (February), 32–33.

Goossens D., Spieksma F.C.R., 2009. The transportation problem with exclusionary side constraints. 4OR, A Quarterly Journal of Operations Research, 7, 51–60. http://doi.org/10.1007/s10288-007-0067-z

Kawa A., Anholcer M., 2018. Exclusionary constraints in storage: an empirical study of logistics service providers. Logforum 14 (3), 4. http://doi.org/10.17270/J.LOG.2018.283

Klingman D., Russel R., 1975. Solving constrained transportation problems. Operations Research , 23, 1, 91-10, Published by: INFORMS https://www.jstor.org/stable/169788

Kurmanov N., Tolysbayev B., Abilmazhinov Y., 2015. The limiting storage life of perishables during joint transportation, CBU International Conference Proceedings, Prague, 3, 499–505. http://doi.org/10.12955/cbup.v3.644

Lu L., Zheng W., Lv Z., Tang Y., 2013. Development and application of time-temperature indicators used on food during the cold chain logistics. Packaging Technology and Science, 26, 1, 80–90. http://doi.org/10.1002/pts.2009

Muncke J., Backhaus T., Geueke B., Maffini M.V., Martin O.V., Myers J.P., Scheringer M., 2017. Scientific challenges in the risk assessment of food contact materials. Environmental Health Perspectives, 125 (9). http://doi.org/10.1289/EHP644

Murray M., 2014. Reducing Transportation Costs, http://logistics.about.com/od/forsmallbusinesses/a/Reducing-Transportation-Costs.htm (access: 10.06.2014).

Öncan T., Zhang R., Punnen A.P., 2013. The minimum cost perfect matching problem with conflict pair constraints, Computers & Operations Research, 40, 4, April 2013, 920–930. https://doi.org/10.1016/j.cor.2012.10.022

Pferschy U., Schauer J., 2013. The maximum flow problem with disjunctive constraints. Journal of Combinatorial Optimization, 26, 109–119. http://doi.org/10.1007/s10878-011-9438-7

Sun M., 2002. The transportation problem with exclusionary side constraints and two branch-and-bound algorithms. European Journal of Operational Research, 140, 629–647. http://doi.org/10.1016/S0377-2217(01)00239-9

Thompson G.L., Setbi A.P., 1986. Solution of constrained generalized transportation problems using the pivot and probe algorithm. Computer and Operations Research, 13:1- 9. http://doi.org/10.1016/0305-0548(86)90059-6

Tseng Y., Yue W.L., Taylor M.A.P., 2005. The role of transportation in logistics chain. Proceedings of the Eastern Asia Society for Transportation Studies, 5, 1657–1672.

Vancroonenburg W., Della Croce F., Goossens D., Spieksma F.C.R., 2014. The Red–Blue transportation problem, European Journal of Operational Research 237, 814–823. http://doi.org/10.1016/j.ejor.2014.02.055

Zhang R., Kabadi S.N., Punnen A.P. (2011), The minimum spanning tree problem with conflict constraints and its variations. Discrete Optim 8(2):191–205. http://doi.org/10.1016/j.disopt.2010.08.001

OGRANICZENIA WYKLUCZAJĄCE W TRANSPORCIE - WYNIKI BADAŃ METODĄ ILOŚCIOWĄ

STRESZCZENIE. Wstęp: Spośród wszystkich procesów w łańcuchu dostaw, transport jest jednym z najbardziej złożonych i najdroższych. Planując proces transportu, należy wziąć pod uwagę różne czynniki, m.in. ograniczenia wykluczające nałożone na wybranych dostawców, produkty czy środki transportu. Chociaż są artykuły, w których autorzy omawiają problem ograniczeń wykluczających, to nie ma tych dotyczących badań empirycznych. Nasza praca stara się wypełnić tę lukę. Głównym celem tego artykułu jest analiza znaczenia i wagi różnych wykluczeń w transporcie obecnych w praktyce gospodarczej.

Metody: Przedstawiamy wyniki badania metodą ilościową przeprowadzonego na losowej próbie 300 dostawców usług logistycznych w Polsce, dotyczącego ograniczeń wykluczających w transporcie.

Wyniki: Badania potwierdzają, że warunki wykluczające stanowią ważną część działalności firm zajmujących się transportem towarów. Chociaż rozkłady częstości są różne, w zależności od czynnika, można zauważyć, że każdy został

zauważony przez znaczną część respondentów. Analiza potencjalnych zależności pomiędzy zmiennymi pokazuje, że znaczenie i częstotliwość czynników jest raczej niezależna od cech przedsiębiorstwa. Nasze badanie stanowi wkład w teorię i praktykę przedsiębiorstw logistycznych.
Wnioski: Badanie to stanowi rozszerzenie wcześniejszych badań nad ograniczeniami wykluczającymi z wykorzystaniem badań empirycznych. W przyszłych pracach wykorzystamy wyniki badań ilościowych do opracowania modeli matematycznych problemów transportowych i chcemy przygotować bardziej efektywne metody planowania dostaw.

Słowa kluczowe: transport, ograniczenia wykluczające, badania metodą ilościową, logistyka.

Marcin Anholcer ORCID ID: https://orcid.org/0000-0001-7322-7095
Poznań University of Economics and Business
Department of Operations Research
al. Niepodległości 10, 61-875 Poznań, **Poland**
e-mail: m.anholcer@ue.poznan.pl

Arkadiusz Kawa ORCID ID: https://orcid.org/0000-0003-0697-8838
Łukasiewicz Research Network – Institute of Logistics and Warehousing
Ul. Estkowskiego 6, 61-755 Poznań, **Poland**
e-mail: arkadiusza.kawa@ilim.lukasiewicz.gov.pl

LogForum

> Scientific Journal of Logistics <

2020, 16 (4), 593-601

http://doi.org/10.17270/J.LOG.2020.497

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

THE CONCEPT OF BUILDING A DIGITAL TRANSFORMATION MODEL FOR ENTERPRISES FROM THE SME SECTOR

Łukasz Szopa, Piotr Cyplik

Poznan University of Technology, Poznań, **Poland**

ABSTRACT. **Background:** The ecosystem of digital solutions and technologies that is a part of digital economy, present in most small and medium-sized enterprises, can be considered underdeveloped and outdated, which has a direct negative impact on the effectiveness of the implementation of activities at the operational level. An important element of building a competitive advantage of small and medium-sized enterprises may be the implementation of a model for their digital transformation as an element of a wider concept of digital supply chains.

Methods: The article uses the method of "case study" and questionnaire research to develop a model of digital transformation of enterprises from the SME sector. It is worth pointing out that small and medium-sized enterprises are the most numerous group of institutional participants in the modern market economy. The work uses the concept of the Digitization Index and quality tools, which include, inter alia, Ishikawa diagram and SWOT analysis. The research environment was a manufacturing company from the furniture industry, also acting as the main coordinator between all the links with which it cooperates within the supply chain

Results: The article describes the phenomena of digital transformation, which is the main driving force of the digital economy and digitization, which is an indispensable element of transforming business models in accordance with its principles. The final effect of digital transformation of supply chains, which is the creation of new business models based on the properties of digital solutions, called digital supply chains, was also characterized. As a result of the considerations, a concept for building a digital transformation model for enterprises in the SME sector was proposed.

Conclusions: The model of digital transformation of enterprises in the SME sector should include both the assessment of the current level of digitization of the enterprise as well as the proposal of its digital transformation. Increasing the degree of digitization of the enterprise surveyed as part of the case study will allow, in the long run, to achieve an increase in the effectiveness of the tasks performed, mainly in terms of reducing the time of their execution and improving the efficiency of information flow between all participants in the supply chain.

Key words: digital transformation model, digital index, SME sector.

INTRODUCTION

Digital economy is a term difficult to define clearly because of highly dynamic technological progress, observable in all economical processes. Main assumption of digital economy is the interchange of all data and information with as little human involvement as possible [Nowicka, 2019]. This allows for shortening the time of information and data interchange, and reducing its cost [Combe, 2006]. The most important characteristics of digital technologies is their capability for dynamic (fast) reaction to sudden changes on the market and customer preferences. They also provide the opportunity of keeping interactive contact with main business partners [Wang et all, 2007]. The environment of digital solutions, a part of digital economy, as present in most of Polish small and medium businesses can be considered poorly developed and obsolete. This has direct, negative influence on the effectiveness of many operational level activities and as such - negatively impacts the overall strategic plans. In current market

Citation: *Szopa Ł., Cyplik P., 2020. The concept of building a digital transformation model for enterprises from the SME sector – case study. LogForum 16 (4), 593-601,* http://doi.org/10.17270/J.LOG.2020.497

Received: 15.05.2020, Accepted: 24.08.2020, on-line: 18.09.2020.

reality an analysis and evaluation of current extent of digitalization, leading to improvements suggestions and their consistent implementation result in gradual digital transformation of entire supply chains into fully digital, is needed. Such analysis makes it possible to gradually digitally transform and reorganize entire supply chains into fully digital, keeping their competitiveness in relation to their main rivals.

The aim of the article is to present a concept of a digital transformation model for enterprises from the SME sector based on analyse and evaluate the extent of digitalization of a manufacturer-distributor company from the furniture sector. The enterprise's profile assumes the necessity of coordinating the entire supply chain. Conducted research showed clear gaps in current extent of digital solutions implementation. The information gathered and conclusions based on them will allow for suggesting potential improvements. The digitization index allows to assess the degree of implementation of digital solutions in entire economies, but it can also be used for individual companies, e.g. coordinators of supply chains.

THEORETICAL BACKGROUND OF A DIGITAL TRANSFORMATION AND DIGITISATION

Digital transformation, a main drive for digital economy is defined as an implementation of breakthrough changes in approach to customers and making business. Such changes rely on digital technologies and result in creation of new, innovative products, services or business models. The fundamental goal of digital transformation, just like in case of every other change of organization's operating model, is generating income and providing the growth of efficiency in the entire enterprise. Full integration of company's activities with digital technologies is the very foundation of digital transformation of business strategies. It's worth noting that mere use of digital technologies does not lead to transformation of enterprise's operating model. The key aspect is, apart from using digital technologies in operational activities, a change of organization's culture, which should also be based on innovative values provided by digital technologies [Kersten et all, 2017, Nowicka, 2019]. Digital transformation is closely connected to those areas of organization's activities it directly influences. It includes: operational processes, current customer needs and offered range of products. Companies wanting to change their functioning via the use of digital transformation process can achieve this in two ways. The transformation may be concentrated around the entire operational model, which generates value for the customer, or just around the value itself (a product). In order to achieve the best possible results of implementation of digital technologies a company should focus on both of these aspects [Berman, 2012, Osmólski, Voronina, Koliński, 2019].

Conducting a digital transformation is an elastic process and can be applied in pretty much every single area of companies' activities. One of these areas, in which a substantial increase in activities' effectiveness can be achieved, is supply chain management. Main requirement for correct conduction of digital transformation process of the supply chain model is the support of innovative technologies with knowledge, personnel and implementing digital technologies not only in own company, but also its business partners. Digitalization is an inherent part of every digital transformation. Results of activities done within as a matter of digitalization, provided they have meaningful impact on the process realization effectiveness growth, may be qualified as the final result of digital transformation process. One needs to emphasise, that they do not have to be treated as strategic tasks. Digitalization addresses mainly the use digital technologies in selected environment, which generates an array of changes and consequences improving its efficiency. Work effectiveness growth relates to its resources and processes that are a part of given environment. Companies' need to maximize profit and increase work efficiency through development of currently used technologies and implementation of new digital solutions leads to shift in approach to supply management from traditional to digital. An important factor concerning supply chain digital transformation is constantly increasing integrations of digital technologies and processes which are a part of organization's general business model [Nowicka, 2019]. The shift of approach to supply chain management can be defined as their digital transformation, of which main aim is easier organization, control and execution of processes currently occurring in the enterprise and its environment [Hines, 2014, Ciesielski, Konecka, 2019]. Companies which conduct the digital transformation may be in three different stages of its adaptation. First stage applies to companies digitalizing only single processes realized in supply chains. In development phase are those organizations which through technology support all those supply chain activities that involve their environment. The advanced phase is the highest level of digital transformation process development, and means the integration of all supply chain links via the use of innovative solutions. It is worth noting that companies in that final stage are the ones most effectively managing their supply networks [Wu et all, 2016, Wieczerniak, Milczarek, 2019]. It is worth noting that the digital supply chain is mainly oriented at improving the information flow process among all its participants. In digital supply chains, the user, due to the increase in the speed of data transmission using the Internet, gains the ability to react faster to unexpected disruptions that appear [Richey Jr et all, 2016, Kache et all, 2017]. The most important attributes of digital supply chains are: the interconnection of all elements of the supply chain, supporting the decision-making process by "intelligent" systems, the ability to implement supply chain processes without interruption and the ability to implement supply chain processes without interruption (continuity of operation) [Wu et all, 2016]. In order to correctly and effectively transform the supply chain into a digital one, a company should make long term implementation plan. Such actions will allow for achieving company's required result, which is generating profit thanks to implemented solutions. Main reasons of failures during the process of supply chain's digital transformation are technological barriers. It is crucial to have the necessary technical foundation which involves substantial expenses not every company can afford. Synchronizing all of company's systems is also important. This will allow for later integration of information interchange between them [Horzela, 2019].

Literature also differentiates, apart from widely understood digital supply chain, an idea of supply chain models managed by the digital technology environments' dynamic abilities:

– Platform model - based mainly on cloud computing technology. Its main paradigm is integration of data and information interchange between all supply chain participants, coordinated by the supply chain management process' owner.
– Dispersed model - it is different form platform model in a way that makes it impossible to single out a subject acting as information interchange coordinator. It is based on blockchain technology.
– Decentralized model - combines both previous models. It allows for effective information flow between processes actors and coordinators. This type of digital supply chain model is supported by Internet of things technology [Goldfarb et all, 2015].

CONCEPT OF DIGITAL TRANSFORMATION MODEL

Model of digital transformation of enterprises from the SME sector should include both of assessment of the current level of digitization of the company as well as a proposal for its digital transformation. The following figure 1.1 presents the phases that are essential when trying to digitally transform the business model of digital transformation of enterprises from the SME sector.

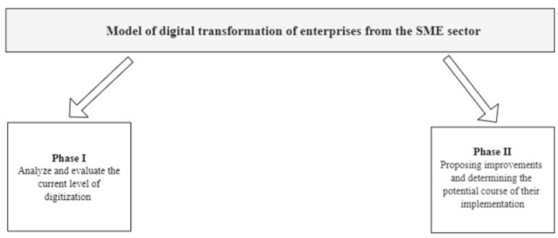


Fig. 1.1. Model of digital transformation of enterprises from the SME sector

The first phase of digital transformation of the company's operating model includes the assessment and analysis of the current level of digitization. In order to measure the general work effectiveness when it comes to digitalization of processes and the transformation of business models through the use of innovative digital technologies a so called Digitalization Index, as shown below in table 1.1, is used. It consists of 21 sub-indexes. It is used to measure digital demand and supply in entire economies, but may also be used to analyse the extent of effective implementation of digital solutions in companies operating independently or as a part of supply chains [McKinsey&Company, 2016].

Table 1.1. Digitalization Index

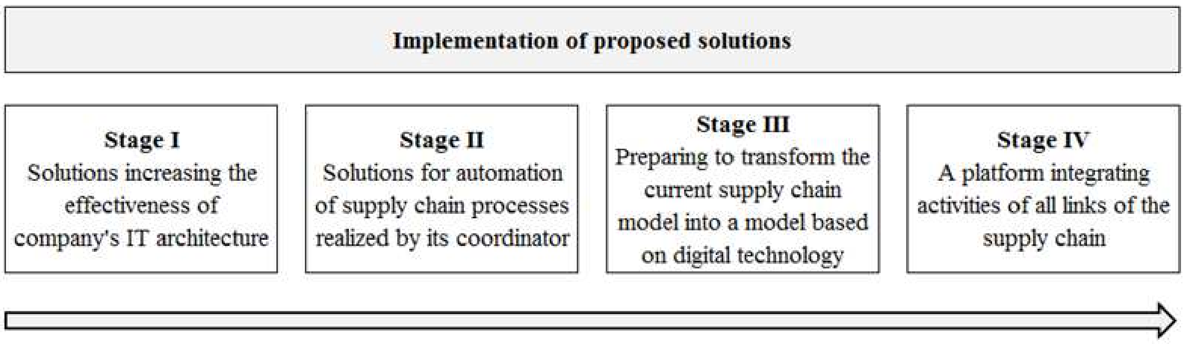
Index			Description
Digital resources supply	Digital assets spending	Hardware spending	Share of ICT hardware (PCs, servers) expenses in relation to total expenses
		Software and IT services spending	Share of software and IT services expenses in relation to total expenses
		Telecommunications spending	Share of telecommunications expenses in relations to total expenses
	Digital assets resources	Hardware assets	Share of ICT hardware in relation to all assets
		Software	Share of software in relation to all assets
	Digital assets spending per employee	Digital technologies for employees spending	ICT hardware expenses calculated per single employee
		Software and IT services spending per employee	Software and IT services expenses calculated per single employee
		Telecommunications spending per employee	Telecommunications expenses calculated per single employee
	Digital capital growth	Hardware assets per employee	ICT hardware assets calculated per single employee
		Software assets per employee	Software assets calculated per single employee
	Work digitalization	Digital workstations	Share of workstations that are digital in character (IT systems managers, web developers, system administrators, database administrators, Big Data analysts) in relation to all workstations
Digital resources demand	Transaction	Companies selling online	Yearly volume of sales realized via computer networks (websites, EDI and other electronic data interchange methods, excluding e-mail)
		Companies buying online	Percentage of companies procuring at least 1% of their resources via computer networks
	Contacts between companies, customers and suppliers	Digital supply chain	Companies sending/receiving information regarding sales chain (stock levels, production plans, predictions, delivery status) via computer networks or websites
		Use of social media	Companies using at least two types of social media: social networks, company blogs, microblogs, knowledge sharing tools based on wiki services, multimedia publishing websites
		Companies in which IT and telecommunications technologies are a part of everyday operations	Data from statistical research (regarding entire economies)
		Companies profiting from external tools addressing customers	
		Companies using social tools to cooperate with partners	
		Companies of which at least half of activities is digital in character	
	Processes	Use of ERP systems	Companies using ERP software to interchange information between departments (i.e. accounting, production, marketing)
		Use of CRM systems	Companies using CRM systems, a software for analysing data about customers for marketing purposes

Source: McKinsey& Company, 2016

The Digitization Index is most commonly used to measure the effectiveness of digital solutions used in the whole economy. It is worth noting, that all sub-indexes of the main digital supply index in the entire economy or a single enterprise have their own respective formulas, as shown above. It allows the final results to be presented as percentage values.

Digital resources demand indicators are applied to the number of enterprises meeting the criteria of sufficient use of digital business innovations. Calculating percentage values of these indexes for a single enterprise is therefore impossible. It is proposed, in case of the analyzed enterprise, values of indicators from this specific group were based on questionnaire interview with company's owners and key personnel.

The second phase of the digital transformation model of enterprises from the SME sector includes proposing right solutions in the area of digital economy and defining the potential course of their implementation. The course of proposed solutions implementation regarding the digital transformation of the companies model is presented in figure 1.2. It was divided into four stages in order to make it easier to integrate them into company's long term strategy, which main goal is to provide the enterprise with a competitive edge.



Source: own study

Fig. 1.2. Implementation of proposed solutions

ANALYSIS AND EVALUATION OF THE DIGITALIZATION LEVEL FROM SUPPLY CHAIN COORDINATOR'S PERSPECTIVE – CASE STUDY

Table 1.2 represents the values of each sub-index of the Digitization Index (digital resource supply), for the analyzed Polish manufacturer of school and office furniture, a coordinator and manager of its own supply chain. The values were calculated in cooperation with company's management. Showing the detailed calculations would require compromising company's sensitive data regarding its spending. With that in mind only the final results are shown.

Table 1.2. Digitization Index (digital resources supply) in analyzed enterprise - index values

Digital resources supply in analyzed enterprise	
Index	Value
Hardware spending	3,2%
Software and IT services spending	5,4%
Telecommunications spending	1,7%
Hardware assets	2,8%
Software assets	4,9%
Digital technologies for employees spending	3,3%
Software and IT services spending / employee	4,8%
Telecommunications spending / employee	1,3%
Hardware assets / employee	2,6%
Software assets / employee	3,4%
Digital related jobs share	2,8%

Source: own study

For the analyzed company the Digitization Index (digital resources supply) is 3.29%. The value was calculated as the arithmetic mean of sub-indexes' values shown in table 1.2. It is worth emphasising that the Digitization Index (digital resources supply) for the entire Polish economy throughout the years is 7%. The company's management plans on reaching that value in the future. Achieving this goal will be made possible through implementation of digital innovations, procurement of larger amounts of hardware and software. Despite this causing a sudden spike of expenses, the company will get the opportunity to increase work effectiveness and to realize many of the processes of its supply chain. The Digitization Index value was determined through the questionnaire interview conducted in the company. Participants of the survey were both management associates and three foremen from production departments. Their task was determining values of each of the Digitization Index's sub-indexes, according to the Likert Scale. Table 1.3 shows the results of the survey. Final results were calculated as the arithmetic mean of all marks.

Table 1.3. The Digitization Index (digital resources demand) in analyzed company - survey results

Demand for digital resources in analyzed company - the extent of digital resources' utilization in current operations								Arithmetic mean
Index	Low			Medium		High		
	1	2	3	4	5	6	7	
Online sales					2	1	2	6
Online procurement					3	2		5,4
The extent of IT and telecommunications utilization in current operations				1	3	1		5
Use of the social media			2	1	2			4
Use of the ERP and CRM systems		2	2	1				2,8
Digital supply chain	3	2						1,4

Source: own study

Summarising the Digitization Index's analysis results, both for the supply and demand of digital resources, one can determine that its value for the surveyed company, a supply chain coordinator, is very low. It means that the substantial current operations effectiveness increase can be achieved through the implementation of new digital technologies and higher utilization of company's digital resources. It needs to be pointed out that determining the Digitization Index value (in this case very low) is the main reason for the organization's management to make decisions regarding the implementation of solutions increasing work digitalization and reorganizing company's current structure according to digital transformation paradigms. In order to survey the current situation even further, the Digitization Index should be supported with quality analyses such as Ichikawa Diagram and SWOT analysis. In case of the surveyerd company the Ishikawa Diagram analysis was supposed to diagnose the reasons for low Digitization Index and its sub-indexes values. SWOT analysis was conducted in order to characterize current solutions implementation in terms of their strengths and weaknesses. It also allowed to determine the opportunities and threats regarding current digitalization extent and potential expansion chances. This information is crucial when creating long term and strategic plans of company's business model digital transformation. One needs to emphasise the fact, that in case of companies acting as supply chain main coordinators the conducted analyses (Digitization Index and quality analyses), can be conducted just for that particular company without the need to take other links partaking in increasing supply chain's value.

Conducting a detailed analysis of current extent of digital solutions implementation in the surveyed company, acting as a supply chain coordinator, allowed the author to define its state. It was deemed underdeveloped. This means that through increasing company's digital resources utilization and implementing new digital technologies, it is possible to achieve a substantial effectiveness growth of current operations.

The first of four stages (compare figure 1.2) of the company's transformation according to the paradigms of digital transformation, accompanied by the digitalization of supply chain processes, assumes increasing currently owned IT architecture's efficiency. Such action may be considered as the preparation phase for the proper implementation of technologies deemed crucial in fully digital supply chains.

Main recommendations for this stage are as follows:

- Modernizing currently owned digital assets in order to increase the data and information throughput between them.
- Achieving the speed up of the entire network through the use of cables allowing for faster clocking speed in comparison to currently used devices.
- The second stage consists of solutions regarding the automation of company's currently realized processes. The main improvements include:
- Implementation of additional ERP modules in current activities.
- Use of the ERP module based on CRP system. It could potentially substantially increase customer relationships management effectiveness and enable the company to gather data on customer preferences.
- Use of the WMS and linking it to such digital technology elements as sensors and automated identification of goods stored in the warehouse (RFID). It would allow for greater control over manufacturing resources stock.
- Modifying the machines of highest utilization in the entire manufacturing process using the CNC technology and supporting them with additional 3D printing technology.

Third phase consists of transforming the current supply chain model into a one managed through digital technology. The recommended technologies for implementation are Cloud Computing, Internet of things, Blockchain and advanced data analysis.

The final effect of correct implementation of fourth phase will be transformation of the entire supply chain into a digital one. Author suggests implementing a model based on a digital platform, integrating operations of all supply chain links, with the company in question as its coordinator. The model should be based on cloud computing technology and supported by the tools for advanced data analysis, as well as Blockchain and Internet of things technologies.

CONCLUSIONS

The purpose of the article is to introduce a concept of building a digital transformation model for enterprises from the SME sector. The proposed model was implemented in the surveyed enterprises in the furniture industry. A thorough analysis of the current degree of implementation of digital solutions in the analyzed company, which is the body coordinating activities throughout the supply chain, was carried out. Also, an analysis of a number of possible solutions to the problem of digital transformation of the entire supply chain was performed. It was found that it is possible to achieve a significant increase in the effectiveness of the implementation of current activities by raising the level of use of digital resources and the implementation of new digital technologies. A number of solutions in the field of digital transformation of the functioning of the manufacturing company and the entire supply chain were proposed.

The developed concept requires further works in the field of detailing the selection of the most effective digital tools adapted to the conditions of the company's operation within the supply chain. An important element of future research remains the identification of the premises for undertaking the research problem related to determining the differences in the selection of methods and tools for the digital transformation of an enterprise depending on its role in the supply chain in which it occurs.

ACKNOWLEDGMENTS AND FUNDING SOURCE DECLARATION

The paper has been the result of the study conducted within the projects pursued at the Poznan University of Technology, Faculty of Engineering Management [project number: 11/140/SBAD/4168].

REFERENCES

Berman S.J., 2012. Digital Transformation: Opportunities to Create New Business Models, „Strategy& Leadership", 40, 2, 2012, 16-24, https://doi.org/10.1108/10878571211209314

Ciesielski M., Konecka S., 2019. The main areas of methodological reflection in the supply chains research . Logforum 15 (3), 4. http://doi.org/10.17270/J.LOG.2019.341

Combe C., 2006. Introduction to E-buisness – managment and strategy, First edition, Elsevier Ltd., Oxford 2006. http://kolegjifama.eu/materialet/Biblioteka%20Elektronike/Introduction%20to%20e-Business%20Management%20and%20Strategy.pdf

Goldfrab A., Greenstein S.M., Tucker C.E., 2015. Economic Analysis of The Digital Economy, National Bureau of Economic Research, The University of Chicago, Chicago. ISBN- 13: 978-0-226-20698. http://doi.org/10.7208/chicago/9780226206981.001.0001

Hines T., 2014. Supply Chain Strategies: Demand Driven and Customer Focused, Routledge, New York, 2014. ISBN: 978-0-20363166-9(ebk)

Horzela A., Supply chain digitization: why two out of three implementations fail and what to do to avoid it? Logistyka, 3/2019, 60-61.

Kache F., Seuring S., 2017. Challenges and opportunities of digital information at the intersection of big data Analytics and supply chain managment, „International Journal of Operations&Production Management", 37(1), January 2017. https://doi.org/10.1108/IJOPM-02-2015-0078

Kersten W., Schröder., Indorf., Potenziale der Digitalisierung für das Supply Chain Risikoschaftliche Forschung (ZfbF), in: Kersten W., Seiter M., von See B., Hackius N., Maurer T., 2017. Trends and Strategies in Logistics and Supply Chain Management. Digital Transformation Opportunities, BVL International, Bremen, Hamburg, http://doi.org/doi.org/10.1007/978-3-658-18488-9_3

McKinsey&Company., Digital Poland. 2016. A chance for a technological leap to the global economic first league, McKinsey &Company, Forbes Polska, 2016, 3-35.

Osmólski W., Voronina R., Koliński A., 2019. Verification of the possibilities of applying the principles of the physical internet in economic practice . Logforum 15 (1), 1. http://doi.org/10.17270/J.LOG.2019.310

Richey Jr R.G., Morgan T.R., Lindsey-Hall K., Adams F.G., 2016. A global exploration of big data in the supply chain, "International Journal of Physical Distribution&Logistics Management", 46, 8, 710-739, http://doi.org/10.1108/IJPDLM-05-2016-0134

Wang C., Ahmed P., 2007. Dynamic capabilities: a review and research agenda, The International Journal of Management Reviews, 9, 1, 31-51. http://doi.org/10.1111/j.1468-2370.2007.00201.x

Wieczerniak S., Milczarek J., 2019. Concept for identifying problems in supply chains in omni-channel systems . Logforum 15 (3), 3. http://doi.org/10.17270/J.LOG.2019.353

Wu L., Yue X., Jin A., Yen D.C., 2016. Smart Supply Chain Management: A Review and Implication for Future Research, The International Journal of Logistics Managment, 27 2/2016, 395-417. http://doi.org/10.1108/IJLM-02-2014-0035

KONCEPCJA BUDOWY TRANSFORMACJI CYFROWEJ PRZEDSIĘBIORSTWA DLA PRZEDSIĘBIORSTW SEKTORA MŚP

STRESZCZENIE. Wstęp: Ekosystem rozwiązań i technologii cyfrowych wchodzący w skład gospodarki cyfrowej, obecny w większości małych bądź średnich przedsiębiorstw w większości przypadków można uznać za słabo rozwinięty i przestarzały, co wpływa w bezpośredni sposób negatywnie na stopień efektywności realizacji ich działań na poziomie operacyjnym. Istotnym elementem budowy przewagi konkurencyjnej małych i średnich przedsiębiorstw może być implementacja modelu przeprowadzenia ich transformacji cyfrowej jako elementu szerszej koncepcji cyfrowych łańcuchów dostaw.

Metody: W artykule zastosowano metodę „case study" oraz badanie ankietowe do opracowania modelu transformacji cyfrowej przedsiębiorstw z sektora MSP. W pracy wykorzystano koncepcję Indeksu Cyfryzacji oraz narzędzia jakościowe, do których zaliczono m.in. diagram Ishikawy oraz analizę SWOT. Środowiskiem badań było przedsiębiorstwo produkcyjne z branży meblowej pełniące również funkcję głównego koordynatora, pomiędzy wszystkimi ogniwami, z którymi współpracuje w ramach łańcucha dostaw.

Wyniki: W artykule opisano zjawiska cyfrowej transformacji, będącej główną siła napędową gospodarki cyfrowej oraz cyfryzacji stanowiącej nieodzowny element przeobrażania modeli funkcjonowania przedsiębiorstw zgodnie z jej zasadami. Scharakteryzowano również końcowy efekt transformacji cyfrowej łańcuchów dostaw, którym jest tworzenie nowych modeli biznesu opartych na właściwościach rozwiązań cyfrowych nazywanych cyfrowymi łańcuchami dostaw. W efekcie rozważań zaproponowano koncepcję budowy modelu transformacji cyfrowej przedsiębiorstw w sektorze MSP.

Wnioski: Model transformacji cyfrowej przedsiębiorstw w sektorze MSP obejmować powinien zarówno ocenę obecnego poziomu cyfryzacji przedsiębiorstwa jak również propozycję jego transformacji cyfrowej. Zwiększenie stopnia cyfryzacji badanego w ramach case study przedsiębiorstwa pozwoli w dłuższej perspektywie czasu na uzyskanie wzrostu efektywności realizowanych zadań głównie pod kątem redukcji czasu ich wykonywania oraz poprawy sprawności przepływu informacji między wszystkimi uczestnikami łańcucha dostaw, zapewniając jednocześnie możliwość uzyskania przewagi konkurencyjnej na głównymi rywalami, którzy nie przeprowadzili cyfrowej transformacji funkcjonowania swojego modelu biznesu.

Słowa kluczowe: model transformacji cyfrowej przedsiębiorstwa, indeks cyfrowy, sektor MŚP

Łukasz Szopa
Poznan University of Technology
Faculty of Engineering Management
2 J. Rychlewskiego Str.
60-965 Poznań, **Poland**
e-mail: szopa.lukaszszczecinek@gmail.com

Piotr Cyplik ORCID ID: https://orcid.org/0000-0002-5775-6760
Poznan University of Technology
Faculty of Engineering Management
2 J. Rychlewskiego Str.
60-965 Poznań, **Poland**
e-mail: piotr.cyplik@put.poznan.pl