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ORIGINAL PAPER

VERIFICATION OF THE POSSIBILITIES OF APPLYING THE PRINCIPLES OF THE PHYSICAL INTERNET IN ECONOMIC PRACTICE

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ABSTRACT. **Background:** Current supply chains, which in fact constitute full ecosystems of product trade, change in an invariably dynamic way, requiring permanent supervision and control of the goods flowing through them. One of the aspects enabling constant development of the entire logistics infrastructure is the use of the solutions of the Physical Internet, both in terms of modular transport units and real-time planning and information exchange, as well as properly designed communication infrastructure. The aim of the article is to present a concept of solutions for the application of the principles of the Physical Internet in logistics processes of various specificity.

Methods: The results of research carried out in the years 2012-2018 within the framework of research and development projects and literature studies reveal that the extent to which the basic principles of the Physical Internet are applied is unsatisfactory. Based on these results, factors directly influencing the possibility of applying the Physical Internet in a comprehensive manner, taking into consideration the specificity of various types of supply chains and networks, were selected and collated.

Results: The results of the Authors' research on the possibility of applying the principles of the Physical Internet include suggestions of solutions, which are the result of design work, aimed not only at popularising the concept of the Physical Internet, but above all at optimisation activities in logistics processes of various specificity and reach. Individual design solutions served as the methodology for verifying the comprehensiveness of the application of the principles of the Physical Internet in economic practice.

Conclusions: In spite of numerous and up-to-date literature references, the analysis of the application of the principles of the Physical Internet still has not been clearly defined. This hinders its application in the economic practice of enterprises. The article focuses on presenting dedicated solutions for individual pillars of the Physical Internet. Further research should be oriented at attempts to integrate the solutions for all the pillars of the Physical Internet.

Key words: Physical Internet, modular transport units, real-time planning, communication infrastructure.

INTRODUCTION

In the current rapidly changing reality, crystallisation of certain trends occurring in logistics can be observed, i.e.:

- economic globalisation – the flow of goods, capital, and information on a global scale,
- customisation – products and services tailored to the customer's needs,
- increased environmental awareness – environmental protection, waste logistics,
- development of information technologies – new management, assessment, and decision-making support tools.

All of these aspects have a lot of common characteristics, which need to be highlighted in an explicit way and their interrelationships parameterised and digitalised. This is particularly important from the point of view of logistics services, whose current coexistence and cooperation is highly inefficient and unsustainable, which poses a risk to the

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effectiveness of the processes carried out. Benoit Montreuil identified thirteen symptoms of this inefficiency and unsustainable development [Montreuil 2001]. Among them, transport constitutes a serious problem with many well-known negative side effects, such as dependence on oil, CO_2 emissions, traffic hold-ups, and even health effects. In spite of all the efforts put into improving technological, organisational, and infrastructural solutions to date, it can be said that CO_2 emissions increased by 23% within the last 10 years. This was caused, among others, by a large increase in the transport of goods on a global scale. Another aspect is the issue of the use of the available cargo space, which is estimated at no more than 60% [Pasi 2007], while so-called empty runs constitute about 25% of all the freight operations. One of the solutions aimed at reducing CO_2 emissions could be to move the volume of cargo from heavy goods vehicles to trains powered by electricity produced in the low-emission mode. However, in spite of lots of effort put into the development of multimodal transport, its share in the whole of cargo transported by way of inland transport remains low, which is yet another manifestation of the inefficiency and impermanence of logistics solutions. In general, these symptoms form a basis for defining, preparing, and implementing a logistics system which would be characterised by efficiency, timeliness of order execution, and low CO_2 emissions and which would constitute ground for combining and sharing logistics resources of numerous companies, in accordance with the principles of the Physical Internet.

RESEARCH METHODOLOGY

Taking into consideration the nature of this publication, whose primary objective is to verify the possibility of applying the principles of the Physical Internet in economic practice, the Authors decided to divide the research work into three aspects:

- a theoretical one, identifying both the definitional problem of the Physical Internet concept and the possibility of applying it in logistics processes,
- a conceptual one, identifying the basic operational scope of the application of the principles of the Physical Internet in logistics processes of various specificity,
- a practical one, presenting the possibilities of using the solutions which are the result of international research and development projects, as a proposal for the implementation of individual key scopes of application of the Physical Internet concept.

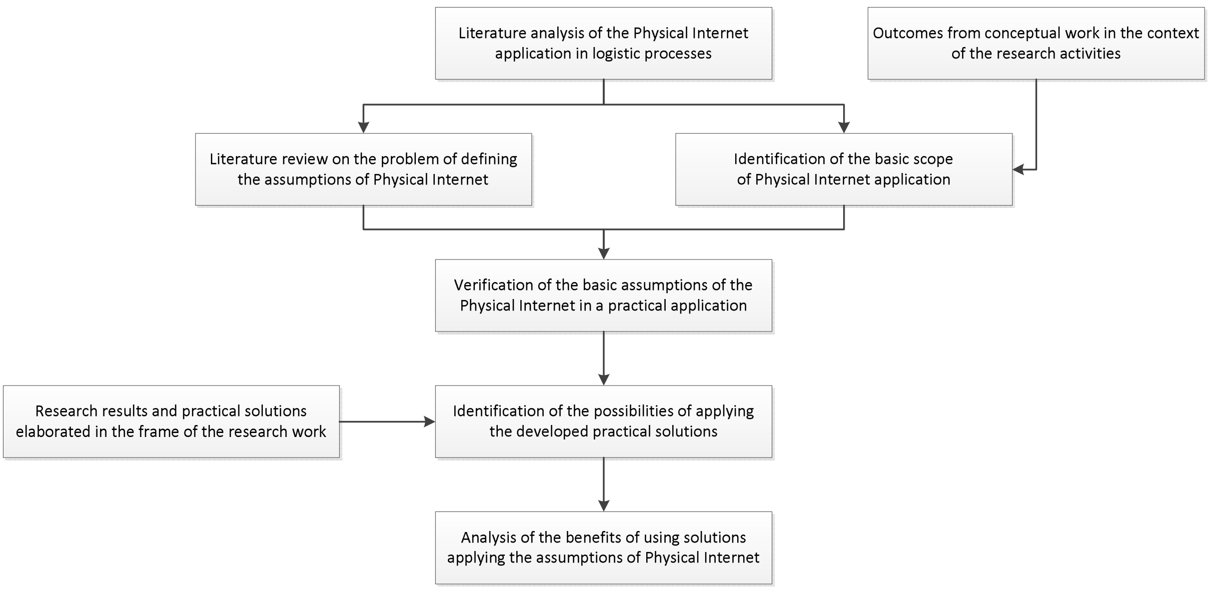

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Fig. 1. Research methodology

The scientific research process presented in the article results from the logic of the structural analysis of the identified research problem. The adopted research methodology aims at systematising procedures based on scientific research principles. The logic of solving the research problem was presented in Fig. 1.

Therefore, this research methodology assumes both theoretical research and a verification of its principles in business practice. According to the Authors, both these aspects – complemented by the conceptual scope aimed not only at confronting the theoretical and practical considerations, but also at organising current knowledge on the principles of the Physical Internet – cannot be separated. The specificity of the research problem in question requires comprehensive research to be carried out on every plane.

The structure of the following part of the article is in keeping with the research logic presented in the research methodology.

IDENTIFICATION OF THE BASIC SCOPES OF APPLICATION OF THE PRINCIPLES OF THE PHYSICAL INTERNET

When analysing customers' requirements concerning the execution of logistics processes in the rapidly changing supply chains, a constant search for both conceptual and technological solutions aimed at improving the efficiency of the supply chain can be observed.

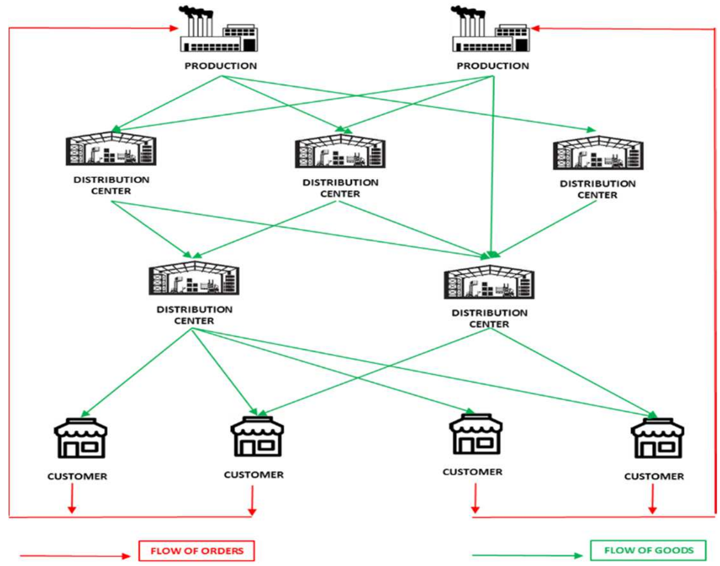

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Fig. 2. The Physical Internet concept

A response to these challenges can be the application of solutions known under the term of the Physical Internet (PI). A review of the related scientific literature reveals diverse types of research approach to the scope of application of the PI [Meller, Ellis, 2011; Ballot et al. 2012; Montreuil, et al. 2012; Trebilcock, 2012; Zhong et al. 2017; Domanski et al. 2018]. According to one of the more general definitions, PI is nothing other than the ability to provide the most efficient way of transporting goods to any given place within a certain predetermined time that will be as short as possible. Another one says that by definition, the "Physical Internet" is supposed to constitute a global logistics system which uses physical and operational, interconnected supply networks within the framework of standardised data packages and connections (interfaces), uniform protocols, and modularised container freight. The concept is reflected in a simplified manner in Fig. 2.

A Professor at Université Laval in Québec City, Canada, Benoit Montreuil, who was the first person to present the concept of the Physical Internet based on statistical analysis, came to a conclusion that a modern logistics system activates less than a half of its transport resources and for this reason, there is a need to implement a new model of this system [Montreuil, et al. 2010]. The first analytical model proved that this solution is much more efficient, decreasing transport performance by 22%, among others, while increasing load capacity by 20% and achieving better results in terms of costs, and at the same time improving service quality [Ballot et al. 2011].

The "Physical Internet" proposes a system whose users have access to an efficiently functioning, open, global logistics chain, an intermodal system (land, rail, maritime, and barge transport) using standard modules of containers used multiple times, located and identified in real time, with the possibility to coordinate the routes of cargo in a shared and widely available logistics space. In other words, all of the supply chain partners – manufacturers, transport service providers, retailers – will be able to act independently, using a common logistics network whose natural characteristic will be the ability to expand spontaneously as necessary at the given moment, should the need to change cargo size arise. This is aimed at minimising and ultimately eliminating empty runs. The implementation of the solutions of this kind requires, among others, perfect cooperation of all the links of the organisational structure based on standardised exchange of information functioning on the basis of related information infrastructure, making it possible to manage the flow of the modular units in real time. These aspects should be considered as the foundations of the Physical Internet (Fig. 3).

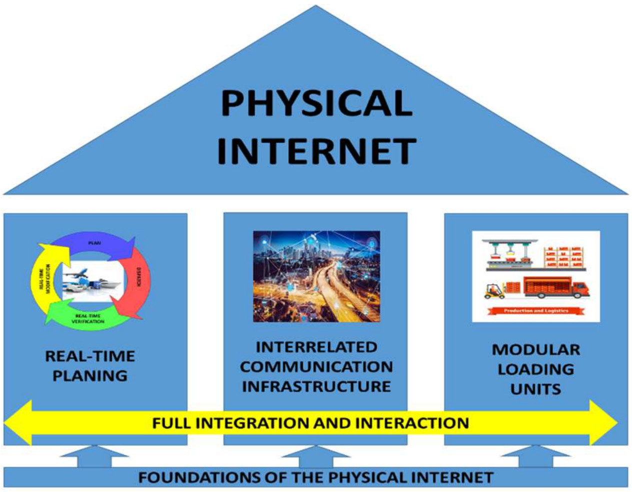

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Fig. 3. The foundations of the Physical Internet

Solutions which actually reflect the nature of the principles of the Physical Internet, thus referring to its foundations, were presented below.

REAL-TIME PLANNING

The aspects of this issue were presented in a precise manner in the solutions of the CLOUD project [http://www.project-cloud.org/], the aim of which was to create the so-called Logistic Single Window (LSW) as an ecosystem offering services and applications for all of the transport users and participants of the supply chain, making it possible to smoothly manage the flow of goods in real time (Fig. 4).

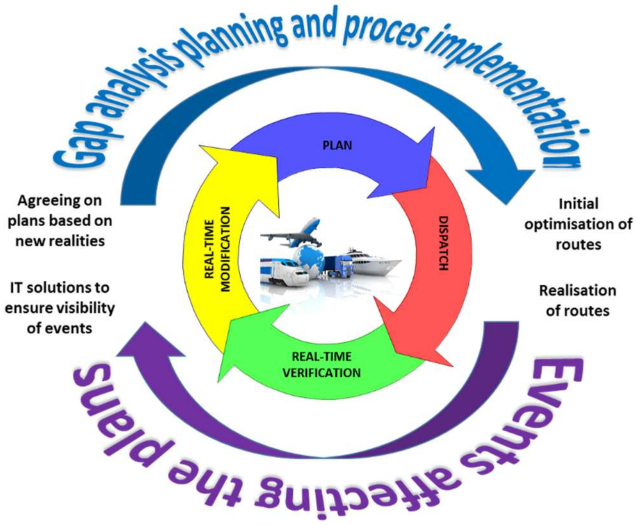

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Fig. 4. Real-time planning

The concept is based on the consolidation and full integration of three completely independent IT solutions in the following areas [Ahn, 2010]:
- management of sea shipments,
- management of the flow of goods in terminals and logistics centres,
- management of the flow of goods from the point of view of the "last mile".

It combines services offered by various branches of the transport industry and different types of logistics operations: sea, rail, water, and road ones. The CLOUD project provides a solution which streamlines cooperation in logistics through more efficient communication in the B2B, M2M, and M2B areas, while at the same time enabling development towards a more efficient, cheaper, better adjusted, and service-oriented sector, supported by full integration and synchronisation of the processes between the entities involved and the available transport resources. This allows stakeholder groups to create communities cooperating in order to combine their transport volumes and select the best transport options based on aggregated transport units. This is executed based on full integration and the principles of interoperability present in mutual system connections, offering the participants of the logistics ecosystem various types of logistics services based on the solutions of local logistics communities.

The benefits of the application of this solution include:
- joint purchasing of transport services,
- sharing intermodal connections,
- using the knowledge on intermodal transport,
- reducing empty runs of containers and road vehicles transporting goods,
- better selection of means of transport – broader use of rail transport.

The possibility to plan logistics processes, particularly transport, in real time, directly translates into an increase in the economic and operational efficiency of the entire supply chain. It not only enables monitoring of the execution of processes in real time, but above all influences the speed of decision-making.

RELATED COMMUNICATION INFRASTRUCTURE

The related communication infrastructure concerns one of the most important aspects of logistics, namely obtaining precise information, required in order to make proper decisions, at a precisely determined time. It is

becoming very important now that huge amounts of information, based on various channels of data transfer, are exchanged between companies. Important data is often either lost in the information exchange chain or presented incorrectly or delivered with considerable delays. In order to overcome these problems and create efficient information exchange chains, focus should be primarily on the following elements:
- creating common data exchange platforms based on communication standards,
- basing their architectural structures on a well-defined, clear model,
- using standard connections in order to integrate systems in the form of access points.

These issues were subjected to full, in-depth functional analysis in the eImpact project [https://www.eimpactproject.eu/]. Within the framework of the project, a platform integrating the flow of information between the IT systems of the container terminal, the railway company, the shipowner, and the intermodal operator was created. Connections between the IT systems were based on access points precisely defined on the basis of the e-Freight standard [Pedersen, 2012; Osmolski, Kolinski, Dujak, 2018], and communication between them takes place based on the principles of the eDelivery model (Fig. 5).

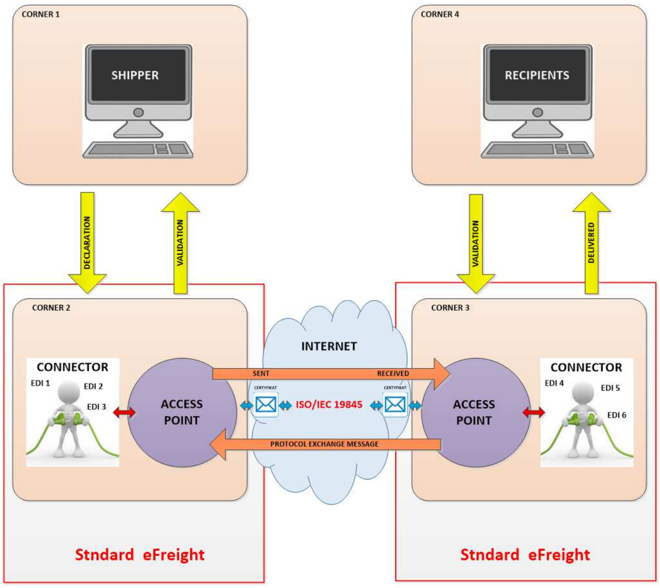

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Fig. 5. Standard e-Delivery (4-Corner model)

The access point transforms data from one standard to another for it to be unambiguously identifiable by the parties participating in the information exchange process. In this structure, each of the entities connected to the data exchange infrastructure has its profile (a role of a user of the platform). One of its elements is a format which uses the entity for electronic data exchange. In the case of using various formats of electronic documents, information transferred from the user who sends it to the platform with the use of a connector is converted by the access point to the e-Delivery standard and then passed on to the next access point which converts messages to standard data formats used by the given users.

In both of the discussed research and development projects, the component architecture solution based on the SOA model was used [Erl, 2005; Krafzig et al., 2005], as presented in Fig. 6.

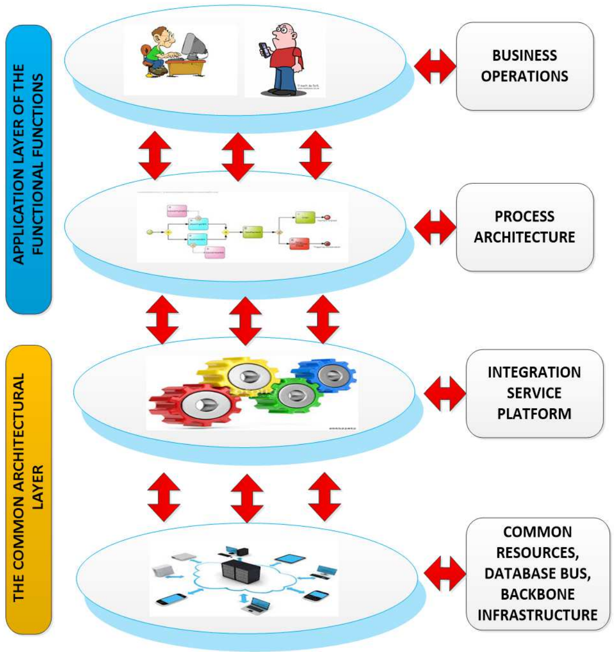

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Fig. 6. Service model (SOA)

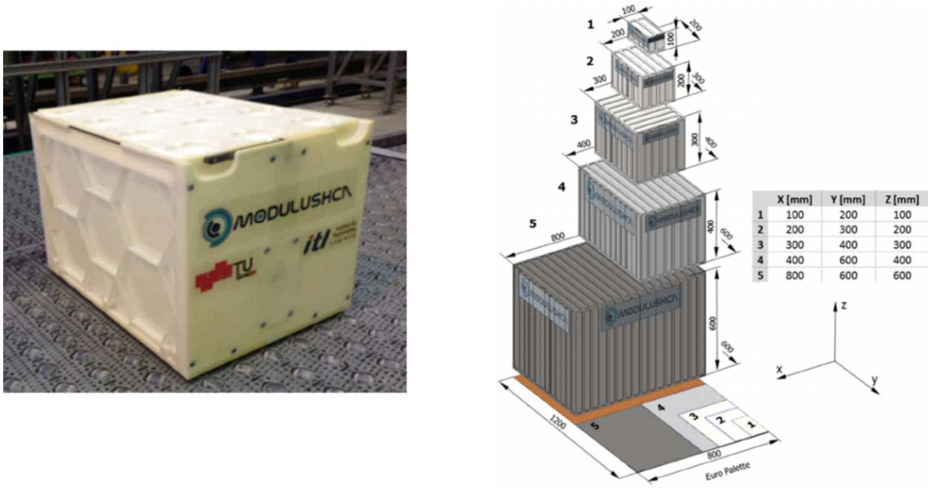
This approach constitutes architecture for business applications created as a set of independent components organised so as to deliver services operating according to specific criteria, supporting the execution of business processes. A significant principle of the SOA is the use of existing applications and systems used by business entities, bringing them down to a uniformly functioning ecosystem. From the technical point of view, it is necessary to create universal connections between the existing and new systems, among others by using integration platforms based on specific information exchange standards. This kind of approach also requires the development of the so-called information architecture that will explicitly connect the elements operating in the areas of individual computer systems, using the available standards based on unified communication units.

The benefits of this kind of solutions include:

– decreasing workloads when modifying and combining systems,
– elimination of errors in the message exchange phase,
– easy, quick, and problem-free access to data,
– speeding up processes,
– low cost of implementing changes.

MODULAR TRANSPORT UNITS

The main objective of the Modulushca project was to develop a model and a prototype of a new standard of a logistics unit, which would make it possible to implement the idea of full cooperation and efficient organisation of logistics within a distribution network in the FMCG sector. Thanks to joint activities of the world of science and business, members of the consortium developed innovative solutions based both on research work and practical solutions of companies from across Europe [Procter & Gamble, CHEP, ITENE, ILIM, EPFL, Jan De Rejik, Poste Italiane, ARMINES, Uni. Laval Canada, PTV, MEWERE, TU Graz, TU Berlin, Kirsen Global Security]. The use of the analogy of the Physical Internet with the traditional solutions of the digital Internet became one of the basic principles of the whole solution concept. In the case of the digital Internet, information is sent, in the case of the Physical Internet – it is commodities. Information on the Internet is sent in the form of precisely specified information packages. Thanks to that, it is possible to identify the package – the name, sender, and recipients, while the content itself, the information is strictly protected and available only to the devices or people with proper authorisation. Similarly, in the Physical Internet, the flow of goods takes place based on specially designed modular transport units (Fig. 7), which make it possible to fully protect the commodities sent in them, which in turn safeguards them from unauthorised interference by outsiders, thus protecting the trade secrets of the shipments' owners.



Source: Landschützer et al. 2015

Fig. 7. A modular transport unit

This kind of solution ultimately also requires a complete exchange of the supply system based on pallet solutions for a system of modular transport units only. Such approach also generates the need to adjust vehicles, loading equipment, and warehouses, yet the simulations carried out show that in the long term, the investments made make it possible to considerably lower the logistics costs related to the transport of goods. Modular transport units were designed in a way that enables combining elements, repeated folding and unfolding, and ultimately, easy recycling. A very important function is the possibility to use the modular units as store display – by easily detaching selected walls. Modular transport units were equipped with sensors making it possible to remain in full control during the execution of the transport process – e.g. of the temperature, humidity, pressure, shock, etc. The units are able to communicate with one another across the entire distribution network based on the installed transmitters sending information in the standardised e-Freight format, which considerably facilitates full monitoring of the condition of the goods and the course of the distribution process in real time.

Taking into consideration the above benefits, the concept of the Physical Internet with the use of standard modular units (PI-boxes) seems to be an interesting alternative to the pallet transport system, which – though well-known and established – still leaves a lot to be desired from the point of view of logistics.

The benefits of this kind of solutions include:

- preventing the spreading of the competitors' business information such as the volumes transported or new packaging for special offers,
- increasing the willingness to share the given means of transport and warehouse resources in the distribution processes by competitors – lowering operating costs,
- full monitoring of the storage and transport conditions and geolocation across the entire distribution process (particularly important

in the case of fresh products or those sensitive to temperature/humidity changes),
- simplified identification of responsibility for damage to products thanks to access to data in real time (e.g. compensation from the carriers),
- the possibility to easily consolidate freight thanks to the modularity of the units – more efficient use of cargo space – lowering transport costs.

CONCLUSIONS

The concept of the Physical Internet is a relatively young issue, both in practical and scientific terms. A constant search for the possibility to increase the competitive advantage not only of single enterprises, but also entire supply chains causes the Physical Internet to gain significance, also from the point of view of the customer. Not just business partners in the supply chain, but also end customers want to have the option to access up-to-date information about their product and the history of its journey from the manufacturer to the customer. All this points to further opportunities of technological development of the solutions and tools used to date.

The use of the solutions described in the individual projects and referring to the idea of the Physical Internet generates numerous benefits in the optimisation of the integrated logistics ecosystem, primarily including:
- a universal approach to the creation of information exchange platforms in various sectors of the economy, based on international standards,
- unification of business processes,
- improvement of the functioning of enterprises, shortening handling times, and lowering the costs of business activity,
- creating an integrated ecosystem based on the transparency of the processes taking place between the entities involved,
- the possibility for the companies to immediately react to any disruptions occurring within the supply chain in order to be able to fully model them, creating real-time scenarios and processes, thus focusing on predicting events,
- combining various business applications created as a set of independent components into one ecosystem.

It should be noted that each of the research and development projects presented in this article contains a solution focused mainly on one of the pillars of the Physical Internet. According to the Authors, the Physical Internet will be successful in economic practice when it is based on existing technical and technological solutions. The direction for further research and development work should be the development of solutions that will enable the use of the already existing standards and tools used in enterprises. In the long term, we should search for the possibility of integrating the solutions currently dedicated separately for the individual pillars of the Physical Internet.

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WERYFIKACJA MOŻLIWOŚCI ZAŁOŻEŃ FIZYCZNEGO INTERNETU W PRAKTYCE GOSPODARCZEJ

STRESZCZENIE. **Wstęp:** Obecne łańcuchy dostaw, a właściwie możemy mówić o pełnych ekosystemach obrotu produktami zmieniają się w sposób niezmiernie dynamiczny, wymagający stałego nadzoru i kontroli towarów w nich przepływających. Jednym z aspektów umożliwiających stały rozwój całej infrastruktury logistycznej jest wykorzystanie rozwiązań z zakresu Fizycznego Internetu, zarówno w ujęciu modularnych jednostek transportowych, planowania i wymiany informacji w czasie rzeczywistym, czy też prawidłowo zaprojektowanej infrastruktury komunikacyjnej. Celem artykułu jest przedstawienie koncepcji rozwiązań zastosowania założeń Fizycznego Internetu w procesach logistycznych o różnej specyfice.

Metody: Wyniki badań przeprowadzonych w latach 2012-2018 w ramach projektów badawczo-rozwojowych oraz badań literaturowych, świadczą o niezadowalającym stopniu wykorzystania podstawowych założeń Fizycznego Internetu. Na ich podstawie dokonano wyboru i zestawienia czynników wpływających bezpośrednio na możliwość zastosowania Fizycznego Internetu w sposób kompleksowy, uwzględniający specyfikę różnych rodzajów łańcuchów i sieci dostaw.
Wyniki: Wynikiem prowadzonych badań nad możliwością zastosowania założeń Fizycznego Internetu są propozycję rozwiązań, będące wynikami prac projektowych, które mają na celu nie tylko rozpowszechnienie koncepcji Fizycznego Internetu, ale przede wszystkim działania optymalizacyjne w procesach logistycznych o różnej specyfice i zasięgu. Poszczególne rozwiązania projektowe posłużyły jako metodologia weryfikacji kompleksowości zastosowania założeń Fizycznego Internetu w praktyce gospodarczej.
Wnioski: Analiza zastosowania założeń Fizycznego Internetu pomimo licznych i aktualnych odniesień literaturowych, wciąż jest niejednoznacznie zdefiniowana. Utrudnia to jej wykorzystanie w praktyce gospodarczej przedsiębiorstw. W niniejszym artykule skoncentrowano się na prezentacji rozwiązań dedykowanych dla poszczególnych filarów Fizycznego Internetu. Kierunkiem dalszych badań powinna być próba integracji rozwiązań dla wszystkich filarów Fizycznego Internetu.

Słowa kluczowe: Fizyczny Internet, modułowe jednostki transportowe, planowanie w czasie rzeczywistym, infrastruktura komunikacyjna

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ORIGINAL PAPER

HUMANITARIAN LOGISTICS AND SUPPLY CHAIN MANAGEMENT-A QUALITATIVE STUDY

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ABSTRACT. **Background:** A common goal of Humanitarian Organizations (HO's) is to deliver the services to humanity in a spirit of impartiality and neutrality without any discrimination. HOs primary functions are remained to deal with disasters, to protect human rights, to provide relief services and promote the universal desire for personal and collective safety, security, respect, and dignity without any view to profit. Logistics and supply chain management operations of HO are known as most expensive part and required sustainable solutions. HOs must utilize their funds effectively and efficiently. In this study we reviewed previous studies and identified areas needing further improvements in Humanitarian Organizations Logistics and Supply Chain Management (HO-LSCM) system.

Methods: Focusing on HO effectiveness and efficiency, this study identified and categorised the HO-LSCM articles into five broad areas: the concept of HO-LSCM, challenges and issues in HO-LSCM, HO performance management, HO effectiveness and efficiency management, types of research and research methodologies adopted in that research. Based on these categories the notable gaps in the existing studies were identified and recommendations for future research suggested.

Results: Existing studies are focused on Effectiveness, applying organizational agility in management, while Efficiency in management, under the heading of Lean Management, is an underdeveloped area which needs further extension to better serve the maximum number in society. Notably, 94% of HO-LSCM studies are based on qualitative research and most of them developed theoretical frameworks which have not been tested and adopted widely. In management of humanitarian organizations logistics and supply chain operations, every HO has varied policies and procedures, thus, standardization is required to streamline the effectiveness and efficiency in logistics and supply chain functions.

Conclusion: This qualitative research study is the first that has reviewed the field of HO-LSCM in terms of Efficiency and Effectiveness, and where prior studies have applied concepts of organizational agility and lean management. We have sought to extend this thinking in regard to Lean Management as it enhances Efficiency in management.

Key words: Humanitarian Organizations (HOs), HO Logistics and Supply Chain Management (HO-LSCM), Effectiveness & Efficiency (E&E), Agility and Lean Management (A & LM).

INTRODUCTION

The concept of humanitarian organizations (HOs) has ancient roots and is admired in both Western and Eastern civilizations. In 1859 during the Second Italian War of Independence, Henri Dunant witnessed the battle of Solferino, and he took action to treat the soldiers who were suffering in the battle. Dunant is credited as the founder of modern humanitarianism and the founder of the International Red Cross and Red Crescent Movement [Bürger 2015]. A common theme of HOs is service to humanity in a spirit of impartiality and neutrality without discrimination. The abiding prime objectives of HOs are to deal with disasters, to protect human rights, to provide relief services and promote the universal desire for personal and collective safety, security, respect, and dignity without any view to profit [Doyle, Gorman, Mihalkanin 2016]. HOs are highly dependent on their logistics and supply chain management which represents approximately 80% of total relief budgets [Kent, 2004, Van

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Wassenhove 2006]. Thus sound, knowledgeable management of logistics and supply chain operations is vital to the successful achievement of HO objectives. Humanitarian Organizations Logistics and Supply Chain Management (HO-LSCM) operation cost is known to be approximately 25% higher than comparable business supply chain management operations [Whiting, Ayala-Öström 2009]. The reasons for this are complex and can involve such factors as inherent uncertainty, limited local use of technology, human resource difficulties, and poor infrastructure [Antai, Mutshinda, Owusu, 2015].

Over the last twelve years, HO-LSCM research has drawn extensive interest for the purpose of improving HO operations. However, HO-LSCM research has generally not yet reached the advanced level of research into business logistics and supply chain management. Today humanitarian organizations are coming under increasing competition from United Nations humanitarian agencies, for-profit organizations and government departments to deliver humanitarian services utilizing scarce funding resources [Oloruntoba, Gray 2009, Scholten, Sharkey Scott, Fynes 2010]. Donor funding behavior is shifting from "project based" toward "performance based" disbursement of funds, in which only with the submission and successful evaluation of activity completion reports will donors release funds to HOs, and only for activities deemed achieved. In this environment of increased competition and pressure from performance-based funding, the importance of efficiency in HOs is quickly catching up with the traditional emphasis on effectiveness. Thus, this study reviews existing HO-LSCM research, focusing on HO operational efficiency and effectiveness.

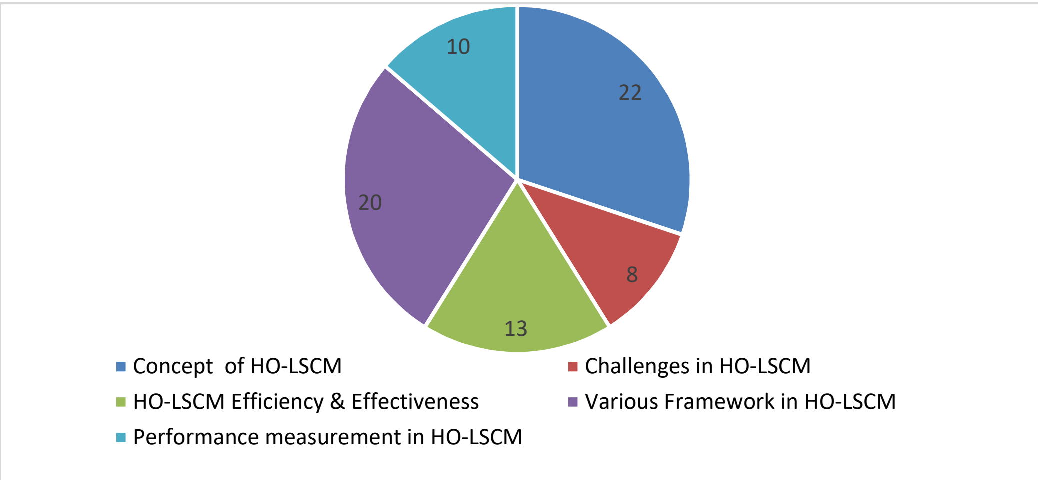

Fig. 1. Major categories of reviewed articles. (Numbers indicate how many review articles are in each category)

Using the key words "humanitarian logistics", "humanitarian supply chain management", "humanitarian operations management", "humanitarian supply chain agility and lean management" and "humanitarian supply chain efficiency and effectiveness", 73 peer reviewed published articles have been identified and analyzed. In this study, systematic and categorical analyses have been conducted on a number of questions, including broad concept of: "What is the concept of HO-LSCM?" and "What are challenges and issues in HO-LSCM?". Specific concepts that this study focuses on include: "What relevant models or frameworks have been developed and tested?", "What tools have been developed for HOs performance measurement?", "What measures have been taken to improve HO operational efficiency and effectiveness?", What types of published research on HO-LSCM exist?" and "What types of research methodology have been adopted?". The primary purpose of this study is to identify some notable gaps in existing research that future studies could address. To answer the above questions, the reviewed literature is divided into the following five major categories: 1) Concept of HO-LSCM, 2) HO-LSCM issues and challenges 3) Performance of HO-LSCM, 4) Construct models/frameworks in HO-LSCM, and 5) Efficiency and Effectiveness in HO-LSCM. Figure 1 presents all the articles reviewed in this study, divided into these five categories.

THE CONCEPT OF HUMANITARIAN ORGANIZATION LOGISTICS AND SUPPLY CHAIN MANAGEMENT (HO-LSCM)

Humanitarian Organizations Logistics and Supply Chain Management (HO-LSCM) processes are almost identical to those of corporate logistics and supply chain management, however HO-LSCM does not involve the process of manufacturing goods. The term Humanitarian Supply Chain Management (HSCM) is defined as coordination and integration of various internal and external stakeholders [Cozzolino 2012], while the term Humanitarian Logistics Management (HLM) is defined by the Council of Logistics and Supply Chain Management as the moving of goods, information, and services from point of origin to final destination [Cozzolino 2012]. Supply chain management is focused on relationships among the stakeholders that make logistics movement possible and is recognized as crucial to properly carrying out any disaster response [Cooper, Lambert, Pagh 1997, Cozzolino 2012]. After gathering the viewpoints of various HO-LSCM professionals, the Fritz Institute (a humanitarian logistics services specialist organization) has defined Humanitarian Logistics Management as "the process of planning, implementing and controlling an efficient, cost-effective flow and storage of goods, materials, and related information from the point of origin to the point of consumption for alleviating the suffering of vulnerable people".

Thus, HLM involves many functions including preparedness, planning, procurement, transport, warehousing, tracking, tracing, and customs clearance from point of origin to point of consumption. HLM is also known as a process or system which involves applying knowledge and skill to mobilize resources and people with the purpose of helping vulnerable and affected communities [Van Wassenhove 2006].

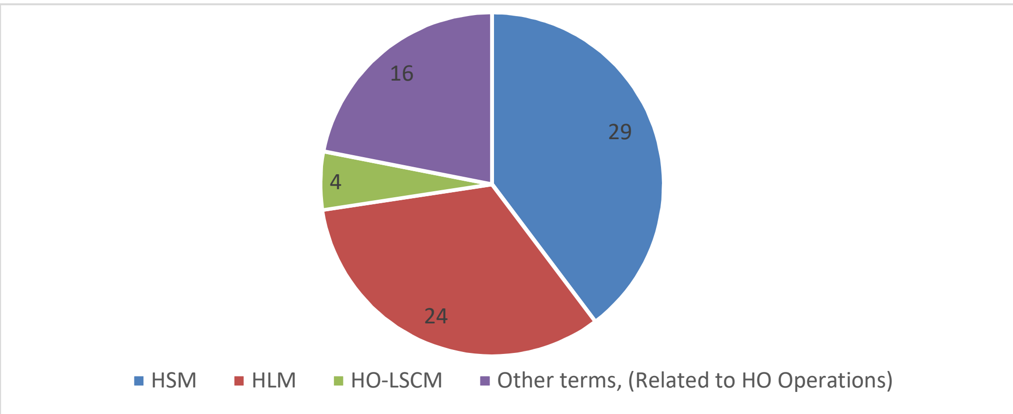

Fig. 2. Reviewed papers grouped by their use of related terms

Some of the authors argued that logistics is a part of supply chain management used to plan, implement, and control the efficient, effective forward and reverse flow and storage of goods, services, and related information from point of origin to point of consumption in order to meet the customers' requirements [Bhimani, Song 2016, Blecken 2010, Overstreet, Hall, Hanna, Kelly Rainer 2011, Van Wassenhove 2006]. However, the literature review of 73 HO-LSCM articles revealed that the terms "Humanitarian Logistics" and "Humanitarian Supply Chain Management" are for the most part used interchangeably, the definitions and functions of both terms overlapping. One study also revealed that the formal job titles of most HO professionals are some variation of "Logistics Director, Manager, Officer", etc. while some organizations name the same role as "Supply Chain Director, Manager, Officer", etc. However, there is no difference in the required skills for the two types of job titles [G. Kovács, Tatham, Larson 2012]. In this matter of nomenclature, there is no uniformity even in academic research. Most studies use "HSCM" in their title, and some of them use "HLM". However, it is rare to distinguish between the two terms in a single paper and treat them separately. A breakdown of the reviewed papers by their use of the terms HLM, HSCM, both HL-SCM and Other Terms related to HO operations is seen in Figure 2.

CHALLENGES AND ISSUES IN HO-LSCM

Authors have identified a variety of challenges typical for HO-LSCM, including assessment and planning problems, limited use of technology, remote and rustic locations of operation and lack of infrastructure [Chandes, Paché 2010, Overstreet et al. 2011, Sandwell 2011]. One notable challenge pointed out is that donor spending behaviors can be short-sighted and superficial. In other words, donors tend to be more willing to provide money for visible or tangible outcomes rather than for preparedness or development of logistics and supply chain management systems [Whiting, Ayala-Öström 2009]. Overstreet et al., [2011] identified the major challenges of HO-LSCM as often having to deal with unknown demand, short delivery time, unexperienced logistics staff, awkward media pressure, lack of funding, insufficient equipment and technology, and inappropriate political interference.

Differences in interpretation of knowledge between practitioners and academics are also a challenge which can affect problem solving approaches and the use of qualitative and quantitative evidence [Jha, Acharya, Tiwari 2017]. As an example, the use of 4WD (4-wheel drive) vehicles in HO fleets to overcome routing problems is an academic sort of recommendation, however in local communities the use of 4WD vehicles is commonly interpreted as an ostentatious display of wealth and power, and awareness of this interpretation and its consequences only comes from practical experience. Thus, academic knowledge and its practical implications in the field are often different [Jha et al. 2017]. HO efficiency and effectiveness requires dealing well with a wide variety of HO-LSCM challenges and contributing in a positive manner to the delivery of humanitarian services to the community in need. Some other challenges that can be a destabilizing influence on humanitarian aid are socio-political factors such as kinship ties, nepotism, patronage, and other similar soft barriers. Some harder barriers may be degraded infrastructure, unreliable communication systems, road blockages and various security issues. These HO-LSCM challenges have been divided into four major types: planning and assessment challenges, operational challenges, collaboration and standardization challenges, and monitoring and control challenges, and these can be seen in Table 1.

The reviewed literature showed that the first three types (Assessment and planning challenges, Operational challenges, Collaboration and standardization challenges) of challenges have drawn more attention in the research field, whereas the last type (monitoring and control challenges) has not garnered the same level of interest and still holds much potential for future research and development for HO-LSCM efficiency management. The literature also revealed that HO-LSCM relevant challenges are often discussed in the same terms as the disaster management cycle (i.e. preparedness, response and recovery). This brings up an important point. Disaster management is only one aspect of the many kinds of work handled by various HOs. HOs also do vast amounts of development work in areas such as education, long term health care, economic development, and poverty alleviation. The challenges faced by these other operations end up being ignored and not addressed to the extent of disaster management issues.

Table 1. Humanitarian Organization Logistics and Supply Chain Management (HO-LSCM) challenges

Type of Challenges	HO-LSCM Challenges	References
Assessment and planning challenges	Pre-occupation with response	Overstreet et al., 2011; Sandwell, 2011)
	Lack of logistics expertise and logistics capacity building program	(Oloruntoba, Glenn Richey, & Gray, 2009; Overstreet et al., 2011; Sandwell, 2011)
	Different nature of disasters	(Sandwell, 2011; Van Wassenhove, 2006)
	Unknown demand	(Overstreet et al., 2011; Van Wassenhove, 2006)
Operational challenges	Remote and rustic region of operations	(Chandes & Paché, 2010; Sandwell, 2011; Van Wassenhove, 2006)
	Ineffective management and tools and techniques	(Sandwell, 2011; Van Wassenhove, 2006)
	Lack of technological involvement	(Chandes & Paché, 2010; Overstreet et al., 2011; Sandwell, 2011)
	Degraded infrastructure	(Chandes & Paché, 2010; Sandwell, 2011; Van Wassenhove, 2006)
	Uncertainty	(Overstreet et al., 2011; Van Wassenhove, 2006)
Collaboration and standardization challenges	Little appreciation for logistics staff	(Sandwell, 2011)
	Low status & limited influence of logistics staff	(Sandwell, 2011)
	Work pressure, high stress	(Sandwell, 2011)
	High turnover of logistics staff	(Oloruntoba et al., 2009; Sandwell, 2011)
	Lack of career path	(Overstreet et al., 2011; Sandwell, 2011)
	Humanitarian culture and ethics	(Sandwell, 2011)
	Lack of standardized processes	(Overstreet et al., 2011; Sandwell, 2011)
	Difference between academic research and practical implications	(Jha et al., 2017)
	Competition for new staff in emergencies	(Sandwell, 2011; Van Wassenhove, 2006)
Monitoring and control challenges	Humanitarian ethics and political interference	(Overstreet et al., 2011; Sandwell, 2011)
	Poor accountability	(Chandes & Paché, 2010; Oloruntoba et al., 2009)
	Lack of performance management of both the system and staff	(Sandwell, 2011)
	Focus on output instead of outcomes	(Sandwell, 2011; Whiting & Ayala-Öström, 2009)
	Donor influence & funding issues	(Oloruntoba et al., 2009; Overstreet et al., 2011; Sandwell, 2011)

HO-LSCM MODELS, FRAMEWORKS, AND THE THEORIES BEHIND THEM

Humanitarian Organization Logistics and Supply Chain Management (HO-LSCM) research is found to focus on a large extent on the development of various fundamental models or frameworks that, although illuminating important major structures, are not usually fleshed out and do not yet address practical implications in the actual field. This shows that research on HOs is still a relatively new and emerging field of academia. Out of the 73 reviewed articles, 27 of them were found to directly address concept-based models and frameworks. The identified frameworks have been divided into three major groups, namely: HO-LSCM assessment and evaluation, business and HO integration and HO-LSCM operations. Numbers of studies found in each group are presented in Figure 3.

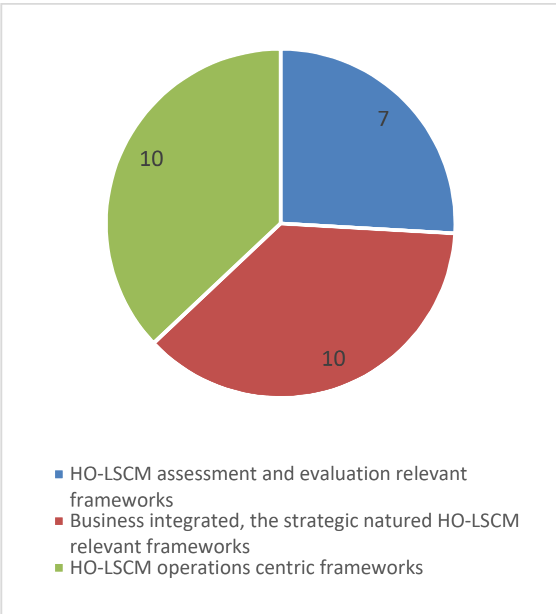

Fig. 3. Framework groups and their number of constituent articles

Framework Group 1: HO-LSCM Assessment & Evaluation

The ability of a humanitarian organization to assess its own performance is vital for gradual improvement of the organization [McLachlin et al. 2009]. Different researchers have proposed many different methods for HO performance assessment. For example, Schiffling and Piecyk [2014] use the Balance Score Card (BSC) business model to identify HOs various stakeholders and their values, and then check if those values are being met by the HO. Some of the main values which identify for HO stakeholders are: reliability, quality, timely delivery, transparency, efficiency and effectiveness [Schiffling, Piecyk, 2014]. Another system for assessing HO performance comes from Helmig et al., [2015] who identify an organization's competitive advantages and then use those to determine the HOs performance. For instance, organization's competitive advantages could be a sense of destiny, trust in goodness, altruism, equality, self-respect, humanity, quality, innovation, competitiveness and efficiency [Helmig, Hinz, Ingerfurth 2015].

Antai et al. [2015] have a completely different approach: the idea that an HO's performance can be measured by compiling and analyzing the failures of that HO. They introduced and tested the HO-LSCM Failure Measurement Framework, which is based on the "3R" factors: Right goods, Right time and Right place. Using linear equations, the authors used a computer to apply simulated data and proved that these 3R factors are accurate indicators of HO performance [Antai et al. 2015]. Another model comes from Beamon and Blacik, [2008]. In Beamon's model, HO-LSCM performance can be measured by identifying and quantifying three specific metrics: "Resources", "Output" and "Flexibility". In the case of HOs, the Output metric is quite different from the Output metric of a business, due to the non-profit goals of HOs. In other words, the Output of a business is how much profit they make, but for an HO, the Output might be how many people they are able to assist and how quickly they can deliver that assistance [Beamon, Balcik 2008]. Although the assessment frameworks in this group have completed development, few of them have been well tested or widely adopted. No framework was found that could assess an HO-LSCM adherence to standards like Humanitarian Spheres or ISO.

Framework Group 2: HOs Partnering with Businesses

The strategic goals of managing HO-LSCM through business partnerships are to reduce operational costs and to improve the delivery of humanitarian services [Beamon, Balcik 2008]. The benefits of an HO partnering with a business can include accelerating the flow of material and information, decreasing inventory levels and lowering supply chain management costs through consolidation [Vojvodic, Dujak, Plazibat 2015]. A successful partnership between an HO and a business often involves three basic principles: to identify and understand the factors which affect the partnership, to understand the suitability and requirements of the partnership and to continuously measure partnership performance on the basis of output and outcomes [Nurmala, de Leeuw, Dullaert 2017]. There are three basic functions of a partnership: transaction management, event management, and process management [McLachlin, Larson 2011]. The goal of transaction management is timely resolution of operational issues (e.g. expediting late deliveries). The goal of event management is joint planning and decision making about specific events, e.g. identifying where supply chain disruptions or bottlenecks may occur. Process management refers to coordinated management of both demand (downstream) and supply (upstream) processes [McLachlin, Larson 2011].

Corporate businesses also face pressure to develop Corporate Social Responsibility (CSR) particularly since corporations are often voracious consumers of natural resources [Bealt, Fernández Barrera, Mansouri 2016, Maon, Lindgreen, Vanhamme 2009, Rueede, Kreutzer 2015]. Business corporations can learn about social responsibility from HO professionals as well as concrete skills such as quickly entering and coping with the difficult environment of front line relief operations as well as the sharing of government, community and military networks in case of disasters [Kusumasari, Alam 2012, Lu, Goh, De Souza

2013, Pettit, Beresford 2009, Thomas, Fritz 2006].

Examples of HOs Partnering with Businesses

Formation of HELP (Humanitarian Emergency Logistics Program) between the company Agility Logistics and the HOs named IMC and WEF is an example of a partnership for delivering emergency products in cases of disaster. Another example of an HO-business partnership is the formation of Logistics Emergency Team (LTS) for delivery of humanitarian services by the private sector companies, e.g. TNT Logistics, Agility Logistics and UPS Logistics. LTS makes their services available to a variety of HOs, and says they are capable of responding to any disaster within 48 hours in any part of the world [Vojvodic et al. 2015]. A partnership between the company DPDHL and the HO UN OCHA has proven helpful to solve issues related to delivery bottlenecks and the arrival of unsolicited relief items at airports. Through this partnership, UN OCHA improved effectiveness of humanitarian distribution networks [Rueede, Kreutzer 2014]. A partnership between American Red Cross and Abbot Laboratories is another example of a cross sector partnership, one which has increased the visibility of HO supply chain management [Thomas, Fritz 2006].

Through cross-sector partnerships and coordination, HO-LSCM performance can be enhanced and a close relationship can be fostered between the two parties. Cooperation and coordination of the HO, corporate and government sectors can improve the management of disasters and can also increase overall awareness and preparedness to better deal with subsequent disasters. In conclusion, the concept of building partnerships between HOs and private sector businesses would lead to better coordination, and increased effectiveness and efficiency [McLachlin, Larson 2011].

Most of the reviewed literature within this group of framework has recommended partnerships between HOs and private businesses and provided some case studies, however none of the reviewed literature provides a comprehensive, standardized model for such partnerships, a model which can assist HO leadership in deciding which of their various operations, or specific activities within those operations, they would best ask the business partner to handle in order to maximize effectiveness and efficiency in the HO's logistics and supply chain. Moreover, the literature has discussed examples of successful partnerships but no examples of unsuccessful partnerships from which one could learn the reasons for failure as well as helpful lessons applicable to future partnerships.

Framework Group 3: Emphasis on Inventory, Transportation, and Procurement Management Operations

HO-LSCM operations have no defined or standardized scope, but they usually consist of the inventory operations, procurement operations, and transportation operations of the HO. Within these three types of operations, each is greatly influenced by various stakeholder's circumstances, as well as by current political and economic conditions, all of which can influence the HOs efficiency and management decisions [Merminod, Nollet, Pache 2014]. The frameworks developed for each of the three main HO-LSCM operations are described below.

Inventory operation management models

The most effective, most efficient response to any disaster is made possible by intelligent pre-positioning of inventory and optimum allocation of resources [Merminod et al. 2014]. Jha et al., [2017] introduced a multi-faceted model within HO-LSCM to optimize inventory practices through careful, methodological analysis of supply and demand, factoring in the risks of either supply or demand being too high or too low. Optimization is determined using mathematical equations, and the results are analyzed through a "non-dominated sorting genetic algorithm-III" program. Jha et al.'s study focused on the example of optimizing disaster related inventory such as food, medicines and other basic relief items [Jha et al. 2017]. To gain the benefits of prepositioning inventory, a group of HOs have developed shared centralized depots called "United Nations Humanitarian Response

Depots (UNHRD)" for pre-positioning of contingent inventory to respond to disasters worldwide. The depots have been established at six different locations: Brindisi, Italy; Dubai, United Arab Emirates; Panama City, Panama; Kuala Lumpur, Malaysia; Accra, Ghana and Las Palmas, Spain. The UNHRD partners claim that this strategy of centralized depots and inventory pre-positioning enables them to respond to any disaster anywhere in the world within 24 to 48 hours [Dufour, Laporte, Paquette, Rancourt 2018].

The important point derived from the literature review is that most of the HO inventory management operation studies discuss the various aspects of disaster management operations, while aspects of normal (non-emergency) operations are rarely explored, which is an important research gap revealed by this literature review.

Transportation operation management models

Delivery of humanitarian services to beneficiaries is one of the most critical operations of HO-LSCM which known as last mile delivery [Balcik et al. 2008]. The focus of last mile delivery is the fleet system used to transport the goods, material and people [Apte 2009]. For HOs, fleet management is the second largest overhead cost, being 15% of the total humanitarian relief logistics cost [Falasca, Zobel 2011, Martinez, Stapleton, Van Wassenhove 2011]. Plans and policies on sourcing and allocation of vehicles by HOs can be suddenly rendered irrelevant on real grounds: the occurrence of natural disasters usually cannot be predicted. This is the nature of such disasters, and local, social, political, safety and security scenarios for the relief mission demands different types of vehicles: heavy duty equipment, 4WD vehicles, or light duty vehicles. In one case study, most of the vehicles were not usefully deployed according to the demands of that HO's mission because 95% of the vehicles were light duty, and not useable [Eftekhar, Van Wassenhove 2016].

Efficient and effective fleet management and distribution systems are highly dependent on selection of an appropriate route. [Dufour et al., 2018] developed a computer simulation for optimization of transport routes which recommended a new route for delivery of relief supplies from UNHRD to East Africa. Using the new route was 21% less expensive than using the existing route. This showed that emergency operations transportation is more difficult to plan and implement than usual, every-day, reconstruction and developmental operations are. Thorough preparedness, coordination and well-informed information systems can overcome these problems to a great extent, however [Berkoune, Renaud, Rekik, Ruiz 2012].

This study found that the literature focus was on emergency fleet or transportation management, and normal and developmental operations fleet management has not been addressed to any great extent. As well, existing research is often relevant to utilization and management of HOs owned vehicles resources, and out-sourcing of fleet management as an efficiency and optimization strategy is a largely ignored area.

Procurement operation management models

Procurement in HOs is the acquisition process of goods, services, works, and leasing during and after a disaster, to enable the distribution of aid to affected and vulnerable communities. In HO-LSCM budgets, 65% is spent on procurement activities [Falasca, Zobel 2011]. Efficiency in expending the procurement budget can be ensured through transparent and accountable management of the various stages of the procurement process, including identification of needs, requisition of needs, announcement of tenders, evaluation of tenders, purchase orders, delivery of supplies, inspection of supplies, and payment to vendors etc. [Falasca, Zobel 2011]. Transparency and accountability in HO-LSCM procurement operations can be ensured through information technology and standardization of overall procurement processes [Falasca, Zobel 2011].

A standardized procurement process framework has been developed for the bid announcement, bid construction and bid evaluation phases. The bid announcement phase is considered more challenging for HO professionals and requires careful development of criteria for deliveries, timing, and bid evaluation. While subject to an unstable environment and the impact of a disaster, suppliers should take decisions to construct their bids in keeping with required place of deliveries, timeframes and other essential requirements [Trestrail, Paul, Maloni 2009, Ertem et al. 2010]. HO-LSCM operations should therefore include standardized processes of procurement of goods and services, information management, written documentation, financial management, warehousing and inventory management logistics and fleet management, and coordination between stakeholders [Blecken, Tatham, 2010]. Another HO-LSCM procurement framework also recommends that emergency goods, supplies, and services be procured from local markets which are likely to provide faster and more timely delivery, and will be efficient in price due to savings in transportation costs [Falasca, Zobel 2011].

The success of HO disaster operations is dependent on timely delivery of goods and supplies, which is possible through good relationships with potential suppliers. HOs maintaining good relationships with short term engaged suppliers as a cost efficiency driver is another gap in the research. This is a difficult area of activity for HOs, given the often-large number of local suppliers that need to be involved, and ensuring best-cost of goods and services from these local suppliers is both essential, and difficult. Especially, procurement operations relevant to normal humanitarian operations are underexplored, particularly when compared to research that has been done on emergency phase procurement operations.

Within our Framework Group 3: Emphasis on Inventory, Transportation, and Procurement Management Operations, the literature review in this study revealed that every operational and donor organization has their own procurement policies and required procedures. This is a challenge for HO-LSCM in maintaining transparency in the execution of their logistics processes. The question must arise, that, if the purpose of every organization is to provide relief to the needy and to vulnerable communities, then why are the processes of each organization so different and complicated. A study shows that 71% organizations have different processes relevant to the same type of operations. Of 100 organizations studied, only 20 had comprehensively reviewed their policy documents, while 32 of those organizations had some sort of the documented processes, and the remaining 48 had no written documented policies for operations management [Blecken, Tatham 2010]. The major focus of previous research has remained on HO-LSCM effectiveness, and efficiency in management gained only rare attention.

HUMANITARIAN ORGANIZATION PERFORMANCE MANAGEMENT

In the realm of business, performance can be measured through customer satisfaction which can be achieved through strong relationships with the customer and with all other involved parties. In business, the concept of the customer is a person whose needs are meet by suppliers, vendors, or sellers in exchange for payment in one form or another [Kendall 2006, Philp Kotler 2012]. Transferring the above concept to application within HO-LSCM, there are two different kinds of customers: one is the donor, and the second is the beneficiary. The donor can be viewed as an “upstream” customer who provides funding to HOs, while, the beneficiary or community can be seen as a “downstream” customer, for whom resources are being spent by the HOs [Antai et al. 2015, Oloruntoba et al. 2009]. Due to the financial dependency of an HO on its donors, these upstream customers tend to wield more influence and negotiation power in an HO than the downstream customers do [Antai et al. 2015]. However, the HO’s performance is critically dependent on the satisfaction of both the donor and beneficiary, and this is achievable through timely provision of quality goods and services to beneficiaries in a transparent and accountable way [Oloruntoba et al. 2009].

As mentioned above, HO-LSCM is involved in two fundamentally different kinds of work. The first is disaster management, which includes preparing against, responding to, and rehabilitating after disasters that affect communities, and the second is long-term development projects related to sustainable development goals such as economic development, education, health, energy, and equality. This brings up another important point. The performance of disaster management related operations is largely a measure of effectiveness (i.e. prompt assistance to the beneficiaries), while the performance of development related operations is instead a measure of efficiency (i.e. cost minimization and sustainable resource consumption).

Significantly, this literature review reveals a striking gap in existing HO-LSCM research: there are insufficient tools for measuring performance. Although assessment of effectiveness has drawn the attention of some researchers [Charles, Lauras, Van Wassenhove 2010], studies of HO-LSCM efficiency have been comparatively few and inadequate.

EFFECTIVENESS AND EFFICIENCY

HO-LSCM effectiveness management is defined by rapid delivery of humanitarian goods, services and any other relief items, in minimum time [Cozzolino 2012]. HO-LSCM efficiency management encompasses the ability to minimize the wastes, avoid redundancy and duplication of activities, conserve energy, and maximize effort while minimizing time taken and overall operational costs [Provan, Kenis 2008]. Efficiency means "doing the thing right," whereas effectiveness means "doing the right thing" [Provan, Kenis 2008]. In HO-LSCM, Effectiveness is conceptualized as “agile management”, while efficiency is conceptualized as “lean management” [Christopher, Towill 2001, Cozzolino 2012]. Both effectiveness and efficiency of the HO’s processes and actions can be achieved through the most common practices which often can provide a solution to 50% of any problem. These common practices include development of a standard set of guidelines, training syllabi, certification processes, process alignment, especially with appropriate IT systems [Tatham, Spens, Kovács, Payne 2013]. The most basic factor affecting the effectiveness and efficiency of a HO-LSCM is strong coordination between the HO and its stakeholders [Tatham, Spens, 2016]. To meet the HOs common goal, various such organizations have developed their clusters of cooperating and coordinating organizations for the provision of humanitarian services. Some examples of such clusters are: the UN logistics cluster, the international search and rescue group (INSARAG), and the urban search and rescue group (USAR) [Tatham, Spens 2016].

In HO supply chain operations, the “Plug and Play” concept, whereby processes and actions can be immediately instituted in an emergency situation, particularly temporary supply chain management (TSC) processes, is only possible through a well-coordinated, efficient and effective flow of information [Merminod et al., 2014]. During the humanitarian response, prioritization of needs is the most important factor for assessment of required resources, implementation of immediate solutions and to decide on the necessary shift from the effectiveness management to efficiency management [Merminod et al., 2014, Tomasini, Van Wassenhove, Van Wassenhove 2009]. Thus, humanitarian organizations need to prioritize these demands and to implement an immediate solutions as per available resources [Tomasini, Van Wassenhove, 2009].

HO-LSCM effectiveness ensures that time is saved, which means more lives saved, while HO-LSCM efficiency ensures that cost savings, which means more lives (peoples) are helped [Cozzolino 2012]. In the humanitarian sector, the often-made complaint is most of the delivered aid does not reach its customers at all, or reach the customer in an unusable condition. Lessons learned from the corporate world can benefit humanitarian organizations in well designed and practiced business policies, appropriately customized for humanitarian operations, will both save lives and help lives. Especially with the application of contemporary IT solutions, standardizing of systems such as backordering, shrinkage, spoilage policy, use of last mile delivery can be optimized, using linear and dynamic programming [Bhimani, Song 2016]. The Lean and Agile paradigms are good for enhancement of competitiveness, cost efficiency and time effectiveness in the HO sector [Kovács, Oloruntoba, Gyöngyi 2015, Gligor, Holcomb, 2012, Ismail, Sharifi 2006].

In the literature, effectiveness, which is considered as Agile Management, has been given more attention, presumably due to the nature of disasters; suddenness, urgency, seriousness, and therefore of the nature of the demands on HOs; meeting emergencies has been seen as the normal situation in which HOs find themselves. Efficiency (Lean Management) has not been explored in any detail in academic and professional research areas. Again, it can be presumed that this is the case due to the nature and scope of HOs disaster management. There has been a perception that normal is not normal, as in not day-to-day, in these operations, so researchers have not given equal importance to the efficiency of the overall HO-LSCM operation.

Agility management in HO-LSCM

According to the international consultancy, McKinsey and Co, "Agility is the ability of an organization to renew itself, adapt, change quickly, and succeed in a rapidly changing, ambiguous, turbulent environment. Agility is not incompatible with stability—quite the contrary. Agility requires stability for most companies". The concept of organization agility, stated as Agile Management (or agility management) arose in the early 1990s, defined by a group in the research institution, the Iacocca Institute, Lehigh University [Rahimnia, Moghadasian 2010, Ramesh, Devadasan 2007]. Agility in management is seen as using market knowledge and, in more recent times, computer technology and networks, to exploit profitable opportunities in volatile marketplace [Naylor, Naim, Berry 1999]. Agility is a holistic and strategic idea and a "business-wide capability", shedding light on all aspects of a supply chain, including internal organizational structures and trade partners. The most important prerequisite to achieving agility is the development of a culture compatible with the agile enterprise. That is, the people side of the supply chain [Aitken, Christopher, Towill 2002, Christopher, Towill 2000]. The key to being agile is at the service level; flexibility and responsiveness, which, together are the market winner characteristics of an agile supply chain, as distinct from cost considerations, which are the market winner characteristics of leanness.

Agility in logistics and supply chain management is defined as the capability of flexibility in the various supply chain management processes; the procurement processes, distribution logistics processes, and manufacturing processes [Charles et al. 2010]. The flexibility capabilities are classified into four categories: volume flexibility, delivery flexibility, mix flexibility, and production flexibility [Slack 2005]. In supply chain management processes, when lead times are long, and demand is unpredictable, agility management techniques should be applied [Christopher 2005].

The humanitarian sector is well known as being expert in agility management by applying various techniques for contingency planning and pre-positioning of inventory. Other techniques recommended for HO-LSCM agility are strong communication with its partners about the current situation, selection of the quick responder nearest suppliers, postponement of supplies, buffer stock, creation of third party logistics relationship and formation of emergency response team [Christopher, 2005]. Being agile in the provision of humanitarian services is a challenging task due to uncertainties, complexities, and the unknown demand for humanitarian services in a timely manner, yet it is almost an imperative in HO-LSCM, especially in operations of disaster response which usually arise suddenly and in great proportion [Cozzolino et al., 2012]. The capability for an agile response can be measured by identifying the agility matrix which is based on an agile framework [Charles et al., 2010]. Business organizations can also measure their supply chain agility on the bases of customer sensitization, processes integration, network integration and virtual integration [van Hoek, Harrison, Christopher, 2001, Merminod et al. 2014]. With the addition of stakeholders, together with the emerging concept of fourth party logistics related to customers, processes and integration of services, agility and the measurement of the agile outcomes in HO-LSCM can be developed.

Lean management in HO-LSCM

Leanness implies improvement in the overall supply chain management systems, focusing on efficiency and cost saving [Cozzolino, Rossi, Conforti 2012a]. Lean thinking started in the 1980s, based on Toyota Production System, but the first time the word "lean" was coined was in 1990 by John Krafcik into his master thesis, reported in [Ohno 1988]. Lean management refers to doing more with less resources, and mainly seeks to minimize on-hand inventory of components and work-in-progress, and to move towards a just-in-time replenishment environment [Ohno 1988]. Lean means the elimination of waste and doing more with the less resources. To overcome inventory outage, lean systems thinking recommends that inventory is produced in advance, but primarily for immediate on-hand requirements, and just-in-time availability, with production only weeks in advance at most, as distinct from the more traditional inventory management thinking of eradicating outages by holding inventory months and even years ahead of allocation to production [Rahimnia, Moghadasian 2010].

In HO-LSCM, 40% of budgets expenditure has been reported as wasted, due to factors such as duplication of ordering, duplication and redundancy of effort, lack of time to carry out effective analysis, and lack of coordination and sequencing of activities. [Bealt et al. 2016, Day, Melnyk, Larson, Davis, Whybark 2012, Van Wassenhove 2006]. HOs are funded and governed in different ways from different donors who are increasingly demanding proper control and accountability, transparency and value for money in return for their sponsorship [Tomasini, Van Wassenhove 2009, Antai et al. 2015]. This return-on-investment is possible through improved, efficient, operational performance, achievable by a professional management approach and supply chain efficiency, enabling continued effective use of resources [Scholten et al. 2010].

In operational performance, the interesting part is the transition and shift from agile (speed) to lean (cost reduction) strategy. During disasters, due to the urgency of immediate needs and high levels of uncertainty, all supply chain process must focus on speed, and cost must take a back seat. Once the immediate urgent operations have been achieved, and the continuing needs roles have been defined, meaning better visibility of the process necessary to assist beneficiaries, then efficient cost drivers can be adopted at this stage [Tomasini, Van Wassenhove 2009]. In all situations, the legitimacy of the need for efficient HO-LSCM system, recommends lean management through the integration of local, regional and central level management plans [Marcinkowski 2017].

Leagility management in HO-LSCM

The term "Leagility" was introduced in the supply chain design to avoid or minimize inflexibility and overage in the supply chain by making it lean and agile. Its origins are unstated, but numerous papers addressing supply chain management have adopted the term. Leagility is the ability of an organization to keep balance in agile and lean practices of supply chain management. Leagility is the combination of leanness and agility within a total supply chain strategy using a decoupling point. The decoupling point in supply chain management is the product axis where lean and agile strategy intersect each other for ensuring deliveries according to customer requirements [Rahimnia, Moghadasian 2010]. Implementation of agile does not exclude the lean principles; rather; both lean and agile can work with in the same supply chain management at different points and at the different moments [Aitken et al., 2002, Christopher 2005,Narasimhan, Swink, Kim 2006, Scholten et al. 2010]. A theoretical decoupling point model was developed on the bases of supply chain disaster management cycle (preparedness, emergency, response, restore, and reconstruction) which explained that Agile management should be decoupled at the restoring phase and lean management should be enabled in reconstruction phase of the disaster management cycle [Cozzolino et al. 2012]. When a disaster occurs, and the situation is uncertain, "leanness needs to be decoupled from part of the supply chain process and agility should be coupled to the whole process as a priority [Childerhouse, Towill 2000].

Lean strategy provides markets with predictable demand, low variety and long product life cycle, whereas agility acts best in a volatile environment with high variety and short product life cycle [Rahimnia, Moghadasian 2010, Cozzolino, Rossi, Conforti 2012b]. Lean management is recommended for HO-LSCM upstream processes e.g. planning, sourcing, storage the lean management, while the downstream processes e.g. transportation and distribution into desired community benefit from agile management techniques. The HOs supply chain needs to respond to a dual customer base; the donor customer and the ultimate beneficiary, community or area. For dealing with the donor customer, lean management is required, whereas dealing with the assistance beneficiary or community customer, applying agile management techniques is essential. This dichotomy is supported in [Rahimnia, Moghadasian 2010], who also emphasized that the HOs emergency projects community customer should be catered for according to the agility concept, while dealing with the donor customer, lean concepts are relevant. Thus, to become an agile and lean (demand driven) HOs need to apply leagility, with strong coordination and communication from community level through to the upstream supply chain management system [Oloruntoba, Gray 2006].

Based on our literature review, we found that the existing Leagility frameworks proposed for the disaster management cycle, and which are very relevant to HO disaster management planning and implementation, have not been studied for their applicability to the normal operations of HOs. Our view is that Leagility should be applied to the detailed activities of HO-LSCM, and Lean and Agility priorities should be optimized in procurement/sourcing and distribution into the beneficiary community. No information was found in the literature that examined, tested or proved the achievements in HO-LSCM by the application of this concept of Leagility, thus we suggest the need for a self-evaluation model to analyze situations before and after adoption of the strategy, and to evaluate the outcomes.

TYPES OF RESEARCH AND ADOPTED METHODOLOGIES

The literature revealed that most of the HO-LSCM research is qualitative in nature. This technique emphasizes the generation of theories and frameworks, and is particularly relevant where information is insufficient, or the study is new in the field. Of 73 studies that we reviewed, 68 were qualitative in nature, only two study had adopted a purely quantitative technique, technique of research, and three studies used both qualitative and quantitative research approaches (see Figure 4).

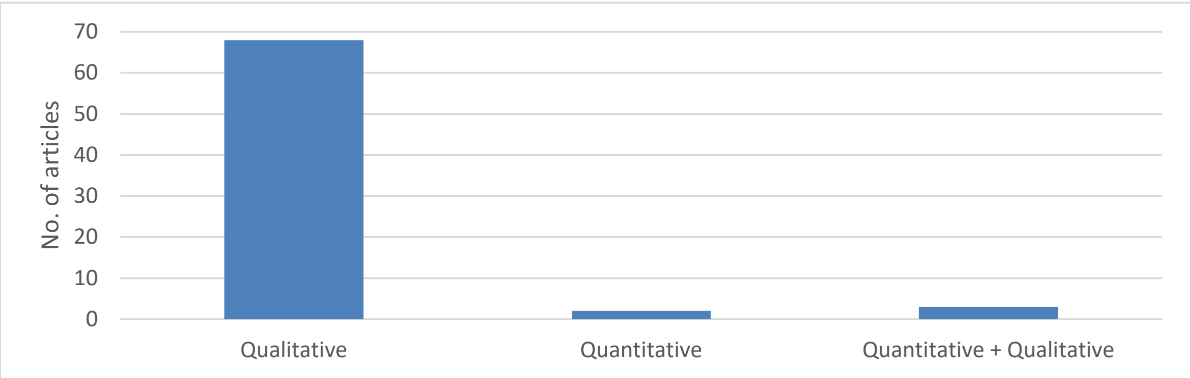

Fig. 4. Representation of qualitative and quantitative type of studies

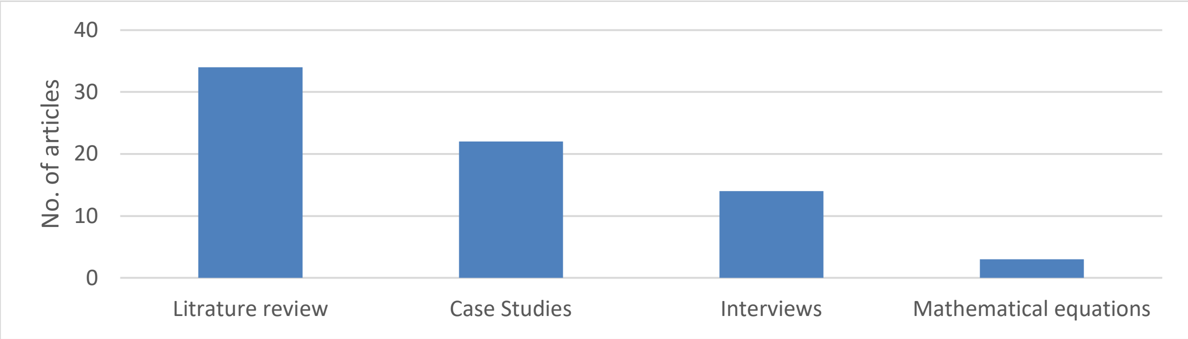

Fig. 5. Categorization of research methodologies, applied in reviewed literature

The 73 reviewed studies most often adopted a research methodology, or conceptualization techniques, based on a literature review (secondary data), case studies and interviews (Figure 5).

NOTABLE GAPS IN HO-LSCM RESEARCH

The terms "logistics" and "supply chain management" in the HO sector are overlapping, as we noted in our literature review. HOs have no standardized role for logistics and supply chain professionals and their jobs responsibilities are varied from organization to organization. The notable gap is; researchers need to present a standardized framework which may regularize the responsibilities of HO-LSCM professionals overall, for any organization, and job descriptions should be standardized, to overcome the often-confused view of what constitutes a "logistics professional" and a "supply chain management professional".

Another matter of significance that is not well addressed in the literature is the fact that the normal HO-LSCM operations are ignored; the challenges and issues of disaster response and aid management are well reported. Our view is that the efficiency of operations, particularly the normal operations, is an important matter requiring well-based studies.

A further matter is that most HO-LSCM studies have presented various frameworks for Agility management, and Efficient management, which we have discussed before, but only some of them have been well tested and few adopted. There are, clearly, no quality assessment and assurance frameworks that have been assessed for their adherence to standardized frameworks within ISO or the humanitarian sphere. Most studies have presented HO-Business partnership frameworks, but none presented a standardized model which may be applicable to every HO in pursuance of effectiveness and efficiency. While HO-Business partnership models have been presented as successful case studies, none have described unsuccessful HO-Business models case studies, by which professionals can learn, and avoid.

Relevant frameworks for HO-LSCM operations (procurement, inventory, fleet) presented various measures to promote effectiveness but there is a lack of research on operational efficiency. Fleet management of HOs, under normal conditions, lack research on optimizing resources, and no studies appear to be available that may guide organizations on developing good relationship management and efficiency, such as that which can be achieved through short term engagement of suppliers. HOs objectives are the same but HO-LSCM policies and implementation procedures vary significantly. Standardization of policies and procedures is a notable gap in the research and proactive measures are needed to bring about efficiency in HO-LSCM.

Leagility management is an important tool for bringing both effectiveness and efficiency in HO-LSCM, and the boundaries between Agility Management and Lean Management need to be redefined in detail for both disaster and normal HO-LSCM operations alike. Furthermore, Lean Management is an ignored area in HOs and very few studies on organizational efficiency are to be found, indicating a need to more extensively explore Lean management in HO-LSCM.

CONCLUSIONS

In this paper, we have presented a review of existing studies in HO-LSCM to explore two broad and six specific questions. The primary purpose of this study was to analyze the available research that focuses on HO operational efficiency and effectiveness. In the terminology of LSCM, effectiveness is achieved and measured through agility, while efficiency is achieved and measured through leanness. Our review of the literature showed that HO-LSCM effectiveness (agility) has gained considerably more attention than efficiency (lean) management, which is a much-neglected topic. As HOs normally engaged in two major scenarios, namely disasters (usually sudden, serious, and widespread, demanding quick and immediate action), and the normal HO-LSCM scenario (when careful planning and consideration of circumstances can occur), our view is that both scenarios demand research attention, which has not been the case for normal operations, in past research. One final comment to be made is that more quantitative research is required, to provide more empirical, well-constructed and well tested case studies, to better support the recommendations regarding the adoption of organizational effectiveness as an informing concept. Qualitative studies, primarily based on personal observations, opinions and feelings, modified by the emotional impact of participating in disasters, are insufficient.

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LOGISTYKA I ZARZĄDZANIE ŁAŃCUCHEM DOSTAW AKCJI HUMANITARNYCH

STRESZCZENIE. **Wstęp:** Wspólnym celem różnych organizacji humanitarnych (HO) jest dostawa dóbr i usług potrzebującym bez jakiejkolwiek dyskryminacji. Podstawowe obszary działalności organizacji humanitarnych to obszary związane z klęskami żywiołowymi, ochron praw człowieka, ułatwianie życia oraz upowszechnianie wiedzy i chęci działania w celu podniesienie bezpieczeństwa, szacunku i poważania zarówno jednostki jak i całego społeczeństwa bez osiągania przy tym zysków. Logistyka i łańcuch dostaw organizacji humanitarnych jest powszechnie uważany za najbardziej kosztochłonną cześć całej działalności humanitarnej i wymaga zrównoważonych rozwiązań. Organizacje humanitarne musza korzystać ze swoich funduszy skutecznie i wydajnie. Prezentowana praca ma na celu przegląd poprzednio wykonywanych badań i zidentyfikowanie obszarów wymagających dalszej poprawy w obszarze logistyki i zarządzania łańcuchem dostaw organizacji humanitarnych (HO-LSCM).

Metody: Koncentrując się na wydajności i skuteczności, w trakcie badań zidentyfikowano i skatalogowano badania dotyczące tematyki HO-LSCM, dzieląc je na pięć grup: koncepcja HO-LSCM, wyzwania i główne zadania HO-LSCM, zarządzanie organizacją, zarządzanie wydajności i skutecznością HO oraz typy badań i metodologii tych badań. W oparciu o te dane zidentyfikowano rozbieżności w dostępnych opracowaniach badań i zidentyfikowano zalecenia dla przyszłych badań.

Wyniki: Istniejące badania skupiają się na skuteczności, uwzględniając sprawność organizacyjną, podczas gdy stosunkowo mało uwagi poświęca się wydajności. 94% badań dotyczących HO-LSCM bazuje na badaniach jakościowych i większość z nich jest podstawą do tworzenie teoretycznych ram, które nie są testowane ani szerzej stosowane. W obszarze zarządzania logistyką i łańcuchem dostaw, każda organizacja humanitarna ma swoją politykę działania i procedury postępowania. Obszar ten wymaga standaryzacji w celu umożliwienie oszacowania i ocenienia wydajności i skuteczności logistyki i łańcucha dostaw tych organizacji.
Wnioski: Przeprowadzone badanie jakościowe skuteczności i wydajności, jest pierwszym jakie zostało wykonane w obszarze HO-LSCM w przeciwieństwie do wcześniej badań, skupiających się jedynie na skuteczności zarządzania. W pracy podkreślono konieczność rozszerzenie analizy badań dotyczących zarządzania w organizacjach humanitarnych.

Słowa kluczowe: Organizacje humanitarne (HO), logistyka i zarządzanie łańcuchem dostaw organizacji humanitarnych (HO-LSCM), skuteczność i wydajność, zwinność i zarządzanie typu Lean (A & LM).

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ORIGINAL PAPER

HOW TO ACHIEVE CUSTOMER SATISFACTION? PERSPECTIVE OF LOGISTICS OUTSOURCING PERFORMANCE

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ABSTRACT. **Background:** The inspiration to undertake research in the field of logistics customer service was formed by the strong relationship between service performance and customer satisfaction, observed within a study of the needs of logistics service providers' (LSPs) customers. The paper aims to understand which elements of service performance are important to customers purchasing logistics services in Poland and are worth investing in by LSPs.
Methods: The study was conducted among 112 production and trade enterprises – customers of LSPs selected in a targeted manner. A questionnaire method was used. Based on the respondents' answers, a model was built in the form of a classification tree with customer satisfaction as a response variable and features of service performance as predictors.
Results: The results show that two main characteristics affect customer satisfaction levels, namely logistics costs and shorter delivery times. According to the respondents, improving the level of customer service and increasing flexibility turned out to be less significant. However, the discriminant analysis has shown that high satisfaction with logistics outsourcing can also be achieved with the assumption of longer delivery.
Conclusions: In order to stand out in the logistics services market, LSPs should not only invest in reducing costs and improving service times, but also in factors that will cause above-average customer satisfaction, like improved operational flexibility and service levels, including pro-environmental activities.

Key words: performance, satisfaction, service quality, Kano's model, logistics service providers (LSPs), sustainability, classification tree.

INTRODUCTION

Observing modern supply chains (especially within e-commerce), it can be seen that a high level of customer service within logistics has become the standard [Saghiri et al. 2018]. Customers expect fast deliveries [DP DHL 2018], flexibility [Świtała et al. 2018, Hartmann et al. 2011, Zhang et al. 2005] and customized solutions [Hu et al. 2016]. Daugherty et al. [2018] define the phenomenon of fast-growing customer expectations as customer impatience. It mainly concerns the B2C market (Business-to-Consumer), but it also affects institutional customers on the B2B market (Business-to-Business). Among the reasons for this, there are social changes – on the demand side –hyper-competition of logistics service providers (LSPs) and a huge rate of technological progress – on the supply side – most often indicated [Langley 2018, Cichosz 2018a]. Considering the above, Daugherty et al. [2018] call for reawakening logistics customer service research, which will allow for providing suggestions to LSPs regarding the main directions of their operations' improvement.

This article responds to this need. It presents the results of the study aimed at identifying and assessing the impact of the complex category of logistics outsourcing performance on customer satisfaction. This objective was achieved thanks to the application of a discriminant analysis. A model

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was built in the form of a classification tree with customer satisfaction as a response variable and features of service performance (i.e. reduction of logistics costs, shortened delivery times, improvement of the customer service level and increased flexibility of customer service) as predictors.

The article consists of three parts. The first part (theoretical) presents key matters for the undertaken subject referring to LSPs, service performance, customer satisfaction and the Kano model discussing dependencies between service performance and customer satisfaction; the second part discusses the primary study methodology and characterizes the study sample; while the third part (empirical) analyzes the results of the study and principles which lead to high and very high customer satisfaction. The summary covers the most important conclusions, study limitations and directions for further studies.

THEORETICAL BACKGROUND

Changes in the market of logistics services

Since the 1990s, the use and significance of logistics outsourcing has increased. Along with this, the number of entities providing logistics services and the range of services offered has also increased [Salakivi et al. 2018, Langley 2018]. Today, according to researchers investigating the logistics services market, it is still at the stage of shaping and change [Świtała 2012, Kawa 2017, Salakivi et al. 2018]. The main players are: transport and forwarding companies, LSPs, CEP (courier, express and postal) operators, railway operators, air operators, maritime shipowners, inland waterway companies and terminal operators. With the development of technology, new entities outside the logistics industry have started fighting for logistics customers. Among them there are: (i) technology companies from the retail industry, e.g. Amazon, (ii) electronic platform operators, including operators offering logistics services in the crowd logistics model, e.g. UberCARGO, Stowga, or (iii) car manufacturers who invest in a fleet of vehicles to offer transport services in the sharing economy model, e.g. Daimler, BMW. Thus, the modern logistics service market is characterized by intense rivalry, often referred to as hyper-competition [Cichosz 2018a].

Studies prove that entities who are able to offer customers value (i.e. to provide a service that will meet or even exceed their expectations in a more cost-effective manner) will win the battle for logistics customers in the long-term perspective [Deepen 2007, Marchet et al. 2017]. As proved by Stank et al. [2003], Deepen et al. [2008] and Świtała et al. [2018] logistics service performance is a key category in building customer satisfaction with logistics outsourcing.

Logistics outsourcing performance

Logistics performance is a complex term. It can be perceived from two perspectives: performance of logistics operations carried out within an enterprise (in-house logistics performance) and performance of outsourced operations (logistics outsourcing performance). In this study, the outsourcing perspective was assumed as the basis for the investigation. This results from the fact that, as observed by Borgstrom et al. [2017], there is no clarity how customers with various needs assess logistics service performance elements, or how they decide on cooperating with a logistics service provider.

In this study logistics service performance is defined in accordance with Fugate et al. [2010] and Świtała et al. [2018] as: effectiveness and efficiency in performing logistics activities and building logistics differentiation. Operationalizing the term of logistics outsourcing performance, most often researchers refer to a three-dimensional scale proposed by Stank et al. [2003] including: operational performance, relational performance and cost performance, or the Knemeyer and Murphy multi-element scale [2004] divided into: operations performance, channel performance and asset reduction performance. For this research we adapted the Knemeyer and Murphy scale [2004] using four elements i.e. reduction of logistics costs, shortened delivery times, improvement in customer service, and increasing customers' flexibility.

Analyzing the relationship between service performance and customer satisfaction, the Deepen et al. [2008] study should be mentioned. They proved that customers of LSPs recognize the difference between the implementation of the objectives agreed under the contract and performance that exceeds the goals assumed. Their study demonstrated that while goal achievement leads to satisfaction, unexpected, above-average services exceeding the contract terms might result in customer loyalty and translate into additional profits for the company.

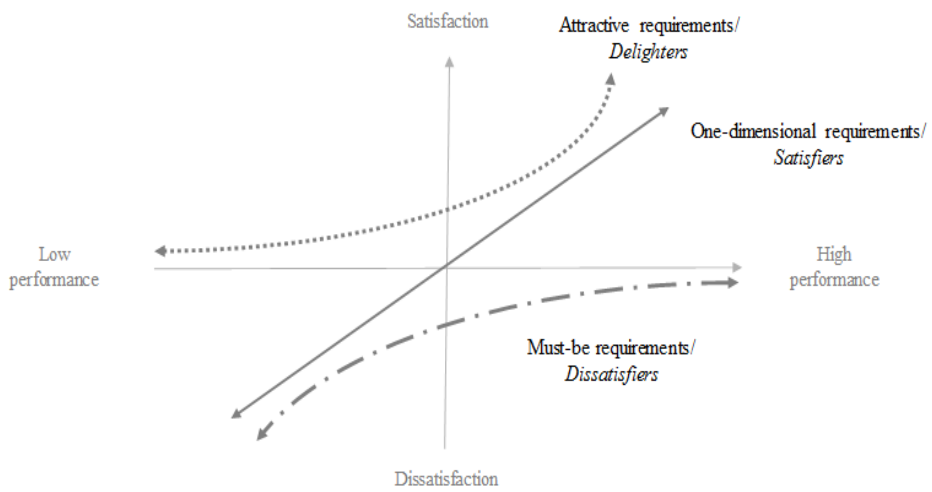
Customer satisfaction

Customer satisfaction is one of the outcomes of service performance offered by LSPs [Cichosz et al. 2017]. It appears as a result of the fulfillment of customers' expectations. It may concern a single transaction or result from an experience during the entire period of cooperation between the LSP and the customer [Stank et al.2003] and in this situation it can be referred as cumulative satisfaction [Zhang et al. 2005]. In the instance when logistics outsourcing fails to fulfill customers' expectations, dissatisfaction might appear and result in losing a customer. Understanding the fact that in a competitive market with freedom of choice in LSPs, satisfaction constitutes to be a mandatory (however insufficient) condition to continue cooperation, so LSPs carry out studies on levels of customer satisfaction.

In this study, customer satisfaction is interpreted, in accordance with Cichosz et al. [2017] and Świtała et al. [2018] as being related to a customer's experience against his/her expectations regarding the level of long-term logistics servicing, as well as other aspects of cooperation with an LSP. Cooperation takes place at subsequent stages, such as: (i) pre-transaction service, when companies conclude a contract and set rules for cooperation, (ii) transaction service, which is related to the provision of logistics services to customers and (iii) post-transaction service, which may, for example, relate to situations associated with the repair of possible service errors.

Kano Model – the relationship between service performance and customer satisfaction

Initially, the dependence between service performance and customer satisfaction was perceived to be linear, i.e. the increase/decrease in service quality causes a proportional increase/decrease in customer satisfaction. However, Kano [Shen et al. 2000] noticed that customers have different types of needs that constitute the quality of their service (logistics outsourcing performance).



Source: Shen et al. 2000

Fig. 1. Kano Model – diversity of the customer satisfaction level

A different level in fulfillment of these needs results in a different level of satisfaction. Kano distinguished three types of needs (Figure 1):

- Must-have requirements – satisfying these needs is necessary to achieve customer satisfaction; an example of such a need in terms of logistics service is the security of the cargo; if the LSP fails in the matter of cargo security, the customer will be extremely dissatisfied, but if the LSP ensures security, the customer will not be dissatisfied; it is therefore a necessary condition; however, it is insufficient to obtain complete customer satisfaction;
- One-dimensional requirements – in relation to these needs, satisfaction will be directly proportional to their implementation, i.e. a higher quality will result in a higher level of satisfaction; these are usually needs explicitly identified by the customer as part of negotiations, like deliveries within a certain time windows or a specified delivery cost;
- Attractive requirements – cause above-average customer satisfaction; as a rule, they have not been clearly named by the customer and their fulfillment is a pleasant surprise for the customer, which leads to delight; failure to meet these needs does not cause dissatisfaction; an example of such a need may be continuous improvement in the level of customer service.

RESEARCH MATERIAL AND METHODS

The studies on which this article is based were conducted among production and trade enterprises representing the main participants of the supply chain. In total, 112 entities selected purposefully constituted subjects of the study. Invitations to participate in the study were sent to respondents using logistics services operating on the national market and employing at least ten employees. Participants of the study completed an online survey.

The questionnaire consisted of two parts. The first part involved scales used to measure service performance and customer satisfaction. The first measurement was made on a multi-item scale by Knemeyer and Murphy [2004], from which four criteria referring to benefits obtained by customers entrusting logistics to specialized service providers (LSPs) were selected, so at the same time we speak about reduction of logistics costs (P_1), shortening of delivery times (P_2), improvement of the level of service for customers (P_3) and increased flexibility (P_4). In terms of the measurement of satisfaction, statements on the scale referred to both general satisfaction arising from cooperation with LSPs (S_1) and the level of satisfaction with the course of service at the pre-transaction (S_2), transaction (S_3) and post-transaction (S_4) stage. It is worth mentioning that when developing the scale, an important point of reference involved studies conducted by Large et al. [2011]. In the case of both variables, seven-degree ordinal scales were used. The second part of the questionnaire consisted of numerical questions containing quotient and nominal ratios that were used to characterize respondents.

In accordance with the suggestion of Henseler et al. [2016], the reliability analysis of both scales was carried out using Cronbach's α and Dillon-Goldstein's ρ. The obtained results are presented in Table 1 from which it can be concluded that in both cases, the variables are characterized by high measurement reliability.

Table 1. Evaluation of the performance and satisfaction measurement reliability

Variable	Cronbach α ($\alpha > 0.7$)	Dillon-Goldstein ρ ($\rho > 0.7$)
Performance	0.847	0.897
Satisfaction	0.917	0.942

Source: own work

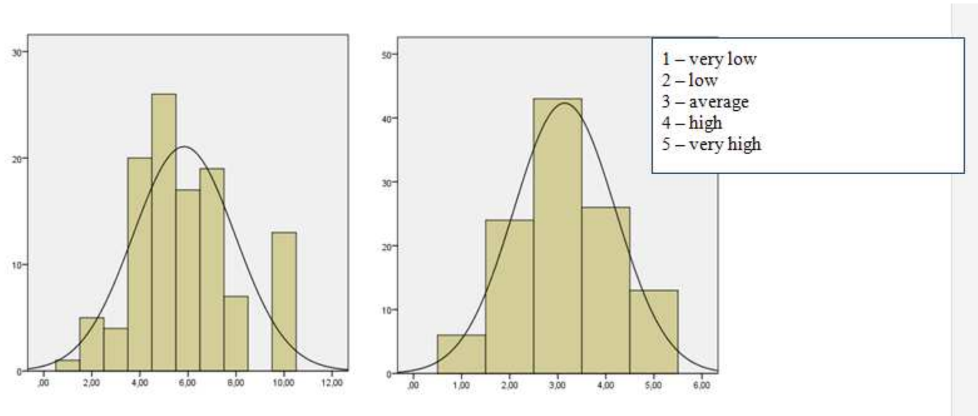
The study sample consisted of production enterprises in 40%, and trade enterprises in 60%. Due to the origin of their capital, the largest segment consisted of companies with domestic capital (76.6%). Foreign capital was indicated by 9.0% of the respondents, and mixed capital - 14.4%. Companies from the SME sector (81.4%) and running business activities on the national or regional (68.2%) market dominated in the study, while the participation of enterprises employing more than 250 employees and operating at an international scale was 18.8% and 31.8% respectively. Responses were given mostly by medium and senior level employees, who at the time of the study were employed as managers of the logistics, production and sales departments. As mentioned before, all respondents outsourced logistics services, of which 51% of the respondents used contract logistics services. Most respondents (68%) also declared a long period of cooperation with LSPs, most often lasting several years.

The research material was subject to statistical analysis using the SPSS package and the R software. For the needs of the research objective, a discriminant analysis was performed. To build the model, the recursive partitioning method (so-called classification trees) was used. In the studied dataset, customer satisfaction was expressed through four variables which correspond to the S1–S4 scales. Using values of these features (i.e. respondents' responses),

a SAT aggregated variable was built:

$$SAT = \frac{1}{4}\sum_{j=1}^{4} S_j. \qquad (1)$$

This variable was subjected to the standardization process using a ten-element stern scale. The distribution of the scale presenting satisfaction after discretization and conversion to a five-point scale is presented in Figure 2. Results from the range: 1-2 sten are considered very low, 3-4 – low, 5-6 sten are considered average, 7-8 – high, and 9-10 – very high.



Source: own work

Fig. 2. Distribution of the satisfaction level after applying the standardization procedure

The only variable (SAT) reshaped and categorized in such a manner represents customer satisfaction and fulfills the role of a dependent variable in the created classification model. While, the P_1–P_4 scales are predictors, related to questions about service performance.

Due to the poor scale of the SAT variable measurement, a discriminant analysis was used for the study, and in this case - classification trees (or a recursive partitioning method). This method does not assume knowledge of the distribution of the studied predictors, and what is more – they may be measured on weak and strong scales. Moreover, it can deal well with the problem of nonresponses and it is resistant to the outliers. All this causes that it has a significantly broader potential area of applications than e.g. Fischer's classical discriminant analysis [Breiman et al. 1984].

To assess the importance of variables P1–P4 within the final model, the values of dedicated measure were computed. These values are located in the interval [0,1] and allow to create a ranking of predictors with increasing explanatory power [Ishwaran 2007].

The classification error for the model is 26.8%, which means that the satisfaction level of the respondent obtained from the model differs from the real, observed satisfaction level in 26.8% of cases (the predictions of the model are accurate in 73.2%).

RESEARCH RESULTS

Logistics service satisfaction level

The average value of the satisfaction index for the whole group was 3.14 and was slightly above the center of the scale, which indicates the average level of satisfaction of the respondents with logistics services. The results presented in Table 2 indicate that almost 30% of the respondents gave low or very low ratings, 38% reported satisfaction at a average level, while high and very high results were observed in 34% of the respondents.

From the data analysis, it can be concluded that the group of customers with low and very low satisfaction (dissatisfied customers) consisted mainly of small trade companies with a rather limited reach of operations, as it concerned nearly exclusively the regional or national market. Logistics service in their case had a rather narrow nature. Cooperation was usually carried out without a permanent contract and it concerned a small number of services outsourced to one entity.

Table 2. Customer satisfaction level

Scale	$\bar{x}$	σ	Satisfaction level in %				
			Very low [1]	Low [2]	Average [3]	High [4]	Very high [5]
Customer satisfaction	3.14	1.06	5.45	21.82	38.18	23.64	10.91

Source: own work

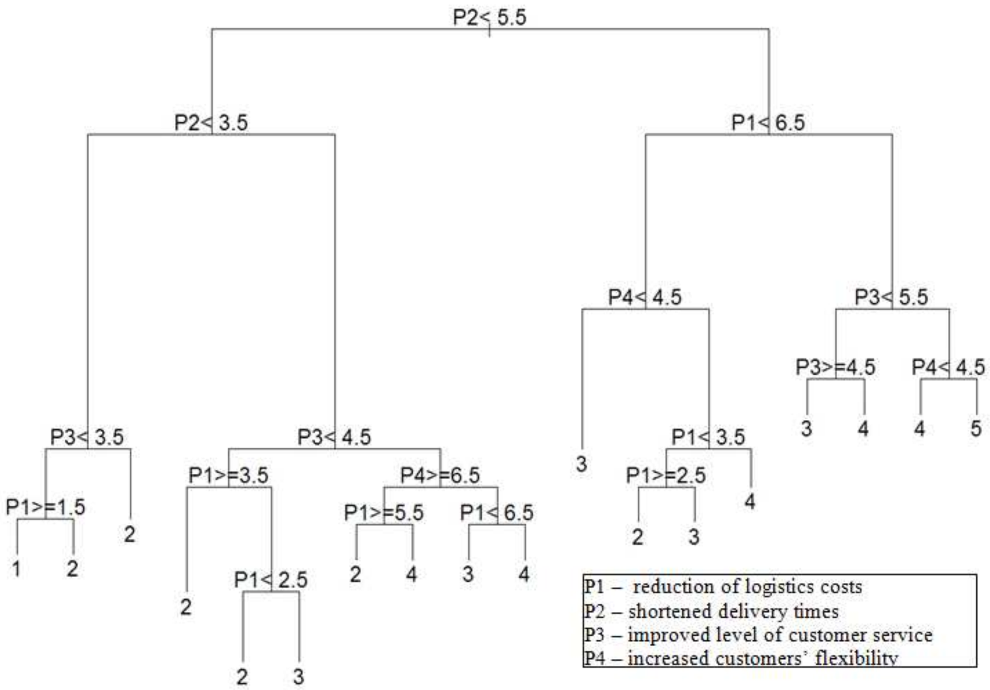
Preferences of the respondents qualified to a group with high and very high satisfaction are different in this context. In this case, the most common form of cooperation was contract logistics. More than 70% of the respondents declared the use of such a logistics offer. What is more, in comparison to dissatisfied customers, this group is characterized by a much longer period of cooperation with LSPs, usually lasting four or more years (dissatisfied customers indicated several months to one year). The number of LSPs outsourced to handle cargo was also larger.

As expected, in the group of customers with a high or very high level of satisfaction, the participation of both production enterprises as well as enterprises conducting international operations was larger. An employment level above 100 people was declared by more than 54% of the respondents, including 23% that indicated employment in a large company, i.e. employing more than 250 people.

The impact of service performance on customer satisfaction

In this part of the article the results of the studies the objective of which was to identify and assess rules ensuring customer satisfaction were presented. The function of predictors was fulfilled by four features of service performance. The classification tree obtained in the analysis is presented in Figure 3. As we can see, the tree consists of 18 nodes (classification rules) of which six lead to high (4) or very high (5) satisfaction, 5 – to satisfaction at an average level (3), and in the case of seven rules low (2) or very low (1) satisfaction was observed.

Delivery time (P_2) is a variable based on which the first partitioning of the tree into two – as it turns out – equal branches in terms of numbers was made. The right part of the tree consists of respondents declaring benefits in the form of faster deliveries ($P_2 \geq 5.5$), while on the left side more diverse opinions on the subject were noted (P_2 < 5.5). 46% were "rather yes", 29% - "hard to tell", and 25% of the respondents denied that deliveries were shortened as a result of operations carried out by LSPs. Analyzing the partitioning of the left part of the tree, we can see that negative opinions of the respondents about delivery times (P_2 < 3.5) constitute the main part of the principle leading to low or very low satisfaction with logistics services.



Source: own work

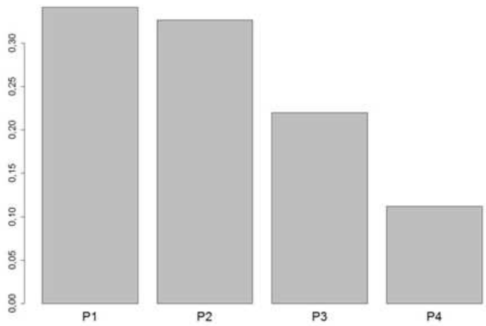
Fig. 3. Satisfaction/dissatisfaction model in the form of a classification tree

It is worth highlighting that only in one case (on the right side of the tree) a very high satisfaction level was achieved (5). It turns out that very satisfied customers are respondents who express a strong belief about benefits resulting from cooperation with LSPs. According to the respondents the service provided led to the shortening of delivery times ('yes" and "definitely yes" for P_2), contributed to the reduction of costs ("definitely yes" for P_1), improved service of subsequent links in the supply chain ("yes" and "definitely yes" for P_3) and led to improved flexibility ("rather yes", "yes", "definitely yes" for P_4). As shown in the results of the studies, a strong belief of the respondents concerning measurable benefits in the form of cost reduction constitutes the key condition of very high satisfaction.

Among customers characterized by high satisfaction (4), five classification rules were identified. In each case, the achievement of satisfaction required the fulfillment of numerous conditions of service performance improvement, although not always in relation to all features included in the study. Considering the right side of the tree, we can see two fundamental differences between customers with high and very high satisfaction levels. It concerns benefits in the form of improvement in the level of their own customer service (P_3), as well as increased flexibility of operations (P_4). Whereas in the group compared in both cases, only positive assessments were made, i.e. confirming the improvement of results in the studied service performance areas, in the second group greater polarization of related assessments was observed. Considering P_4, customers' responses indicate the lack of positive effects of service (neutral responses, such as "neither yes or no" and "rather not", "no", "definitely no" were recorded), while in the case of P_3, there were positive responses; however, they were not strong judgments (responses such as “rather yes” were observed). Hence, it can be assumed that in the discussed matter opinions of the groups differ significantly. What is important, in both groups benefits in the form of the reduction of logistics costs and shortening of delivery times constitute the sine qua non condition for satisfaction to be ensured.

In comparison to this, the classification rules of the left side of the tree seem interesting, as in this case it can be noticed that shorter delivery times do not constitute a mandatory condition for a high level of satisfaction to be achieved (4). From the interpretation of the figure it can be concluded that it is possible with the combined fulfillment of the following conditions: first of all, improvement of delivery times will be assessed rather positively (“rather yes”) or neutrally (“neither yes or no”); second of all, respondents will assess the improvement of service of the subsequent links of the supply chain positively (“yes” and “definitely yes”) or neutrally (“neither yes or no”); third of all – which seems to be the most important – other benefits will be assessed definitely positively. In other words, the respondents will be convinced that thanks to the cooperation with LSPs logistics costs were reduced and the company’s ability to respond to changes occurring on the market increased. What is more, it may be assumed that positive results of P_1 and P_4 service constitute sufficient compensation for the respondents for – as it seems – not fully met expectations in relation to P_2 and P_3.

Figure 4 presents the ranking of the significance of predictors. The results of the study demonstrate that mainly two features decide about the customer satisfaction levels, i.e. lower logistics costs (P_1) and shorter delivery times (P_2). P3 (improvement of the customer service level) turned out to be less significant, i.e. with a more limited impact, while P_4 (increased flexibility) was considered the least significant feature the force of impact on the form of the model of which – in comparison to P_1 and P_2 – was twice as low.



Source: own work

Fig. 4. Ranking of predictors with increasing explanatory power

DISCUSSION AND CONCLUSIONS

The studies confirmed a strong relationship between service performance and customer satisfaction in the logistics industry and allowed for the identification of key performance criteria, which decide the satisfaction level of customers purchasing logistics services in Poland.

Theoretical implications

Within the study, a discriminant analysis was performed in the field of data exploration. Based on the recursive partitioning method, a classification tree was built which shows various combinations of service performance elements (i.e. reduction of logistics costs, shortened delivery time, improved customer service levels and increased flexibility of customer service) ensuring various levels of customer satisfaction with logistics services (from 1 – very low, to 5 – very high). The tree presents various paths to achieve a high (4) and very high (5) level of customer satisfaction by managing particular elements of service performance. The use of the classification tree for the analysis of key factors of logistics service performance is an innovative approach in the area of logistics and supply chain management, which constitutes an input into studies conducted in this field.

Managerial implications

Among the benefits for business practice, it is worth listing several facets. Firstly, the study's results indicate that services provided by LSPs constitute an area that requires further improvement. The obtained results prove that for 18 analyzed classification rules only in one case the highest level of customer satisfaction, arising from the improvement of logistics performance, was observed. What is important, the declaration about very high service satisfaction was made only by 10.91% of the respondents. It can be assumed that in other cases the respondents' requirements were not completely fulfilled, which may suggest that in the Polish market of logistics services there is still a gap to be filled.

Additionally, the study showed that LSPs could achieve a higher level of customer satisfaction from logistics service performance within long-term cooperation (70% of satisfied and very satisfied customers cooperated with LSPs for more than four years within contract logistics). From signing a several-year-long contract, an LSP is able to become more familiar with their customers' expectations and adjust their system of providing services to meet the needs of each customer. Long-term cooperation is essential, in particular in the case of incurring high investment expenditures on additional potential (i.e. equipment, human resources), modern technologies dedicated to a given customer (i.e. IT system supporting warehouse operations, transport planning systems, autonomous vehicles, inclusion of robots, co-robots, drones in the service, artificial intelligence application at various stages of the service process, etc.) or a complex adjustment of processes to meet customers' individual requirements. Basically, long-term cooperation between LSPs and customers is associated with better communication between them, including more trust, as well as sharing risks and benefits [Deepen et al. 2008], thanks to which LSPs can reduce the cost of logistics service and improve the ability to respond and be flexible to changes in the environment, which subsequently allows both companies to achieve better results.

The third observation arising from the analysis of the study's results indicates the significant role of the reduction of costs and service times in the achievement of customer satisfaction with logistics outsourcing. These results are not surprising. It is rather obvious that customers of LSPs want to pay less and be serviced faster in such a competitive market. However, it is worth noticing that the criteria will not ensure companies above-average customer satisfaction. They belong to the category responding to one-dimensional needs, which means that satisfaction arising from their improvement is directly proportional to their change. If LSPs wish to achieve above-average satisfaction that will lead to long-term relationships and customer loyalty, and build logistics diversity and a competitive advantage of the operator at the same time, LPSs should pay attention to constant (preferably proactive) improvement of cooperation with customers [Wallenburg 2009] and building skills to respond to external problems that may occur in the changing environment.

More interesting takeaways for logistics managers arising from these studies are provided by the analysis of service performance criteria for a large group of customers on the left side of the classification tree, for which shorter delivery times do not constitute a mandatory condition to achieve high satisfaction (4). It is possible assuming: (i) rather positive or neutral improvement of delivery times, (ii) rather positive or neutral improvement of customer service, (iii) definitely positive assessment of cost reduction and (iv) improvement of flexibility. These results are confirmed among others by the increasing popularity of the sustainable logistics environment policy of LSPs in recent years [Evangelista et al. 2018]. Here, it is worth convincing LSPs to offer customers a sustainable transport environment, and in particular to encourage an increase in the use of multimodal transportation (carried out using at least two modes of transport), which is implemented using environmentally-friendly modes of transport over a substantial part of the route. Such transport is promoted by the European Union [COM 2011]. Although it takes longer, it is cheaper and more ecologically sustainable, which as indicated by the studies, could be accepted by customers.

A particular variety of multimodal transportation is synchromodal transport, which is currently gaining popularity [Pleszko 2012]. It constitutes a higher level of cooperation between the shipper and the LSP under the conditions of integrated transport, as well as the information and communication infrastructure. The service is contracted without specifying a particular mode, mean and route of transport. Therefore, the operators can freely select an optimal solution, and in the case of unexpected situations – have the flexibility dynamically respond to a given problem. The main attributes of synchromodal transport include its price, flexibility and high level of complex logistics service. However, customers must accept a longer transport time in comparison to road door-to-door transport [Cichosz 2018b].

Limitations and future studies

It should be emphasized that discriminant analysis has its limitations. In this study, the classification error is 26.7%. This means that nearly 27% of the respondents were classified into the wrong class in terms of the SAT variable. Hence, we need to be careful about interpreting the results. Although it is possible to build a classification tree with a smaller classification error, it would mean increasing the model complexity, and consequently, a certain loss of interpretability. A more complex tree will generate many more classification rules describing various levels of customer satisfaction.

An additional limitation of this study might be the size of the study sample. Within future studies, it would be worth analyzing the impact of service performance on customer satisfaction with logistics services by using a larger sample. It would be particularly interesting to study the cooperation of logistics operators, including CEP operators, with e-commerce customers. With the growing popularity of omnichanneling (i.e. integration of various delivery channels in order to create unified customer experience), it is worth verifying which aspects of logistics service performance become the deciding factors to achieve customer satisfaction with logistics services.

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LOGISTICS OUTSOURCING PERFORMANCE JAKO CZYNNIK SPRZYJAJĄCY SATYSFAKCJI KLIENTÓW Z USŁUG LOGISTYCZNYCH

STRESZCZENIE. Wstęp: Inspiracją do podjęcia badań z zakresu logistycznej obsługi klienta była silna relacja między performance'm obsługi a satysfakcją klienta, którą zaobserwowano w badaniu klientów operatorów logistycznych. Autorzy chcieli bliżej poznać, które elementy performance'u obsługi są istotne dla klientów nabywających usługi logistyczne w Polsce i jak te elementy wpływają na poziom satysfakcji klientów z usług logistycznych. Badanie miało na celu wskazanie operatorom logistycznym, w które elementy performance'u obsługi warto inwestować.

Metody: Badanie zostało przeprowadzone wśród 112 przedsiębiorstw produkcyjnych i handlowych – klientów LSPs dobranych w sposób celowy. Wykorzystano metodę kwestionariusza ankietowego. W oparciu o odpowiedzi respondentów zbudowano model w postaci drzewa klasyfikacyjnego z satysfakcją klienta w charakterze zmiennej objaśnianej oraz cechami performance'u obsługi w roli zmiennych objaśniających.

Wyniki: Wyniki pokazują, iż o poziomie satysfakcji klienta decydują głównie dwie cechy, tj. niższe koszty logistyczne oraz krótsze czasy dostaw. Mniej istotne, wg respondentów, okazały się poprawa poziomu obsługi klienta oraz wzrost elastyczności. Jednak analiza dyskryminacyjna pozwoliła zauważyć, że wysoką satysfakcję z logistycznej obsługi klienta można również osiągnąć przy założeniu dłuższych czasów dostaw.
Wnioski: Chcąc wyróżnić się na rynku usług logistycznych, LSP powinien inwestować nie tylko w obniżkę kosztów i poprawę czasu obsługi, ale również w czynniki, które spowodują ponadprzeciętną satysfakcję klienta, tj. poprawę elastyczności działania i poziomu obsługi, w tym działania proekologiczne.

Słowa kluczowe: performance, satysfakcja, jakość usług, model Kano, usługodawcy logistyczni, zrównoważony rozwój, drzewo decyzyjne.

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ORIGINAL PAPER

FOOD INTEGRITY THROUGHOUT THE CHAIN: THE CASE OF GOOD DISTRIBUTION PRACTICE

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ABSTRACT. **Background:** The importance of supply chain management has increased, as consumer concerns about food safety and quality have become more important, along with the demands for large amounts of consistent and reliable products. During distribution, food is exposed to various risks, such as inadequate storage or failure to keep a certain temperature, which consequently affects food integrity. This paper explains the procedures distributors are implementing to guarantee food safety, food quality and overall food integrity in the supply chain.

Methods: This paper involves a qualitative study approach. Face to face interviews were conducted in the four (4) leading logistics companies in the cold chain segment, which provide logistics solutions, from delivery of the goods from the manufacturing company to the point of sale.

Results: In order to ensure that high quality products are transported properly, and risks are managed effectively, the companies operate in accordance with the principles of different standards. They have work procedures within each activity in the food supply chain to avoid the distortion of food quality and product safety. The whole process of food transport is followed by IT technology, and food categories are divided into nine groups according to the required prescribed temperature. As special requirements need to be respected during the handling of sensitive products, the investigated companies point out the importance of investing in their employees.

Conclusions: Food integrity is a holistic concept that relates to food production and distribution, safety and quality. The food supply chain, which tends to be long, global and highly interconnected, leading to greater risk exposure, requires temperature monitoring at every link in the supply chain, particularly in the warehouse and transportation vehicles. Special emphasis on the role of IT and employees is given.

Key words: food supply chain, food integrity, food safety, good distribution practice, logistics service providers, Croatia.

INTRODUCTION

In personalized nutrition, food is a tool for good health, implying an instrumental relationship between food and health [Nordström et al. 2013], where customer trust and confidence are paramount [PwC, 2015]. Nowadays the majority of food products are trustworthy and meet consumer expectations [SGS 2013], but there still are reported cases of consumer-related food incidents, such as razor blades, a sewing needle and other metal objects found in George Weston Foods cakes and a botulism outbreak in Bumblebee Seafoods in 2007 [APEC 2015], a series of food safety incidents in the Chinese food industry in 2008 [Avery 2014, Shears 2010], the horsemeat scandal in the UK in 2013 [Ali et al. 2017], and the Hungarian beef case in 2014 [Donnelley 2014]. For organisations involved in such incidents, it can result in costly product recalls [Whipple et al., 2009], market withdrawals, safety alerts, doubtful reputation of the company and its brands [Hornibrook et al. 2005] and lost consumer trust [Trienekens, Zuurbier 2008]. However, failures in food safety can have serious negative consequences not only for the companies involved, but also for consumers,

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and the worst case scenario occurs when incidents lead to deaths or illness [Trienekens, Zuurbier 2008].

There is undisputed demographic growth with projections that the human population will increase by 50% by 2050 as compared to 7,5 billion people 2017 [United Nations Department of Economic and Social Affairs Population Division 2017, Worldometers, 2017]. This fact demands the modern production-to-consumption food system be capable of feeding few billion people, which on the other hand, has resulted in an extremely complicated food supply chain which over time has evolved into a global system of immense size and complexity. The process of the globalization of the food industry has sparked heightened awareness about the various risks and vulnerabilities that products are exposed to as they move along the supply chain continuum from design and sourcing to manufacturing, transportation, distribution and final sale to the consumer [Marucheck et al., 2011].

The main purpose of this paper is to explore how to ensure that food products are safe, high quality, nutritious, abundant, diverse, convenient, less costly and more readily accessible during the process of distribution in the food supply chain which tends to be long, global and highly interconnected, leading to greater risk exposure [Roth et al., 2008]. Therefore, the paper is structured in a way that it begins with the theoretical background and a definition of the term food integrity and characteristics of the food supply chain and the processes of managing the procurement, movement, storage and handling of food products through the supply chain in order to preserve the safety and quality of food during the distribution phase.

In particular, the paper examines the role of temperature and transport in the food supply chain as the literature [Gustafsson et al., 2009, Hoorfar, Prugger 2011, Smolander et al. 2004] considers temperature monitoring during the transport and storage along the entire food supply chain as key factor to ensure food quality and safety. Despite the noteworthy body of knowledge on the investigated areas, we have also identified a lack in scientific exploration of food integrity from the perspective of the distributor as a member of the supply chain. Therefore, we contribute to the current knowledge by sharing concrete knowledge gained from four leading logistics service providers (LSP) in Croatia.

LITERATURE REVIEW

Our production-to-consumption food systems are characterized by complexity, shaped by the dynamic interplays of numerous inputs, processes, outputs, and actors that can affect food integrity [Wang et al. 2017]. Food integrity encapsulates the complete supply chain [Ali et al. 2017] as all participants of the supply chain are required to provide certain conditions that food demands as one of the most sensitive products on the market. The literature review shows that both concepts are mutually closely related and therefore in the following explanations, a correlation of some the terms is evident.

Defining the Concept of Food Integrity

Integrity, as defined in the Webster's New World 3rd Edition, means the quality or state of being complete; entirety, perfect; and wholeness [Zulfakar et al. 2012]. In the context of the food industry, integrity implies consumer confidence in food, i.e. that the food they consume is genuine food, with quality ingredients, and is safe to eat. In his report for the government study, Elliott [2014] defined it as follows: "Food integrity can be seen as ensuring that food which is offered for sale or sold is not only safe and of the nature, substance and quality expected by the purchaser but also captures other aspects of food production, such as the way it has been sourced, procured and distributed and being honest about those elements to consumers". In their exploration of evolving definitions of the term Wang et al. [2017] relied on distinguished quality control experts that observe food integrity from an evolving perspective of the quality corresponding to the changing nature of food production, from conformance to requirements [Crosby 1979], total quality control [Feigenbaum 1983], customer expectations [Ishikawa 1985], to an open-systems view of total quality management

[Deming 1986]. However, food integrity issues include not only food quality and food authenticity. Rather, due to the globalization of the food trade, there is safety as well as origin fraud and quality concerns [Charlebois, Haratifar 2015]. There is an interesting explanation of food integrity by Grunert [2002] and Barnet et al. [2016] who stated that product integrity is a combination of basic and credence requirements and food scandals, like the horsemeat scandal, which challenge consumer confidence. In explaining food integrity Elliott [2014] used a system approach based on eight pillars: (1) consumers first, (2) zero tolerance, (3) intelligence gathering, (4) laboratory services, (5) audit, (6) government support, (7) leadership, and (8) crisis management. Only the supply chain which encompasses food safety, security, traceability, origin authenticity, quality attributes and product information can result in a final food product with integrity [Davidson et al. 2017].

Integrity throughout the Food Supply Chain

As a network of partners who collectively convert a basic commodity (up-stream) into a finished product (downstream) that is valued by end-customers, and who manage returns at each stage [Harrison, van Hoek 2008] supply chain management is concerned with managing the entire chain of processes, including the raw material supply, manufacture, packaging and distribution to the end-consumer. It can also be defined as the task of integrating organizational units along the supply chain and coordinating material, information and financial flows in order to fulfil (ultimate) customer demands with the aim of improving competitiveness of a supply chain as a whole [Stadtler, Kilger 2008]. Food chain integrity is multi-disciplinary, covering all the aspects of the food chain from producers to consumers [Hoorfar, Prugger 2011]. Each supply chain is unique, showing that there is no single approach to assuring supply chain integrity [Elliot 2014]. Ali et al. [2017] propose several dimensions of food supply chain integrity:

- raw materials integrity – raw materials have always been discussed after any incident involving product recall,
- production integrity - focuses on ensuring processes, management systems, and facilities during the manufacturing process,
- service integrity – not only quality of products but also quality of service is important,
- information integrity - the information given to consumers should uphold the integrity of the processes.

Sowinski [2013] notes that although food safety and security is better today than ever before, there is a big risk with food safety in the global food chain at multiple points of vulnerability directly related to the complexity and length of the supply chain, i.e. lots of food facilities that process or distribute food that are registered with the FDA, food containers moved on trucks, trains and ships every year; and over a million points of sale, such as restaurants, grocery stores and other food service outlets for the distribution of food. The greater the complexity in the supply chain, the greater the chances are the products involved are likely to have issues of authenticity [de Castella, Wheeler 2013] as some processed food products have ingredients from different countries. Ali et al. [2014] point out that chain members that are well equipped in terms of food SC integrity are able to track down possible causes of any incidents. Floros et al. [2010] and SGS [2013] point out the challenge of the large, growing food security gap in certain places around the world, where proper handling, processing, packaging, and distribution methods are lacking. Improving the integrity of the food chain, making certain that food is traceable, safe to eat, high quality and genuine requires communication between all food chain participants. Verbeke [2011] considers effective and efficient communication crucial for active food chains in today's global food market. Techniques based on barcoding are very effective in communication and certifying both the origin and quality of food products [Charlebois, Haratifar 2015]. Technological advancements, such as active RFID tags are the most cutting-edge technology for supply chain integrity and traceability and can automatically capture a range of information concerning product identity, properties, and data (e.g., temperature history), thus providing a supply chain management system with a complete description of the current state of the product [Dabbene et al. 2014].

Feinman [2013] adds that implementing preventive and proactive controls built on actionable intelligence to protect the food supply chain is significantly more effective than reacting to an adulteration event after it happens. Ratiu and Mortan [2013] believe that in this context, a proper functioning of the food supply chain should take into consideration the ethical issues in the relationships with a wide diversity of stakeholders like farmers, food processors, traders, consumers, employees, community and last but not least the environment. Hong et al. [2011] consider regulations or standards, obtaining the certifications necessary in managing food chain integrity and building customer confidence.

Arevalo Chavez and Seow [2012], Aung and Chang [2014], and Trienekens and Zuurbier [2008] expect that quality assurance will dominate the process of production and distribution in food supply chains in the future. Today`s food supply chain ensures „from farm to fork" integrity without unnecessary costs in order to improve the trust in food.

The Importance of Temperature Tracking

As food is a temperature-sensitive product, it can be damaged when not kept within a specific temperature range, and supply chain integrity includes the additional requirements of proper packaging, temperature protection, and monitoring. Smith [2006] and Jol et al. [2006] warn that bacterial growth can be out of control without the appropriate temperature and humidity in managing food throughout the supply chain. A temperature-controlled supply chain or a cold chain provides the essential facilities and methods required to maintain the quality of food [Aung, Chang 2014] as temperature is the most important factor in prolonging or maintaining the food product characteristics and shelf life [Bogataj et al. 2005, Montanari 2008, Sahin et al. 2007]. This is in line with the work of Zhang et al. [2003] who linked quality degradation of products to time and temperature during production, transportation, and storage. In the literature [Rivigo 2017, Wedding 2016] it is also known as temperature integrity that must be preserved from the point of production, processing, through each of the transport stages – handling, loading, unloading, and storage – and extends to storage at the consuming household [Salin, Nayga 2003]. This concept has been evolving since the 1980s [Fernie, Sparks 2004], because earlier, chains simply meant storing at a specific temperature in warehouses and refrigerated vehicles [Bharti 2016]. The changes started taking place with the advent of chambers capable of storing at different temperature ranges [Duiven, Binard 2002], advanced transportation system [James et al. 2006] and the shortening of ordering and replenishment cycles [McKinnon, Campbell 1998].

Moureh and Flick [2004] particularly consider transport as an important link in the chain as temperature maintenance is critical in order to preserve, safety and shelf life of food. Moreover, some warehouses can have poor temperature maintenance and control, while others do not have different temperature storage facilities so all the freight is stored at the same temperature [Hofstra 2018].

Chatzopoulou [2015] warned that food products that are transported in long distance for long periods of time before reaching retailers or processing factories require special refrigerators and temperature conditions. The situation is more complex if we take into account that due to cheaper operational costs and the need to deliver food products to all parts of the world almost all food companies have outsourced their transportation activities to the third party logistics (3PL) service providers [Elmuti, Kathawala 2000]. As the same temperature should be ensured during transportation and storage in the supply chain, the logistics service providers (LSP) have the greatest responsibility [Zulfakar et al. 2014] and have already implemented some technologies for temperature tracking [Raab et al. 2011]. There is a certain amount of literature regarding the significance of technological progress made in the field of temperature monitoring systems [Raab et al., 2011], from conventional thermometry [Taoukis, Labuza 1989], electronic data loggers [Bharti 2016], time–temperature indicators (TTIs) [Bharti 2016, Kumar, Budin 2006, Sahin et al. 2007], to wireless communications systems like wireless wide area networks (WWAN), wireless local area networks (WLAN), and wireless sensor networks (WSN) systems [Wang et al. 2006, Ruiz-Garcia et al. 2009]. Moreover, some works [e.g. Amador et al. 2009, Ruiz-Garcia et al. 2009] discuss increasing the application of Radio frequency identification technology (RFID) combined with temperature sensors can monitor temperature conditions within the supply chain during recent years. Advantages from using technology solutions in temperature tracking include the reduction of costs for logistical operations, minimization of product value losses, decision-making support, meeting food safety requirements and improved communication within the chain [Sahin et al. 2007, Kang et al. 2012].

Regulation Issues

In order to ensure food integrity and to have safe foods, there is a wide range of different standards, regulations and certifications in the food sector [Rehber 2012]. They are based on domestic law and practice and also operate within an international framework of rules and agreements. Increased globalisation has led to food safety hazards [Manning, Baines 2004] and resulted in a complex network of public and private incentives to implement enhanced food safety controls [Martinez, Poole 2004]. Spink and Moyer [2011] discuss about changes in food safety approaches which ranged from reactive tactics to proactive strategy with preventative measures such as the Good Manufacturing Practices (GMPs) regulations, the Hazard Analysis Critical Control Points (HACCP), and Good Hygienic Practices (GHPs).

Verbruggen [2016] made a significant contribution to understand the actors involved in the regulatory governance of food safety clasifying them into public or private actors at the national or transnational level. He was discussing about co-regulation between public and private regulatory activities, at national and international sphere as a regulatory strategy to ensure the safety of food supply. It can help to reduce the administrative burden of regulation on business and promote more efficient approaches to regulatory inspections and the management of food safety, particularly in relation to enforcement and monitoring activities [Martinez et al. 2013]. At a global level, there are the international trade agreements developed by the World Trade Organisation (WTO). The United Nations Food and Agriculture Organization (FAO) and World Health Organization (WHO) established Codex which adopted one of the key standards related to food safety - the Hazard Analysis and Critical Control Points (HACCP) standard [Verbruggen 2016]. The measures cover „all stages after primary production, during preparation, processing, manufacturing, packaging, storing, transportation, distribution, handling and offering for sale or supply to the consumer" [Manning, Baines 2004]. There is the Agreement on the International Carriage of Perishable Foodstuffs and on the Special Equipment to be used for such Carriage which establishes standards for the international transport of perishable foodstuffs between the states that ratify the treaty ECE/TRANS/271. [2017].

With the rise of non-state food safety standards a group of globally leading retailers established the Global Food Safety Initiative (GFSI) which can be considered as a transnational meta-regulator in the field of private food safety governance [Verbruggen and Havinga]. The European Commission is the key institutional actor on the public level, at a regional sphere. The quantity of European legislation regarding food is overwhelming [van der Meulen 2013]. The EU's General Food Law has objectives to facilitate the free trading of food across all EU countries by ensuring the same high level of consumer protection in all Member States. It covers all parts of the food chain from animal feed and food production to processing, storage, transport, import and export, as well as retail sales. European Food Safety Authority (EFSA) provides scientific advice to the European Commission and EU countries, to help them take effective decisions to protect consumers. It also plays an essential role in helping the EU respond swiftly to food safety crises [European Union Explained, 2014].

At a national level, many ministries and departments are involved in food safety regulations. The Food Act (Official Gazette No. 46/07) is the basic framework law on food safety in Croatia. The Food Act transposes the provisions of Regulation (EC) No 178/2002 and provides the basis for the assurance of a high level of protection of human health and consumers' interest in relation to food [Miškulin et al. 2013].

RESEARCH METHODOLOGY

For the purpose of this research, a qualitative study was applied. Face to face interviews were conducted in the four (4) leading logistics companies in the cold chain segment, which provide logistics solutions, from taking delivery of the goods from the manufacturing company to the point of sale. The companies were chosen due to the growing importance of this industry in Croatia and in the European Union, as well. The Croatian road transport industry is marked by small companies, most of which own a fleet of under 5 freight vehicles. The concerning fact is that the average age of the road transport companies' fleets in Croatia has been growing, especially for the reason of higher road charges for older vehicles in most of the EU member states. One of the key issues for the Croatian road transport industry is its fragmentation [Žibret, Čorak 2012] and there is no such company that could significantly influence the profitability of this industry [Naletina 2016]. In 2015, there were 3 222 active companies that registered their activities in the road transport industry [Companies Registry 2017]. It is important to point out that most of the Croatian transport companies deal with general and bulk transport, while those specialized in dangerous goods transport, food products transport or special freight, are rare. It is for these reasons and for the purpose of conducting this research, that the sample comprises the largest companies which deal with road transport of food products. Relating to that, most of the food industry companies transport the goods using their own fleet of vehicles.

Interviews were conducted from July to September 2017 and lasted approximately one hour. The research instrument was structured as an interview remainder, which consisted of 21 questions altogether. The questions related to the number of freight vehicles in the fleet, the number of employees, the importance of the preservation of food quality and safety, and the certifications they possess. Furthermore, the research focused on the way companies ensure food safety, i.e. providing cold chain integrity, and the education of employees on the prescriptive regulations on hygienic practices. Then, the respondents answered questions about food storage; storage equipment for different temperature regimes for preserving different types of foods, as well as how they are equipped with refrigerated vehicles, cold refrigerators and storage. The respondents also commented on the critical phases in the food handling process; the way they enable control and the listing of the achieved temperatures in the transport vehicles during transport; and the anticipated challenges in the future related to maintaining food safety and quality. Companies' and respondents' characteristics are listed below (Table 1).

Table 1. Characteristics of Logistics Service Providers and Socio-demographic Characteristics of the Respondents

Name of the company	No of freight vehicles in the fleet	No of employees	Function	Gender	Age	Professional qualification	Years in the company	Quality certificates
LSP1	150	from 50 to 250 employees	Transport organization and logistics specialist	M	from 26 to 35	SSS	2 years	HACCAP ISO 9001 ISO 14001
LSP2	50	from 50 to 250 employees	Vehicle fleet manager	W	from 26 to 35	VSS	10 years	FRC
LSP3	10	from 50 to 250 employees	Head manager	M	over 56	VSS	25 years	HACCP IFS
LSP4	200	more than 250 employees	Dispatcher	M	from 26 to 35	VSS	5 years	ISO HACCP IFS

Source: own work

Research Results

Companies base their business on the quality of their services in order to completely satisfy their customers. Therefore, in order to ensure that high quality products are transported properly, the companies operate in accordance with the principles of HACCP, ISO 9001, ISO 14 001, IFS, FRC standards.

Ensuring the Integrity of the Cold Chain

Companies state that they offer a high degree of security and assure that what clients produce reach the consumer without affecting the quality of the product. Therefore, they put special emphasis on the traceability in the cold chain because a break in the traceability of temperature leads to food spoilage and as such, can cause health hazards. In order to avoid the distortion of food quality and product safety, companies mention they have work procedures in place and they have work procedures within each activity. The whole process of food transport in the cold chain is followed by IT technology, meaning that at any time temperature in the chamber can be read. Due to the WMS system for warehouse management, companies can follow product traceability, the location of the product in a retail store as well as the transport vehicle in which the product was delivered, in order to be able to react promptly and in necessary cases, withdraw the product.

In order to operate successfully, it is important to invest in employees, so as to better perform their duties in the hiring of employees depending on the function to be performed passing the definition of training and familiarization with the work of the LS company. So, during the employment phase, the company has made special manuals to help their employees carry out their functions and meet special requirements that need to be respected during the handling of sensitive products. For instance, the company has a special manual which consists of all the information that drivers need to know to do their job safely and in accordance with the rules and principles. All employees have the necessary sanitary booklets.

As certain food groups require special temperature regimes, companies divide the food categories into separate food groups. There is the example of temperature conditions, which has divided food categories into nine groups according to the required prescribed temperature. Table II shows the transport temperature conditions according to the type of the food and the operation of the chiller machine. Normally, retail companies, as well as transport companies, divide the food category into the subcategories FOOD I and FOOD II. The required temperature conditions for meat and meat products, fish and fish products, eggs, milk and milk products, fruit and vegetables, bakery and cereal products, combined products, oils and fats and dried products are shown in the Table (Table 2). Permanent work means that aggregates are constantly working and maintaining the same temperature, while the start-stop indicates that the aggregates are on or off.

Table 2. Transport Temperature Conditions according to the Type of Food and the Working Mode of the Chiller Machine

Product category	type of food	temperature	working model
Meat and meat products	fresh meat deep frozen meet minced meat poultry meat offal of domestic ungulates meat products canned meat products	+2°C to +4°C -18°C max. +2°C max. +4°C +4°C +4°C to +8°C +10°C to +25°C	permanent start-stop permanent permanent permanent start-stop start-stop
Fish and fish products	fresh fish frozen fish fish products canned fish	0°C to +2°C -18°C +4°C to +8°C +10°C to +25°C	permanent start-stop start-stop start-stop
Eggs	fresh eggs egg powder pasteurized eggs in the bag frozen eggs	+4°C to + 8°C +10°C to +25°C + 2 °C to +4 °C -18°C	permanent start-stop permanent start-stop
Milk and milk products	UHT milk fresh milk cheeses and cheese spreads yoghurt, sour cream and related products butter frozen dairy desserts	+10°C to +25°C +4°C to +8°C +2°C to +6°C +2°C to +6°C +2°C to +6°C -18°C	start-stop start-stop start-stop start-stop start-stop start-stop
Fruit and vegetables	frozen fruits and vegetables in containers fresh fruit and vegetables compotes and preserves pickled vegetables in containers marmalades and jams	+4°C to +12°C -18°C +10°C to +25°C +10°C to +25°C +10°C to +25°C	permanent start-stop start-stop start-stop start-stop
Bakery and cereal products	transportation of deep frozen raw pasta products start-stop finished products made of dough – dry products bread and pastry products – products for consumption without heat treatment	-18°C to -25°C +15°C to +20°C +10°C to +15°C	start-stop start-stop
Combined products	chocolate candy biscuits and related products	+15°C to+20°C +15°C to +20°C +15°C to +20°C	start-stop start-stop start-stop
Oils and fats	oils fats	+10°C to + 20°C +5°C to +10°C	start-stop start-stop
Dried products	dried fruits and vegetables in containers dried nuts in packaging dried seeds in the package	+10°C to +25°C +10°C to +25°C +10°C to +25°C	start-stop start-stop start-stop

Source: own work

Storages are fully equipped with the appropriate cooling systems that maintain the temperature. There are three types of temperature regimes: (1) frozen (-18°C to -

25°C), (2) cold (0°C to +8°C) and (3) ambient (10°C to +25°C). In order to ensure an adequate temperature, storage areas are equipped with measuring devices, and all the measuring devices that are found in the warehouses are connected to the associated program by which employees can monitor and regulate the temperature on the computer. The person responsible for setting up the temperature can, at any given moment, control the temperature level in each warehouse. For example, in a storage area, there are three sensors at different locations, at the entrance, in the middle and at the end of the warehouse, and based on these temperatures, the program shows the average storage temperature. In addition, besides the proper temperature, storages should be disinfected after storing certain types of food in order to prevent contamination. The storage space has a specific market spot for food manipulation and a space in which employees can walk.

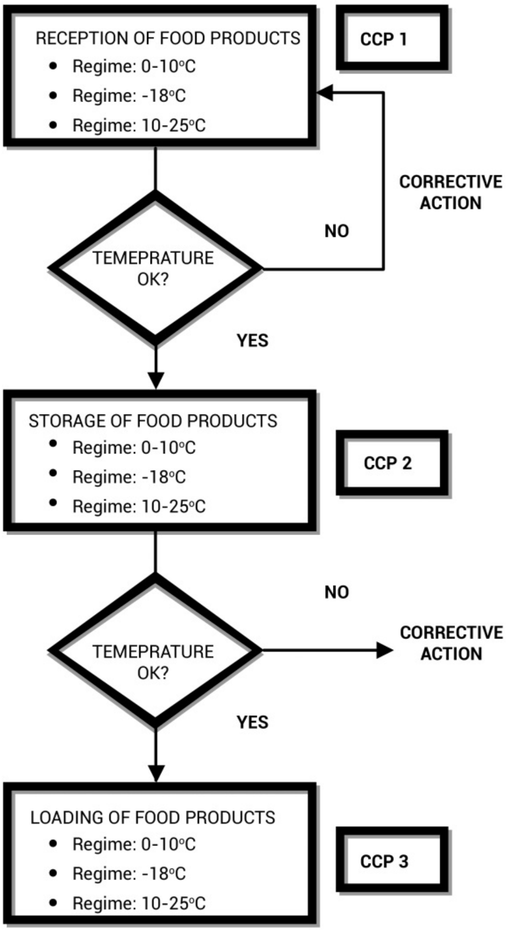
The process of transporting food from manufacturers to retail stores is temperature-controlled. The process can be described as follows: the company receives a food transport order from the manufacturer, in which the manufacturer specifies the type of food transported, the amount, the date and the addresses for loading and unloading and the temperature regime that the food requires. The company then issues an order for shipping with all the necessary information: the number of vehicles, the type of vehicle, the time and address for loading, the type of goods, weight, temperature, note on the loading, the number of pallets, the unloading time and address and the name of the driver. The entire process of the collection and delivery of goods must be accompanied by a specific form as prescribed under HACCP principles. After the driver receives the order, he takes the food over to the pre-determined address. On the order, the driver writes the data, such as: the date, time and place of loading, the type and quantity of goods and the temperature at which the goods were taken. The form must be confirmed by the manufacturer that the food was taken from. When the vehicle reaches the destination for unloading the form shall contain the following information: the date, time and place of unloading, information about damage, if any, the type and quantity of goods and the temperature at which the food is unloaded. To finish the procedure, the signature and seal of the person who took over the goods is needed. The form must include the number and licence plate, also the way of cleaning the vehicle before loading (swept, washed with water, disinfected) should be indicated. Together with this form, a temperature form obtained from the printers that are located on the vehicle and connected to a cooling device if the vehicle has to be attached. The printed pages show the temperature level for every hour during the transport of goods. With this form, the company ensures that the transportation service was provided as well as the delivery of goods, respecting the prescribed temperature regime and food safety during transport.

During the processes of storage and transportation, the food is going through critical phases. The following figures show the warehouse and transport processes by flow diagrams. Flow diagrams capture all the phases of storage (Figure 1) and distribution of the food products.

Food Storage Process

The first activity is the receipt of the food products, which represents the first critical control point (CCP1) of the process. If the temperature is not appropriate, corrective actions are needed, otherwise the process continues. The next process is food storage at an adequate temperature, which represents second critical control point (CPP2). If the temperature is not appropriate, corrective actions are needed, otherwise the process continues. The third critical control point (CCP3) is checking the temperature during loading the food into the transport vehicle.

Every step in the warehouse process, together with the list of activities which are taken care of during that process and the temperature limits are shown in Table 3.



Source: own work

Fig. 1. Storage Flow Chart

Table 3. Description of Storage Process

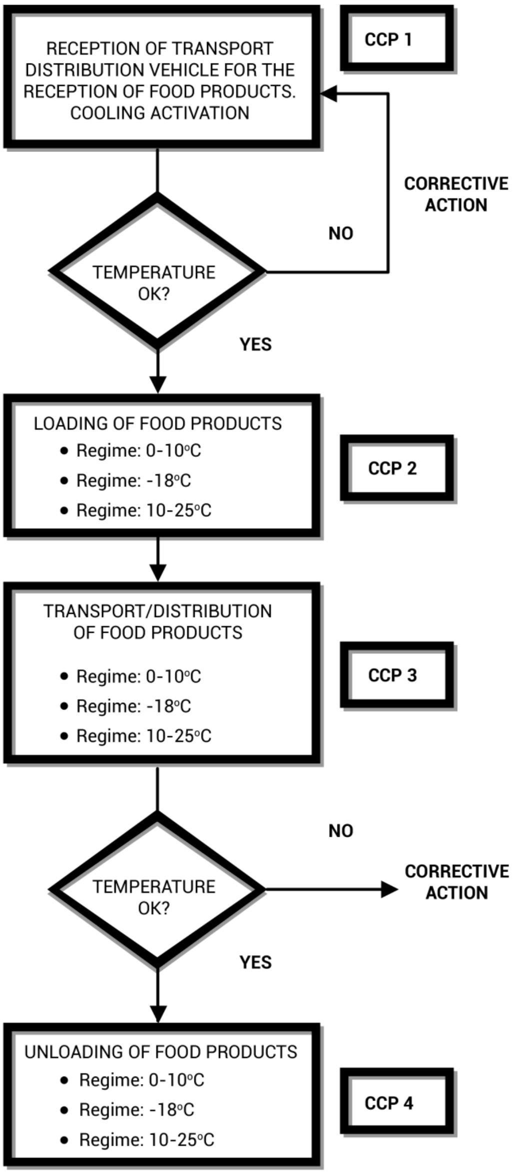
Step	Description of activities	Temperature limits
Reception	• measuring the temperature of the goods • damage control • thermographic picture of the vehicle • supporting documents for the goods • control of the agreement of the documentation with the facts	regime: 0-10^{0}C regime: -18^{0}C regime: 10-25^{0}C
Warehousing	• temperature control in the warehouse • thermographic printing • correctly and neatly stacking of goods under a pre-arranged schedule • control of WMS system	regime: 0-10^{0}C regime: -18^{0}C regime: 10-25^{0}C
Loading	• temperature measurement • thermographic printing of chamber before loading	regime: 0-10^{0}C regime: -18^{0}C regime: 10-25^{0}C

Source: own work

Process of Food Transportation and Distribution

Figure 2 shows the flow chart of the transportation and distribution process for food products. As can be seen from the diagram, this process has four (4) critical control points. The first critical control spot is preparing the vehicle for the transport of a certain type of food. The temperature should be appropriate for the prescribed type of food being transported, and if this is not the case, the process is stopped in order to prepare the vehicle for transport in the appropriate conditions. The second critical control spot is the loading of the goods into the vehicle, where employees are checking that the conditions are according to the prescribed ones. The third critical control spot is the transport and distribution of the food at the given temperature regime. Here, employees are checking whether the temperature is matching the regime, otherwise, the corrective actions are in place. If everything is satisfactory, the process continues. The last critical control point is unloading the food in the prescribed conditions.

Table 4 describes every step which must be taken during the transport and food distribution process.



Source: own work

Fig. 2. Transportation and Distribution Flow Chart

Table 4. Description of the Transport and Distribution Process

Step	Description of activities	Temperature limits
Vehicle preparation	• measuring the temperature of the goods • damage control • thermographic picture of the vehicle • supporting documentation on the goods • control of the agreement of the documentation with the facts	regime: 0-10^{0}C regime: -18^{0}C regime: 10-25^{0}C
Loading of the vehicle	• temperature control of the goods • thermographic printout • correctly and neatly stacking of goods according to pre-existing practices	regime: 0-10^{0}C regime: -18^{0}C regime: 10-25^{0}C
Transport / Distribution	• thermographic printout • HACCP form for the transport • ensuring the goods against damage	regime: 0-10^{0}C regime: -18^{0}C regime: 10-25^{0}C
Unloading	• measuring the temperature of the goods • damage control • thermographic picture of the vehicle • supporting documentation on the goods • control of the agreement of the documentation with the facts	regime: 0-10^{0}C regime: -18^{0}C regime: 10-25^{0}C

Source: own work

CONCLUSIONS

If, during food distribution food changes its biological, chemical or other characteristics, its quality, safety and healthiness could be challenged. Accordingly, food integrity is questioned. It is therefore important to stress and emphasize the importance of temperature monitoring at every link in the supply chain. The value of this paper is in elaborating on the food conditions needed in the warehouse and transportation vehicles in order to maintain the integrity of the temperature-controlled supply chain and food quality during distribution from the production to the consumption phase of the supply chain. The research results are of both, academic and industrial value, as they show how to accomplish food security and preserve food quality during the distribution phase in food supply chain management. The main limitation of the conducted study is that it is case-based, on the sample of four logistics service providers. Preferably, future studies should stress the whole food supply chain and give the perspective of all chain members, not only the logistics service providers as the focal companies.

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INTEGRALNOŚĆ ŻYWNOŚCI W ŁAŃCUCHU DOTAW: DOBRA PRAKTYKA DYSTRUBUCYJNA

STRESZCZENIE. **Wstęp:** Obserwuje się wzrastającą rolę zarządzania łańcuchem dostaw ze względu na fakt, że klienci coraz bardziej zwracają uwagę na bezpieczeństwo żywności i jego, jakość, co wywołuje popyt na produkty o odpowiedniej i stabilnej, jakości. W trakcie dystrybucji żywność jest narażona na różnego rodzaju ryzyka, takie jak nieodpowiednie przechowywanie lub niedotrzymanie wymaganej temperatury. W pracy omówiono procedury stosowane przez dystrybutorów dla zapewnienia bezpieczeństwa żywności oraz jej, jakości w całym łańcuchu dostaw.
Metody: W pracy zastosowano jakościowe podejście do problem. Zostały przeprowadzone bezpośrednie wywiady w czterech wiodących przedsiębiorstwach logistycznych z obszaru chłodniczego, które oferują usługi dostawy produktów od producenta do punktu sprzedaży.

Wyniki: W celu zapewnienia wysokiej jakości transportu produktów, ryzyka są zarządzane efektywnie. Przedsiębiorstwa pracują w zgodzie z różnymi standardami, po wypracowaniu procedur odpowiednich dla poszczególnych obszarów łańcucha dostaw w celu uniknięcia pogorszenia jakości i bezpieczeństwa żywności. Cały proces transportu żywności jest nadzorowany przez narzędzia IT, poszczególne grupy żywności są podzielone w dziewięć grup w zależności w wymaganej temperatury przechowywania. Ze względu na specyficzne wymagania obchodzenia się z wrażliwymi produktami, przedsiębiorstwa kładą istotny nacisk na inwestycje w pracowników.
Wnioski: Integralność żywności jest koncepcją holistyczną, powiązaną z produkcją żywności, jej dystrybucją, bezpieczeństwem i jakością. Łańcuch dostaw żywności, długi ze swojej natury, globalny i nieciągły, naraża żywność na różne ryzyka i wymaga monitorowania temperatury na każdym etapie łańcucha, szczególnie w magazynach oraz w środkach transportu. Specjalny nacisk jest położony na narzędzia IT oraz na pracowników.

Słowa kluczowe: łańcuch dostaw żywności, integralność żywności, bezpieczeństwo żywności, dobra praktyka dystrybucyjna, dostawcy usług logistycznych, Chorwacja

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ORIGINAL PAPER

THE LOCATION OF AN INTERNATIONAL LOGISTICS CENTER IN POLAND AS A PART OF THE ONE BELT ONE ROAD INITIATIVE

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ABSTRACT. **Background:** The One Belt One Road initiative opens up many development opportunities for Central and Eastern European countries, some related to the possible construction of a logistics center in this area. For Poland, such an investment would also bring many benefits, not only due to infrastructure development, but also through acceleration of economic growth and job creation. In this context, the crucial issue becomes, what should be the role of an international logistics center and where should it be located. Due to the novelty of the subject, there is a shortcoming of scientific papers related to this issue. The scientific goal of the present paper is to fulfill the gap and to address the question of the role of logistics center and to examine the most prospective future sites for an international logistics center in Poland as well as to formulate an opinion about most favorable location.

Method: This is a review article, theoretical in character. The method used is the analysis of literature sources. As the issue of the choice and location of an international logistics center in Poland on the New Silk Road is the new one, there are very few scientific papers devoted to this subject, and in Polish language only. That is why the authors had to use besides scientific papers the website's sources.

Results: In this paper, a classification of logistics centers, and a discussion of factors that are taken into account in the choice of location for such an investment have been presented as well as the discussion of the advantages and disadvantages of various locations, and of the most likely choice.

Conclusion: Stanisławów (located between Warsaw and Łódź) is the most likely location for an international logistics center servicing the NSR in Poland. Other sites, such as Łódź, Gdańsk or Gorzyczki could provide auxiliary, regional distribution centers.

Key words: logistics center, One belt One Road, New Silk Road, location, Poland.

INTRODUCTION

Clearly, logistics centers are important components of the infrastructure of every country. They stimulate economic growth, streamline the flow of goods and improve the efficiency of supply chains. Global forecasts indicate that logistics centers, both industry-wide, local, regional and international, will decisively shape supply networks. In the context of the New Silk Road (NSR) initiative, which is bound to change the prevailing international order, the role of logistics centers in the development of Central and Eastern European countries may become even more important. The NSR encourages the creation of a logistics platform with complete infrastructure, one that not only helps China expand, but also supports a deliberate shaping of international economic relations. This trade route will have a significant impact on the operation of global supply chains by shortening the time it takes to transport goods and by expanding interconnections of infrastructure, finance and IT. The New Silk Road opens up opportunities for Poland to play the role of an important logistics hub and distribution center for goods exported from China to EU countries. Poland's strength lies in its geographical location, allowing goods to reach their destination by crossing no more

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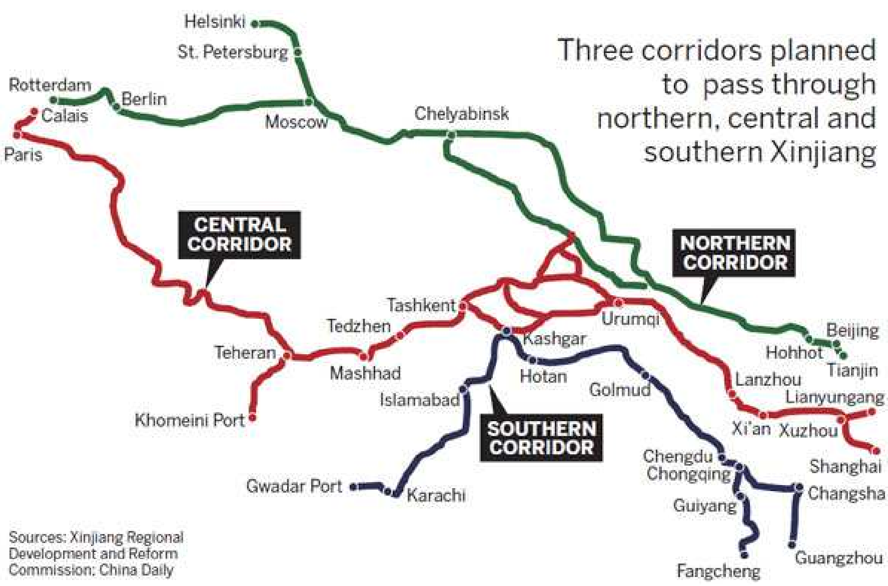
than two customs borders. This is due to the fact that Kazakhstan, Russia and Belarus form a customs union within the Eurasian Economic Union. It is important to see the NSR as a logistics corridor, in which logistics centers will play pivotal role. This is where various branches of transport will meet, ensuring continuity of the flow of freight [Kazak et. al. 2018].

The growing importance of the NSR prompted the authors to consider the possibilities of locating an international logistics center in Poland, and to point out its importance for the country's economic development. The scientific goal of the paper is to elaborate a content-related opinion on the optimal location of a logistic center in Poland, which would be part of New Silk Road. As a research method, literature studies were used. This review article, theoretical in character, consists of three parts. In the first, the NSR initiative is described; in the second, a number of definitions of a logistics center, their classification and factors affecting the choice of location are presented. In the third part, potential locations of an international logistics center in Poland are discussed. The article concludes with a discussion of the preferred location of the international logistics center in Poland.

ONE BELT, ONE ROAD INITIATIVE AND LOGISTICS CORRIDORS

In 2013, Xi Jinping, China's President, proposed a new initiative to its neighbors and trade partners which was named as "One Belt, One Road" (after OBOR). This program is aimed at improvement of trade connectivity among OBOR economies and also countries on the main sea routes from China. The media and public opinion have already hailed this new project as the New Silk Road of our times. In fact, the initiative attracts much attention as it will affect about 65 countries, 4.4 billion people and 63 percent of the global population [Kong 2017]. The main aims of this project, apart from China's strong desire to strengthen its position on the world arena and escape "the trap for middle-income countries", are as follows:

– investment infrastructure and new trade routes as tools to spread economic development around the world,
– global partnerships networks as the source of interdependence of China and other countries and regions, and focus on Asia as part of the new "neighborhood diplomacy".



Source: http://www.chinadaily.com.cn/business/2014-06/28/content_17621525.html

Fig. 1. Three corridors planned to pass through northern, central and southern Hinjang

Indeed, the NSR seems to be a logistic corridor which will offer efficient and seamless transport of cargo. The New Silk Road (NSR) will fill all the existing gaps in the corridor with a help of overall coordination of various transport services and actions designed to eliminate slowdowns, e.g. due to border inspections [Nazarko at al. 2016]. To achieve this, not only "hard" (infrastructure), but also "soft" criteria have to be met, i.e. regulatory reforms in service markets, including transport, logistics, and telecommunications [LPI 2016].

There are three main alternative corridors along the NSR (Fig. 1) and Poland is part of one of them :

1. The Northern Corridor: This corridor starts in Kazakhstan, passes the Russian mainland, and reaches Belarus and Poland as a gate to Europe. It uses the Russian Trans-Siberian Railway line. It is already operational. Amongst the three alternatives, this variant involves the smallest number of border crossings.
2. The Southern Corridor: It begins Kazakhstan, passes through Turkmenistan or Kyrgyzstan and Tajikistan, Iran and Turkey. It enters Europe via Turkey. The main disadvantages of this corridor are many border crossings and political instability in the region.
3. The Middle Corridor: It starts in Kazakhstan and leads to the Kazakh Caspian port of Aktau. It continues by sea to the newly built Azeri port of Alat. It passes through the South Caucasus and connects with Europe via Turkey. The main disadvantage is transport inter-modality [Nazarko at al. 2016].

International logistics corridors have many benefits. First of all, they significantly reduce transit time and costs, thus expanding access to markets and opening new opportunities for regional industries. They eliminate infrastructural bottlenecks and increase the technical and organizational interoperability of national systems. However, it should be noted that the development of these corridors requires the presence of efficiently functioning intermodal logistics centers that act as load generators and play the key role of nodes in transport systems and supply chains [ctc-egtc.ed 2018]. Therefore, to make them feasible, new logistics centers, dry ports [Oláh et al. 2018, Oláh et al. 2018a], airports with ensured customs clearance and storage services should be built and economic zones with tax incentives along the corridor should be created [Nazarko et al. 2016].

The New Silk Road creates an opportunity for Poland to become an important logistics hub and distribution center of goods exported from China to the European Union member states. Poland's strength is its geographic location, which allows freight to reach its destination with only two border crossings. An analysis of the possible locations for a logistics center in Poland is preceded by a discussion of the meanings of the term "logistics center" and of the main criteria influencing the choice of location for such a center.

LITERATURE REVIEW – DEFINITIONS OF A LOGISTICS CENTER

Market globalization, the development of innovative technologies and the search for new business models to make the delivery of goods through global supply chains more efficient, led to the rapid development of logistics centers. The latter offer facilities for the consolidation and distribution of goods, labelling, assembly and sometimes even processing that adds value. Though the first such facilities were built over 30 years ago, no single, universally accepted definition of a logistics center has emerged yet. On the one hand, this lack of terminological consensus is the consequence of the fact that "logistics researchers have made little effort to build a unified logistics conception" [Rimiene K., Grundey 2007], and there are shortage of standard methodologies for selection of decision criteria on the other. Regional terminological preferences are also a contributing factor [Rodrigue et. al., 2010]; e.g. in United Kingdom the term freight villages is used [Baydar, Süral, Çelik 2017, Izdebski at. al. 2017]; in France - platformes multimodales/logistiques; in Germany – Güterverkehrszentern; and Interporti in Italy

(These centers differ not only in name, but also in the way they operate. This will be described below). The term "logistics center" is most commonly used in the USA, Japan, China and Singapore [Europlatforms EEIG 2018]. Since logistics centers are usually seen as the places where different means of transport converge, they are often referred to as intermodal centers [Erfurth, Bendul 2017]. This leads to another problem, due to differences in the interpretation of the concept of intermodal transport. A fragmented description and discrepancies in the definition of a logistics center are the inevitable outcome [Notteboom, Rodrigue, 2009]. An extensive review of the definitions of a logistics center in the current literature can also be found in Higgins, Ferguson and Kanaroglou [2012]. For the purposes of the present paper, it seems best to treat a logistics center as: (1) an element of logistics infrastructure, and (2) a business entity. Both perspectives highlight the role and importance of centers in the modern economy. The New Silk Road project, which involves the expansion of rail and maritime connections between China and countries in Eurasia and Africa, gives rise to expectations in Poland and many other countries of new investments and acceleration of economic growth.

Bearing in mind the fact that the NSR would transit through Central and Eastern European countries, including Poland, logistics centers should be considered in the context of infrastructure, as transshipment points and intermodal terminals of the highest complexity. They are the main elements of regional and international macrologistics systems, linking streams of goods flowing through global supply chains. They are an integrator of various transport modes, able to promote intermodal transport [Higgins, Ferguson., Kanaroglou 2012]. From an infrastructure-oriented perspective, logistics centers are components of an integrated transport chain. This is where the greatest number of infrastructure elements related to the services provided is located [Francik et. al. 2017]. In the context of the Silk Road, it seems useful to define a logistics centre as "[…] an area within which all activities relating to transport, logistics and the distribution of goods, both for national and international transit, are carried out by various operators" [Europlatforms EEIG 2018, Uyanik, Tuzkaya, Oğuztimur 2018]. Winkler and Seebacher [2011] define the logistics center in a similar spirit: "logistical interconnection points within a logistics network that primarily function as an interface between local and long-distance goods transport". Logistics centers are multifunction terminals, equipped with the necessary infrastructure and organization, providing logistics services related to the taking of deliveries, storage, distribution and dispatch of goods, as well as added value services, provided by independent businesses.

Bearing in mind the pursuit of economic growth by the respective countries and their expectations of economic benefits connected with the NSR project, it seems reasonable to treat logistics centers as business ventures. In this approach, a logistics center is an organization bringing together many businesses, which provide services to other businesses. From the business-oriented point of view, a logistics center is a group of enterprises operating in the transport, forwarding, logistics and other service industries, as well as production and trade enterprises, operating independently or as members of larger entities of various types. Such a structure is usually headed by a special organization, the so-called board, responsible for the development and proper operation of the center as a whole. Thanks to integration and cooperation, such entities can rapidly acquire new expertise, competencies and technologies to streamline logistics processes. Economic benefits are built into the very concept of the center, established in order to allow the entities comprising it to operate in favorable conditions and to ensure competitive advantage. In this context, a logistics center is "[…] a place of logistics services provision or logistics activities concentration place, through which large companies realize business service tasks of their customers" [Palsaitis, 2004]. UNESCAP [2009] defines a logistics center as "an area of land dedicated to a number of transport and logistics facilities, activities and services, which are not just co-located but also coordinated to encourage maximum synergy and efficiency. Distinguishing features include an intermodal terminal and shared access to facilities and services". Rimiene and Grundey, on the other hand, describe a logistics center as "a village planned and built to best manage all the activities involved in freight movement. Logistics centers are seen as promoters of local consolidation, intermodal transportation, and regional economic activity" [Higgins, Ferguson., Kanaroglou 2012]. Logistics centers understood in this way are carefully planned solutions, which allow the distance from suppliers to recipients and storage area along supply chains to be reduced. This helps businesses optimize their operations and flexibly respond to changing market needs, stimulates business activity and national/regional economic growth. In order to take full advantage of the opportunities offered by a logistics center, its location should allow access not only to local entities but also (and perhaps most importantly) to foreign ones. This increases the competitive advantage of the center and facilitates its integration with global supply chains.

Considering the route of the Silk Road, it is clear that, due to their geographic location, Central and Eastern European countries, including Poland, are well-positioned to build and expand competitive international logistics centers, linking Eurasian transport networks.

CLASSIFICATION OF LOGISTICS CENTERS AND THE FACTORS THAT DETERMINE THEIR LOCATION

The construction of logistics centers along the Silk Road to service freight streams and direct them from China to destination markets should be in the interest of every Central and Eastern European country. The choice of location for a center brings very large investments and economic benefits, not only to the state – in the form of budget revenue – but also to many enterprises in the construction, IT and production sectors. The question arises where such a center should be located and what criteria the Chinese investors will take into consideration in their choice of its location. Indeed, this is the classic problem of choosing a location.

The problem of location is connected with the determination of the spatial distribution of infrastructure elements in a given area, taking into account investor preferences. The problem has been extensively discussed in the literature [including: Özcan, Celebi, Esnaf 2011; Żak, Węgliński 2014], mainly due to its strategic significance and the often irreversible nature of such a decision. Location decisions are made in the context of a certain economic and spatial system, which creates specific conditions for actions designed to optimize the placement of the newly planned facilities.

Choosing the right location for a logistics center is not easy. Usually, many criteria are taken into account, such as:

- technical (usability) – including road density, efficient telecommunications networks, the number of potential contractors, storage infrastructure, intellectual resources;
- economic – capital expenditure, annual operating costs, the measures of cost (e.g. the cost of moving a unit of cargo), development trends indicators, share in international turnover,
- hard to measure, including reliability, flexibility, scalability.

Usually, however, the choice of location for a logistics center boils down to finding the lowest costs, while taking into account multiple sources of raw materials and distribution of finished products [Wiśniewski 2015, Wichmann et al. 2015]. This means that economic factors are given priority. They are three key economic factors determining location choice: land, labour and capital. The construction of the center in an urban area is more expensive, due to higher real estate prices. Labour costs are closely related to income levels in a given area, and the importance of capital increases with economic incentives (e.g. economic zones) for potential investors [Cheba, Kiba-Janiak 2017]. The extent of involvement is not without significance. If it is relatively large (as it will be in the case of a center built to meet the needs of the Silk Road), to the above-mentioned factors, others must be added, such as macroeconomic, environmental and urban; a regional/national development strategy is also important.

The choice of location should always be carefully thought out and based on detailed studies. This is particularly important if the center is to occupy a large area or needs well-equipped facilities and communication infrastructure. The center serving freight movement along the NSR will have to meet such criteria. Therefore, the decision concerning its location could be based on the criterion of intermodal transportation, and result in the choice of a site near the transportation corridors comprising the Silk Road. Another solution would be to locate such a center in sea port or near an airport. In this case, the main criterion is the easy accessibility of the ports involved in international trade. Van Thai and Grewal [2005] listed eight factors they believed to have the greatest impact on the choice of a seaport or airport: availability of suitable handling equipment, the percentage of lost or damaged consignments, convenience and reliability of pickups and deliveries, frequency of port calls or landings, efficiency of seaport or airport operations, strategic location, competitive fees and taxes, speed of response to customer needs and expectations. The proposed list of factors is an example of a comprehensive approach to the problem of choosing the best location for a logistics center. Nevertheless, the choice of any option must be based on many parameters, which determine or at least affect the final location decision.

NSR AND LOCATION OF AN INTERNATIONAL LOGISTICS CENTER IN POLAND

It is in Poland's interest that an international intermodal logistics center should be built within its borders, serving freight streams and directing them to their destination countries. The radius of the area served by such an international logistics hub is estimated at 500 to 800 km. It must be equipped with a full-featured, advanced infrastructure and a comprehensive IT system, and must offer the full range of logistics services . Such a project offers the unique opportunity for investment and modernization of transport infrastructure, mainly railways. A center located in Poland would bring very large investments and contracts, from which many companies in the construction, IT and production industries would benefit. It would also create many jobs. The construction of such a center would strongly stimulate the growth of road and rail carriers and forwarders, intermodal transport and Polish trading companies. It would also bring significant state budget revenues.

Of course, other countries, including Poland's immediate neighbours, are also aware of the opportunities such an investment would bring. Therefore, while it is important to exercise caution in making such decisions – concerning, for instance, the principles on which Chinese capital would participate in Polish investments, so as to erasure a controlling stake for the Polish side – it is also important that such decisions should be made without unnecessary delay. Otherwise, Germany, the Czech Republic or Hungary – countries more advanced than Poland in economic cooperation with China – will reap the benefits of building a European logistics center. It will be crucial to prevent the loss of such a project due to inaction, political conflicts or disputes over location.

Poland has a number of advantages, for example, in infrastructure. Significant progress has been made over the last couple of years. The Polish road network has been improved. It has been expanding since 2007, when the first 100 km of new highways were built. A further 200 km of highways were added in 2012, and in 2013 another 330 km of expressways and 300 km of highways. The National Road Construction Program for the years 2014-2023 (with a possible extension to 2025) adopted by the government assumes the construction of approximately 3,900 km of highways and expressways.

Poland's flagship project is the modernization and expansion of the Gdańsk port, which is gaining in importance as a container port in the Baltic. The port is growing rapidly and keeps investing in container transshipment, which was rewarded by the inclusion of the port in the prestigious World Top Container Ports 2017 list. Gdańsk also has regular container connections with Asia. In May 2017, Ocean Alliance, the largest such organization in the world, began cooperating with the Gdańsk port on a permanent basis. The alliance includes the leading container shipowners: OOCL, Cosco Shipping, CMA CGM and Evergreen. The alliance's ships will call to the Gdańsk port once a week, connecting such ports as Shanghai, Ningbo, Xiamen, Yantian, Singapore, Felixtowe, Rotterdam, Gdańsk and Wilhelmshaven .

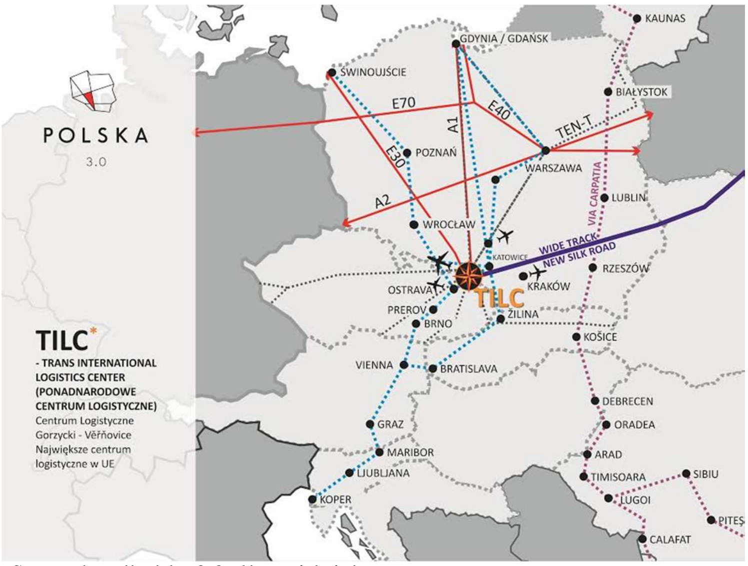
The successes of the Gdańsk port and the improvements in road transport infrastructure notwithstanding, Poland is currently ranked 33rd according to the Logistics Performance Index, behind many countries in the region (such as Austria, Hungary, the Czech Republic and Lithuania), where competing logistics centers could also be built.

Another difficulty faced by Poland arises from the fact that the New Silk Road consists mainly of rail connections. The density and capacity of railways in Poland leaves much to be desired. According to PKP (the leading Polish railway carrier), goods trains currently move through the network with an average speed of about 20 km/h.

POTENTIAL LOCATIONS OF AN INTERMODAL LOGISTICS CENTER IN POLAND, SERVICING THE NSR

There are several potential locations for the international logistics center on the New Silk Road in Poland (Fig. 2 and 3). One of them is Łódź, located in central Poland, approximately 136 km from Warsaw. Its advantage is the central location near the intersection of north-south and east-west highways. Łódź is already on the New Silk Road. Since 2014, a regular cargo rail connection with the Chinese province of Sichuan has been operational. Trains enter Poland across its eastern border at Małaszewicze and continue to Łódź. It takes 12 days for a train from China to reach its destination, while the maritime route via the Suez Canal to the port of Piraeus requires a month. Hence China's interest in this solution. The Łódź lobby and PKP support the idea of routing the New Silk Road from China to Western Europe via Łódź. PKP declared its readiness to contribute its own real estate with an area of 55 hectares to the construction of a logistics center. Another point in favour of Łódź is the fact that the Łódź Special Economic Zone signed an agreement with the international railway hub in Chengdu (China) in September 2017. This means that Łódź has officially become part of the OBOR project – a network of rail connections linking China with Europe, which is supported by the Chinese government. The two parties have convergent objectives: expand the terminal and build a logistics and industrial center. The signing of the agreement means that Łódź has now been accepted as part of the OBOR network, with the likely outcome of "an increase in the number of trains running in both directions between Poland and China" [polandinenglish.info, 2018].

Another potential location is the Central Communication Port (CCP), located near the town of Stanisławów (between Warsaw and Łódź), in the immediate vicinity of the A2 motorway, the Warsaw-Łódź railway line and the planned track of the High-Speed Railway [Darasz J. 2017]. The Economics Committee of the Council of Ministers adopted the construction recommendation on 4 March 2017; the project's aims are to "build and operate a profitable, innovative transport hub, which will rank as one the world's top ten airports, and at the same time will become an important component of the national rail passenger transport system and an attractive alternative to road transport." The construction of Central Communication Port project consists of the following main parts: the construction of an international airport, located 45 km west of Warsaw; the construction of a railway hub, whose functions will go beyond those of an airport railway station; the construction of railway lines within the borders of Poland, with a total length of over 900 km; the construction of a logistics center, 100 hectares in area; the construction of 65 km to 250 km (depending on the option chosen) of roads in Poland; rapid growth of PLL LOT, with the Polish airlines to become the main carrier in Central Europe; integration of the Warsaw and Łódź agglomerations; the development of the "Airport City", with hotels, exhibition and congress facilities, and company headquarters.



Source: http://polska-3-0.pl/o-projekcie/

Fig. 2. Location of Trans International Logistics Center Gorzyczki

Source: https://www.trojmiasto.pl/wiadomosci/Nowa-linia-kolejowa-polaczy-Trojmiasto-i-Centralny-Port-Komunikacyjny-pod-Warszawa-n118721.html#

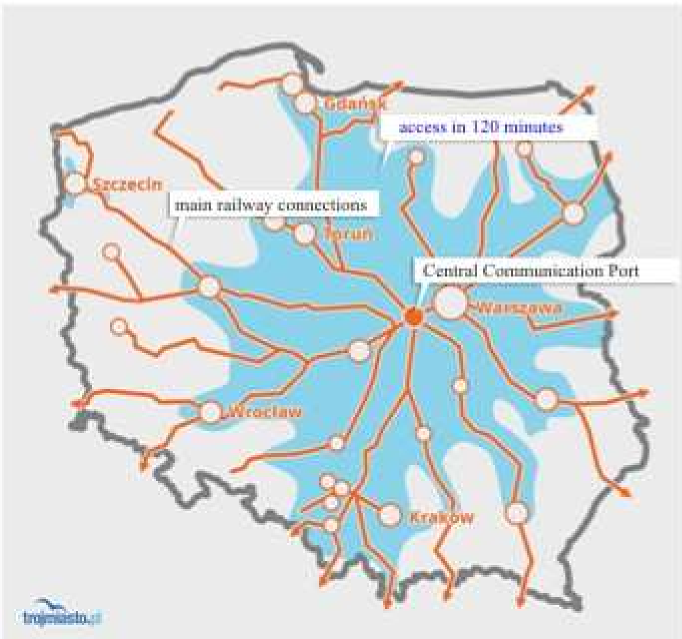


Fig. 3. Map of Poland, with Gdańsk, Warsaw, Centralny Port Komunikacyjny and the main railways connections

CCP will provide services for 500 inter-regional trains a day. Commercial speed on railway lines leading to the CKP is to be at least 140 km/h, and the expansion of the railway network will be carried out in two stages:

- stage 1 (2018-2027) – elimination of the major gaps in the current rail network in Poland, as well as modernization of existing lines to utilize their maximum potential for domestic transport
- stage 2 (2025-2035) – improvement of the quality of the domestic infrastructure through the construction of new sections of high-speed rail, to meet both domestic needs and those of international transport

networks, linking Poland and other countries in the Three Seas (the Baltic, Adriatic, Black Sea) region.

The total cost of the expansion of the domestic railway network through the addition of new segments in connection with the construction of infrastructure for the CCP-based transport system, scheduled for 2020-2030(35) is estimated at PLN 35-40 billion. It is assumed that 37,000 additional jobs (including 14,500 as a result of direct employment) will be created by the CCP. In view of the fact that one job in the aviation sector generates on average three jobs in other sectors, one should expect employment to grow by approximately 110,000 jobs. Next to Port Solidarność, the Airport City with an area of 800-1200 hectares is to be built, with hotels and a trade and exhibition center.

CCP is also expected to lead to the integration of Łódź and Warsaw, and to stimulate economic growth and revitalization of Łódź.

As is apparent from the above, the construction of the CCP would involve not only the creation of a logistics hub, but also the supporting rail and road infrastructure, to ensure smooth operation of the center [Wikipedia, 2018].

Yet another project combines the Gorzyczki transnational logistics center investment and Poland 3.0 program. According to its creators, it is the largest cluster project in Europe, a grassroots economic program for Poland. The aim of Poland 3.0 is to connect the networks of Polish rivers, highways and railways and to construct in Gorzyczki the largest intermodal transnational logistics center in Europe. The envisaged Gorzyczki-Wierzniowce logistics center on the Polish-Czech border lies at the intersection of all the main transport corridors which comprise the 6th Multimodal North-South Corridor. The planned logistics center is located at the intersection of the main trans-European transport routes: the A1 Highway, the E-30 Waterway, the broad gauge railway from the Far East and the 2nd trans-European rail corridor. Three airports are in close proximity: in Katowice, in Ostrava and in Kraków. According to UN experts, this is the most promising area in all of Europe as regards development prospects.

As emphasized by the initiators of the Poland 3.0 program, it is an integral part of the Baltic-Adriatic and the Baltic-Black Sea corridors. The program will include multimodal transport projects, infrastructure projects, the New Silk Road, but also cross-border cooperation projects, energy security, new technologies, exchange of knowledge and technology transfer projects. The ultimate goal is to increase the region's competitive advantage in new ways [Jarosławska 2018].

The port of Gdańsk, located in the central part of the southern Baltic coast, one of the fastest growing regions of Europe, also has great potential. Gdańsk is a major international transport hub. According to current European Union strategy, it plays a significant role as a link in the Trans-European Transport Corridor No. 6, connecting Scandinavian countries with South-Eastern Europe. Within the Port of Gdańsk, two areas with distinct operational parameters can be distinguished: the Inner Port and the Northern Port, with direct access to the Gulf of Gdańsk. The Northern Port includes a modern deepwater container terminal (DCT) .

In 2017, 40.613 million tons of cargo were transshipped in the Port of Gdańsk. This makes it the 6th largest port in the Baltic Sea.

However, as far as container transshipment is concerned, Gdańsk is the leader among Baltic ports. Its DCT (Deep Container Terminal) can service the largest commercial vessels (Triple-E class), which puts it in the elite group of only 14 such ports in the world. The DCT in Gdańsk is the only Baltic Sea deepwater port of call for ships from the Far East. In 2016, 1.28 million TEU were transshipped at the DCT. Only the port in Saint-Petersburg, which consists of six terminals, reported the higher figure of 1.7 million TEU.

Cooperation with the 2M Alliance – formed by the two largest container lines in the world: Maersk Line (ML) and Mediterranean

Shipping Company (MSC) – began in 2015. The first ship carrying containers of both lines called to the Gdańsk port on 19 February 2015. Connections from Shanghai to Gdańsk (32 days) and from Busan (South Korea) to Gdańsk (36 days) were launched. Gdańsk has also reached an agreement with another association of the largest carriers in the world – the G6 Alliance of six container shipowners: APL, Hyundai Merchant Marine, Mitsui O.S.K. Lines (MOL), Hapag-Lloyd, Nippon Yusen Kaisha (NYK) and Orient Overseas Container Line (OOCL). The routes of G6 ships carrying goods from Asia to Europe, the so-called Loop 7, were extended to Gdańsk. The first ship called to the Gdańsk port in August 2015. Currently, ships with a total capacity of 13,000 TEU call regularly every week. A container ship from Qingdao in China takes about 40 days to arrive in Gdańsk, and one from Singapore about 28 days. The DCT was expanded in 2016, while the planned investments in railway lines, connecting Polish ports with the rest of the country, will further increase its attractiveness [Weedy S., 2017].

RESULTS

As the result of literature research, the authors may formulate the following conclusions. The business and academic communities, and recently also government circles, are well aware of the benefits that the construction of an international logistics center would bring to Poland. However, practically to this day no consensus as to the location of such a center has been reached.

The lobby advocating the construction of a logistics center in Łódź has been particularly vocal over the last few years. The geographic location of the city and its existing railway connection with China are important advantages. However, despite negotiations with China and PKP's interest in this project, no agreement between the Polish and Chinese governments has been reached.

The choice of Gorzyczki as the location of a transnational logistics center is very attractive, due to its intermodal and transnational character. However, its weakness is the fact that it is supported mainly by grassroots initiatives, without government involvement. Furthermore, there is no definite investment plan, with a clear timetable and funding schedule. Like the former, this initiative never advanced beyond the planning stage.

The advantages of Gdańsk as the location for a logistics center are indubitable. Gdańsk has been the port of call for container ships from the Far East for several years now. The expansion of the railway network to improve Gdańsk's connections with the rest of the country will also help. However, so far Gdańsk has not been taken into consideration as a potential location for an international logistics center. It is a disadvantage that the Gdańsk area is highly urbanized, and therefore real estate prices in close proximity to the city are relatively high.

In this context, the government's initiative to build Central Communication Port in Stanisławów (45 km from Warsaw), may yet prove to be the dark horse of the race. This project is to be co-financed by the EU. It has been planned on a grand scale and would meet the criterion of intermodal transport. It is also integrated with extensive investments in the railway network. It would include the construction of a logistics center with an area of 100 hectares, offering complete infrastructure and IT system, as required of an international logistics center. This location would also provide access to existing road and rail networks. Its emplacement outside metropolitan areas would ensure relatively low costs. Another advantage of Stanisławów is its location in central Poland. Government support is also crucial, as it would guarantee the availability of funds.

The above considerations suggest that Stanisławów is the most likely location for an international logistics center servicing the NSR in Poland. Other sites, such as Łódź, Gdańsk or Gorzyczki could provide auxiliary, regional distribution centers.

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LOKALIZACJA MIĘDZYNARODOWEGO CENTRUM LOGISTYCZNEGO W POLSCE JAKO CZĘŚĆ INICJATYWY JEDEN PAS JEDNA DROGA

STRESZCZENIE. **Wstęp:** Inicjatywa Jednego Pasa i Drogi otwiera wiele możliwości rozwoju dla krajów Europy Środkowo-Wschodniej. Niektóre z nich są związane z możliwością budowy centrum logistycznego w tym rejonie. Dla Polski taka inwestycja przyniosłaby wiele korzyści, nie tylko z powodu rozwoju infrastruktury, ale także z tytułu przyśpieszenia wzrostu gospodarczego i tworzenia nowych miejsc pracy. W tym kontekście kluczowa staje się rola i lokalizacja takiego centrum logistycznego. Ze względu na nowość zagadnienia, zauważa się znaczny niedobór artykułów naukowych związanych z tą kwestią. Celem naukowym niniejszego artykułu jest wypełnienie istniejącej luki, określenie roli jaką powinno spełniać polskie centrum logistyczne na Nowym Jedwabnym Szlaku, przedstawienie najbardziej perspektywicznych przyszłych lokalizacji, a także sformułowanie opinii na temat jego najkorzystniejszej lokalizacji.
Metody: Jest to artykuł poglądowy o charakterze teoretycznym. Zastosowana metoda polega na analizie źródeł literaturowych. Ponieważ kwestia budowy i lokalizacji w Polsce międzynarodowego centrum logistycznego na Nowym Jedwabnym Szlaku jest nowa, istnieje ograniczona liczba artykułów naukowych i tylko w języku polskim, poświęconych temu zagadnieniu. Z tego względu autorki oprócz prac naukowych wykorzystały także źródła internetowe.
Wyniki: W niniejszym artykule zaprezentowano klasyfikację centrów logistycznych oraz omówiono czynniki brane pod uwagę przy wyborze lokalizacji dla takiej inwestycji. Omówiono zalety i wady potencjalnych lokalizacji oraz tę najbardziej prawdopodobną.
Wnioski: Stanisławów (zlokalizowany między Warszawą a Łodzią) jest najbardziej prawdopodobną lokalizacją dla międzynarodowego centrum logistycznego obsługującego NSR w Polsce. Inne obiekty, takie jak Łódź, Gdańsk czy Gorzyczki, mogłyby pełnić rolę pomocniczych, regionalnych centrów dystrybucyjnych.

Słowa kluczowe: centrum logistyczne, Jeden Pas Jedna droga, Nowy Jedwabny Szlak, lokalizacja, Polska

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ORIGINAL PAPER

DECOMPOSITION ANALYSIS OF FACTORS INFLUENCING INTEREST OF COMPANIES IN CODE SYSTEMS FOR MULTIPLE PACKAGES IN POLAND

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ABSTRACT. **Background:** Over last years the growing tendency towards the use of barcodes can be observed. They are started to be implemented practically in every activity within the supply chain. The paper presents the analysis of the number of participants of GS1 system in regards to the change of number of companies in Poland and the level of the use of various code systems.
The aim of this paper was to identify the main drivers of changes in the implementation of barcodes for multiple packages and trade items among companies in Poland in years 2006-2016.
Methods: The decomposition was conducted by the use of LMDI method (Logarithmic Mean Divisia Index). The decomposition analysis was made in the relation to the number of companies enrolled in REGON register. Two indices were used: first one shows the interest in barcodes among companies, the second one relates to total number of companies.
Results and conclusions: The results obtained from the decomposition analysis shows factors influencing the interest of companies in code systems: GS1: EAN-13, ITF-14, GS1-128 and SSCC and allows to identify opportunities created by economic growth. They indicate the relationship between the implementation of SSCC identifiers and the interest of companies. The use of GS1 logistics labels should be supported and promoted, and GS1 Poland should play a key role in this activity.

Key words: trade items, multiple packages, logistics standards of barcodes, decomposition analysis, supply chain.

INTRODUCTION

The barcodes play important role in the trade and the distribution of goods within the whole supply chain. International organization GS1 manages barcode systems in 150 countries, where they are implemented in more than 2 M companies [Krasoń-Wałęsiak, 2018, Tengler et al, 2017, Javato-Martín et al. 2017, Smith, 2019]. GS1 Poland manages GSI system in Poland and at the same time represents interest of 23 thousands of companies (participants).

The barcode standards cover the identification of goods and resources and their localization, which is recognized all over the world as well as enable the full traceability within the supply chains, including warehouses.

The presented paper covers the analysis of number of participants of GS1 system in regards to the changes of number of companies in Poland and the usage level of:

– coding of trade items (enabling the identification at cash desks) in EAN-13 barcode,

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- coding of variable measure trade items – (packages/containers not scanned in general retail at point-of-sale) in ITF-14 barcode,
- codes belonging to GS1-128 barcodes to present business date connecting with the content of homogeneous and not homogeneous packages creating the logistics units,
- SSCC identifiers (Serial Shipping Container Code) of logistics units of various contents, creating for warehousing and transport purposes.

The aim of this paper was the identification of drivers of changes in the use of barcodes for multiple packages and logistics units by companies in Poland during the period of 2006-2016.The decomposition analysis using Logarithmic Mean Divisia Index was applied to the analysis of the change of number of companies employing particular code system.

METHODOLOGY

The decomposition analysis using the method of Logarithmic Mean Division Index (LMDI) was implemented in this research. This method is used i.a. in researches for energy use, where the key aim of the decomposition analysis is the determination of structural factors being the drivers for changes of energy input indices as well as environmental impacts indices [Ang 2004, Stachura 2017]. This method is used also to determine drivers for change of SO_2 emission in power stations in Poland in 1995-2008 [Iskrzycki 2011]. Additionally it is used to analyze drivers of greenhouse gases emission e.g. deriving from car transport [Gozdek 2015], as well as to investigate the research and development strategies of Japanese companies concentrated on patent expansion in the area of environment protection [Fujii 2006]. It is also used to trace the added value in Chinese export [Zhao 2018] or economy drivers in Chine [Wang 2017]. Therefore it seems that the decomposition analysis, which consists in division of changes in total number of companies using the code system for multiple packages into individual factors triggering these changes, can be useful for the identification of drivers for the implementation of barcodes by companies.

The advantage of LMDI method, comparing to others, is to obtain the perfect decomposition and elimination of the problem of zero values of data. It is achieved by adding small values ranging from 10^{-20} to 10^{-10} [Ang 2001]. The simple formula used for calculation is also the advantage of this method [Ang 2005]. The formula of method of Logarithmic Mean Division Index is as follows [Gozdek, Szaruga 2015]:

$$\Delta V = \sum_{i=1}^{n} \left[\frac{V_n^t - V_n^{t-1}}{ln\left(\frac{V_n^t}{V_n^{t-1}}\right)} ln\left(\frac{x_i^t}{x_i^{t-1}}\right) \right]$$

where:

V is determined by n factors (x_1, x_2 …),
ΔV is the sum of effects of all factors considered in given period of time [t-1, t],
t means the present year
t-1 means previous year

The number of total companies was assumed on the basis of number of companies registered in REGON register from Statistics Poland [GUS 2007-2017]. The number of companies using the barcode systems was taken from the database of GS1 Poland, the manager of GS1 system in Poland. The research covered the period from 2006 to 2016.

The decomposition analysis was conducted according to rules presented in Fujii's work [Fujii, 2016].

DISSCUSSION OF RESULTS

The number of companies enrolled in REGON register is presented in the Table 1 and the number of companies registered in GS1 database is presented in the Table 2.

Table 1. The numbers of companies in REGON register

	Year										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of companies	3 636 039	3 685 608	3 757 093	3 742 673	3 909 802	3 869 897	3 975 334	4 070 259	4 119 671	4 184 409	4 237 691

Source: Statistical Yearbook 2007-2017

Table 2. The number of companies using coding system of handling units according to GS1 Poland in years 2006-2016

	Year										
Type of code system	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
EAN-13	5 360	6 874	7 769	8 101	8 364	8 514	9 331	9 071	9 171	10 826	11 108
ITF-14	112	139	160	172	188	221	269	282	285	315	354
GS1-128	289	356	425	513	621	717	835	949	959	1 181	1 270
SSCC	no data	190	311	448	554	689	842	946	956	1 344	2 034
Total*	**5 761**	**7 437**	**7 906**	**8 399**	**8 883**	**9 222**	**9 904**	**10 303**	**10 415**	**12 322**	**12 009**

* Due to fact, that some companies use more than one coding system, the sum of positions in each column is higher than presented in the row "Total".

Source: GS1 Poland database

During the analysis of data in the table 1, it can be observed the systematic increase of number of registered companies from 3 636 039 in year 2006 up to 4 237 691 in year 2016. It means the increase of number of companies by 16%. Only in year 2008 the small decrease in comparison to previous year was observed. The number of companies using code system also was growing systemically from 5 761 to 12 009 participants, but its growth was definitely higher and was equal to 108%. Year 2016 was the only exception in this trend, when the small decrease of number of GS1 Members was observed (from 12 322 to 12 009 companies).

The number of participants using following systems: EAN-13, IF-14, GS1-128 or SSCC identifiers also increased year by year in the analyzed period. The very strong jump in numbers of SSCC identifiers was especially in year 2016, when it was higher than 50%. Relatively fast increase of interest for SSCC identifiers over last few years was the reason that at present they are used more often than GS1-128 system. However it should be emphasized that in absolute values, their application is much lower than codes belonging to EAN-13 system (which amounts to almost 70% of all applications).

The decomposition analysis LMDI was used to identify and clear all factors influencing the number of companies, which use barcodes [Fujii, 2016]. The analysis was conducted in relation to the number of companies enrolled in REGON register. Two indicators were implemented in this analysis. The first of them (PRIORITY) gives information about increase or decrease of the interest in barcodes among companies. The second one (SCALE) gives information about influence of total number of companies. The indicator PRIORITY means the number of companies using code system for multiple packages by the total number of companies enrolled in REGON register. This indicator increases when the number of companies coding multiple packages increases faster that the number of all companies. It shows that companies focus on the implementation of analyzed standards giving them higher priority. The indicator SCALE gives information about changes in total number of companies.

The decomposition analysis was conducted using the following formula:

$$BARCODE = \frac{BARCODE}{TOTAL} * TOTAL = PRIORITY * SCALE$$

where:

BARCODE means the number of companies using code system

TOTAL means total number of companies enrolled in REGON register

The following formula was used to compare changes in various periods:

$$\frac{BARCODE^t}{BARCODE^{t-1}} = \frac{PRIORITY^t}{PRIORITY^{t-1}} * \frac{SCALE^t}{SCALE^{t-1}}$$

where:
t means present year
t-1 means previous year

After logarithm and multiplication of both side of the formula by the indicator

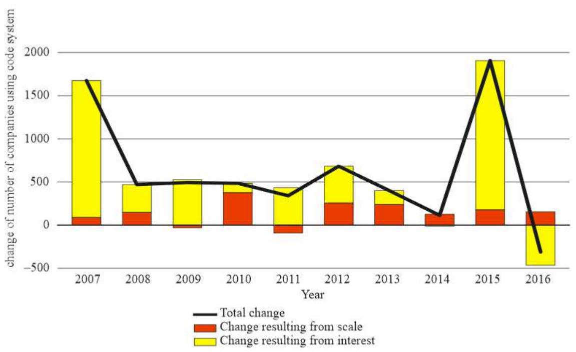
$$\omega^t = \frac{BARCODE^t - BARCODE^{t-1}}{\ln(BARCODE^t) - \ln(BARCODE^{t-1})}$$

the following formula was obtained:

$$\Delta BARCODE^{t,t-1} = \omega^t ln\left(\frac{PRIORITY^t}{PRIORITY^{t-1}}\right) + \omega^t ln\left(\frac{SCALE^t}{SCALE^{t-1}}\right)$$

The obtained relation allows to analyze the activity of companies in relation to shown interest in code system and total number of companies. The first component in the right part of the formula shows the priority of coding while the second component shows the influence of the scale effect.

ΔBARCODE$^{t,t-1}$ means the change of companies using code system in two subsequent years.

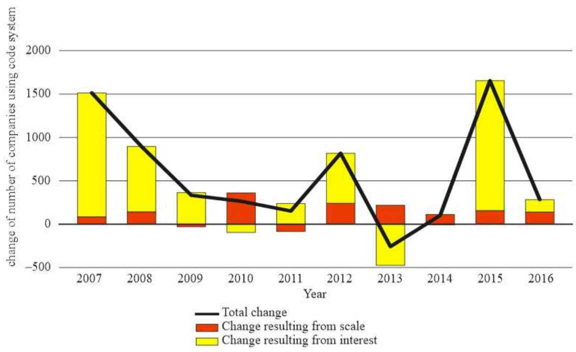


Source: own work

Fig. 1. The influence of interest in coding of multiple packages and total number of companies on the change of number of companies using code systems

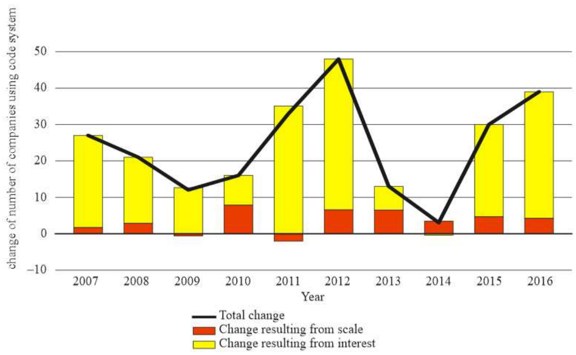
It can be concluded from the figure 1, that the increase of number of companies coding collective units results in most of cases for the analyzed period from scale effect i.e. the increase of total registered companies as well as from the significant increase of interest in coding of multiple packages. There were only two years (2014 and 2016) when the increase of companies using code system was smaller than the increase of total registered companies. During all other years the increase of companies using code system results mainly from the first factor, described as PRIORITY. The biggest share of this factor was in years 2007 and 2015. The influence of scale effect (indicator SCALE) was significantly smaller, except from years 2010 and 2014, when it was the most important reason for the increase of companies using analyzed standards. The scale effect shows negative values in years 2009 and 2011. The increase of the number of registered companies in GS1 Poland results mainly from the increase of the interest in such proceedings. The scale effect also causes the increase of the number of registered companies but it is definitely smaller.

The influence of the interest in coding of multiple packages by the use of various code systems as well as total number of companies on the change of the number of companies using code systems was presented in figures 2-5.



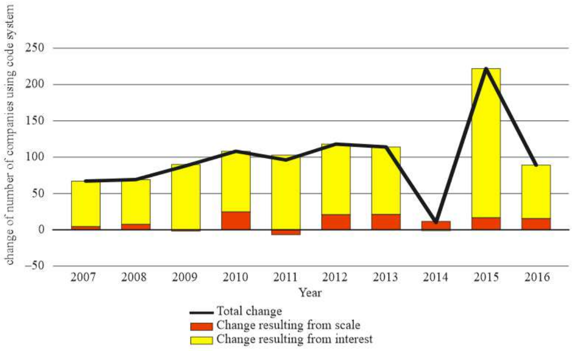
Source: own work

Fig. 2. The influence of interest in coding of multiple packages and total number of companies on the change of number of companies using EAN-13 systems



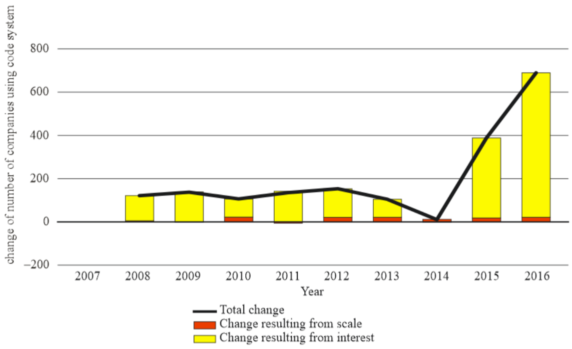
Source: own work

Fig. 3. The influence of interest in coding of multiple packages and total number of companies on the change of number of companies using ITF-14 systems



Source: own work

Fig. 4. The influence of interest in coding of multiple packages and total number of companies on the change of number of companies using GS1-128 systems



Source: own work

Fig. 5. The influence of interest in coding of multiple packages and total number of companies on the change of number of companies using SSCC identifiers

As it can be concluded from presented figures, there is a distinctive difference between characteristics of changes for EAN-13 codes and other three ones. In case of GS1-128, IFT-14 and SSCC, the increase of number of companies depends mainly on interest and only in small part on the effect scale. The year 2011 is very interesting one, when the scale effect is of negative values for all analyzed standards. The other strange data can be observed in year 2014, when the increase of the number of registered companies in GS1 Poland results practically only from scale effect.

The diagram presented the influence of different factors on the number of companies using EAN-13 system is more ambiguous. The factors dependent on interest had bigger significance in some years, while in other the factor dependent on the scale is more important.

The interest of using the EAN-13 code system for multiple packages being at the same time the trade units grew in different way. The increase of number of companies using EAN-13 code system for multiple packages is connected with the increase of number of operating companies. It could be caused by the attractive price of goods bought in multiple packages in shops and discounts. The decrease was observed only in 2013 year.

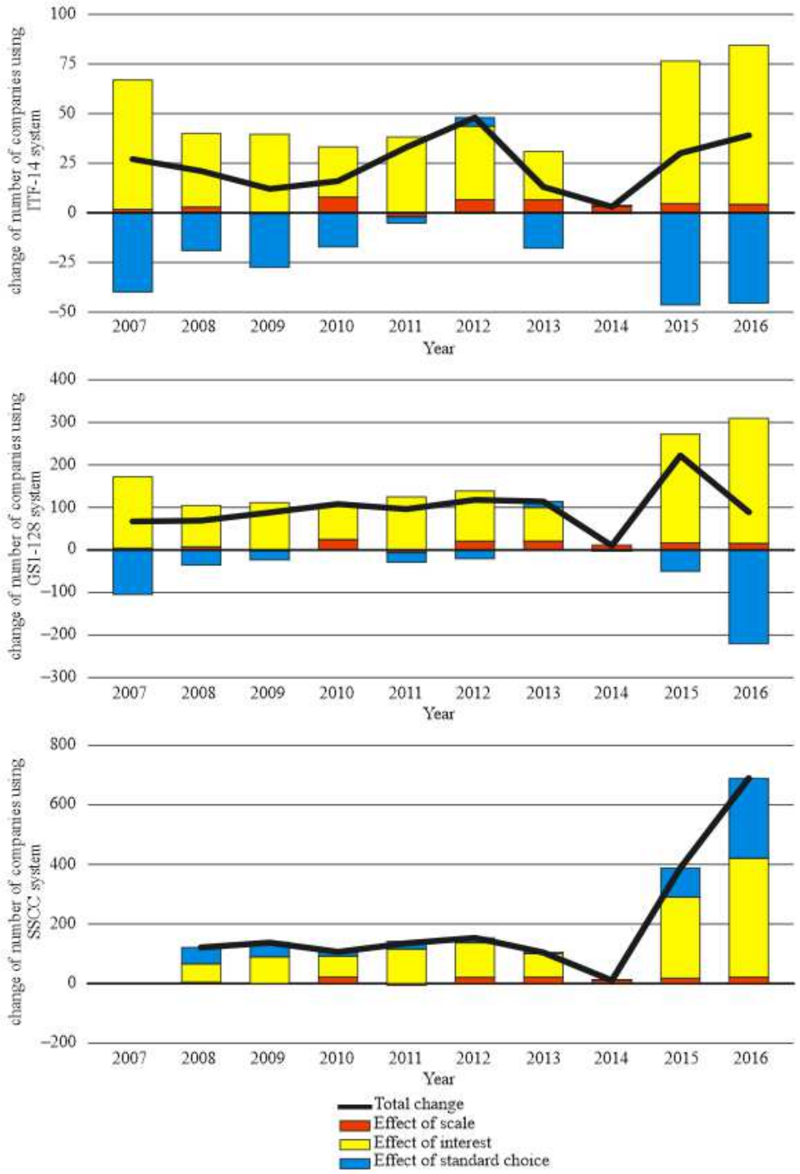
In order to deep the analysis of the influence of particular system on the interest of companies in code system, the following formula was used:

$$BARSTAND = \frac{BARSTAND}{BARCODE} * \frac{BARCODE}{TOTAL} * TOTAL$$
$$= STANDARD * PRIORITY * SCALE$$

where BARSTAND means the number of companies using particular standard, and the compound STANDARD shows the interest of particular system.

Such method of the presentation allows to analyze the activity of companies according to the interest in code system in given standard (STANDARD), interest of coding (PRIORIRTY) and the number of all companies (SCALE). The figure 6 presents the results of the analysis for ITF-14, GS1-128 and SSCC systems.

EAN-13 system was not taken into consideration because it is the only system offering barcodes, which can be read at the cash points. The other systems are implemented for other purposes. They are used for the identification of units in logistics processes within supply chains, especially in warehouses. It can be concluded during the comparison of GS1-128, IFT-14 and SSCC systems that in case of GS1-128 and IFT-14 systems, the increase depends only on scale effect and total interest in coding. However in case of SSCC system, the increase of number of companies using this type of coding, depends also on the interest on SSC identifier. The special increase of the implementation of SSCC system can result from its multi-purpose nature. The SSCC identifier can be used for many purposes and do not need to be used in the form of a barcode.



Source: own work

Fig. 6. The influence of interest in coding of multiple packages in code systems ITF-14, GS1-128 and SSCC

Additionally there is a common connection between GS1-128 and SSCC identifier. It results from the implementation of logistics labels GS1 in supply chains. Application identifiers presented in GS1-128 system are used on labels. The SSCC identifier is the only compulsory one on the label.

CONCLUSIONS

The use of decomposition analysis for the evaluation of factors influencing the interest of investigated GS1 standards allows to identify the possibilities resulting from economic development as well as to indicate the possibilities and directions of development and further implementation of code standards. Based on the conducted analysis of the use of code systems by companies, it can be observed the growth of the interest of the implementation of barcodes. The number of companies using EAN-13 code for multiple packages is connected with the total number of companies. Therefore the special efforts should be concentrated to reach new companies which will be new suppliers of commercial nets.

The use of SSCC depends also on the interest of companies in such identifier, therefore it should still be put an effort to increase the knowledge of this system and its advantages in supply chains among producers, logistics operators as well as trade cooperators. The army is another possible customer of this code system. Suppliers are obliged to use GS1 logistics labels. Many of them start to join GS1 system and need a support in the beginning phase of this implementation from the side of manager of this system i.e. GS1 Poland.

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ANALIZA DEKOMPOZYCYJNA CZYNNIKÓW WPŁYWAJĄCYCH NA ZAINTERESOWANIE PRZEDSIĘBIORSTW KODOWANIEM JEDNOSTEK ZBIORCZYCH I LOGISTYCZNYCH W POLSCE

STRESZCZENIE. **Wstęp:** W ostatnich latach można zaobserwować rosnącą tendencję zastosowania kodów kreskowych praktycznie we wszystkich obszarach w obrębie łańcucha dostaw. W prezentowanej pracy poddano analizie zmiany liczby uczestników systemu GS1 w odniesieniu do zmian liczby przedsiębiorstw w Polsce oraz poziom korzystania z różnych standardów kodowania.
Celem pracy była identyfikacja czynników determinujących zmiany w wykorzystaniu kodów kreskowych stosowanych na jednostkach zbiorczych i logistycznych przez przedsiębiorstwa w Polsce w latach 2006-2016.
Metody: Dekompozycję wykonano metodą logarytmicznej średniej ważonej indeksu Divisia LMDI (Logarithmic Mean Divisia Index). W analizie wykorzystano dwa wskaźniki. Pierwszy z nich odnosił się do wzrostu lub spadku zainteresowania kodami kreskowymi wśród przedsiębiorstw natomiast drugi odnosił się do ogólnej liczby przedsiębiorstw.
Wyniki i wnioski: Wyniki analizy dekompozycyjnej do oceny czynników wpływających na zainteresowanie standardami GS1: EAN-13, ITF-14, GS1-128 i SSCC, pozwalają na identyfikację szans wynikających z rozwoju gospodarczego. Wskazują także na zależność stosowania identyfikatora SSCC od zainteresowania firm. Stosowanie etykiet logistycznych GS1 w obrębie łańcuchów dostaw powinno być wspierane i promowane, gdzie szczególną rolę powinna odgrywać organizacja GS1 Polska.

Słowa kluczowe: jednostki zbiorcze i logistyczne standardy kodów kreskowych, analiza dekompozycyjna, łańcuchy dostaw

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ORIGINAL PAPER

HOW TO IMPROVE FREIGHT TRANSPORT EMISSIONS' MANAGEMENT?

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ABSTRACT. **Background**: To fight against climate change, the EU is committed to the world's most ambitious climate and energy targets, i.e. CO_2 reduction at least 20% by the year 2020 and 80-95% by 2050, in reference to 1990. This paper aims to look at the problem of freight transport emissions' measurement and management in order to reduce CO_2. The focus is on the chemical industry itself. The authors try to answer following research questions: (i) Do chemical and logistics companies in Poland measure and manage freight transport emissions? (ii) Where do they see the biggest challenges to emissions' management and how do they address them? (iii) Is a toolbox facilitating modal shift able to increase the usage of multimodal transport by chemical and logistics companies?

Methods: The research problem is investigated using a two-stage effort. Stage one is structured, in-depth interviews conducted among chemical and logistics companies operating in Poland. The results of this stage have provided the base for the toolbox developed to facilitate the modal shift in chemical transports. Stage two presents the results of the toolbox's beta-version tests conducted among chemical companies in Poland in 2017.

Results: Within the findings, the authors diagnose the obstacles which prevent companies from multimodal transport, and present toolbox consisting of: consulting services, multimodal planning guidelines, IT visualization, and CO_2 calculator. The toolbox facilitates transport partners' cooperation on shifting chemical freight from road to multimodal.

Conclusions: With technological developments, which strongly influence shippers and transport providers and offer improvement opportunities in efficient transport management, the topic of freight transport emissions' measurement and management in order to reduce CO_2 should be investigated in more detail.

Key words: sustainability, multimodal transport, intermodal transport, CO_2 reduction, chemical freight, logistics service provider (LSP).

INTRODUCTION

The Earth's climate is warming which results in serious damage to economies and the environment. The consensus among climate experts is that the main cause of recent warming are greenhouse gases (GHG) emitted by human activities, in particular the burning of fossil fuels and the destruction of forests. The 28 European Union (EU) member countries are responsible for around 9% of world GHG emissions. Nearly 80% of the EU's emissions come from the production and use of energy, including in transport [COM 2016]. According to the International Energy Agency (IEA), transport alone causes 23% of energy-related emissions, 75% thereof emitted by road transport [2014]. Emissions from freight transport account for approximately one third of total transport GHG emissions [Cefic and ECTA 2011]. To fight against climate change, the EU is committed to the world's most ambitious climate and energy targets, i.e. reduction CO_2 at least 20% by the year 2020 and 80-95% by 2050, in reference to 1990 [COM 2011].

While over the past decade most sectors managed to reduce their GHG emission levels, the transport sector has not seen the same gradual decline. The main reasons behind it

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are: globalization, longer supply chains, and related to it, increased population and goods mobility. Thus making transport more efficient, when ensuring Europe stays competitive and able to respond to increasing mobility, needs strategic, tactical and operational management of transport emissions in general, and freight transport emissions in particular [COM 2016]. To achieve it, governments as well as transport and logistics industry should start, firstly, measure and further manage energy consumption's reductions [Busse et al. 2017]. Despite an increasing number of logistics companies regarding environmental sustainability as an opportunity for improving competitiveness [Rossi et al. 2013, Liu et al. 2018], there is still a great deal of uncertainty on how to implement environmental strategies and how to translate green efforts into practice [Evangelista et al. 2017], and how digital technology can help transport and logistics companies to achieve modal shift and emissions' reduction.

This paper aims to look at the problem of freight transport emissions' measurement and management in order to reduce CO_2. The paper is focused on the chemical industry itself. The EU chemical industry ranks second, along with the United States [Cefic 2016]. In Central Europe (CE), chemical industry generates a 117 billion Euro turnover and employs 340.000 people [Eurostat 2016]. Polish chemical companies are important players in the region. In 2015 their total production sales amounted at 34 billion Euros. Chemical companies are important stakeholders of transport and logistics companies, as they are responsible for 8% of freight transport in CE. They transport large volumes at long distances and they are the object to freight transport emissions management [ChemMultimodal 2017].

The purpose of the study is to look at chemical and logistics companies cooperation and find answers for the following research questions: (i) Do chemical and logistics companies in Poland measure and manage freight transport emissions? (ii) Where do they see the biggest challenges to emissions' management and how do they address them? and finally (iii) Is a toolbox facilitating modal shift able to increase the usage of multimodal transport by chemical and logistics companies?

The empirical research to answer these questions is part of the "Promotion of Multimodal Transport in Chemical Logistics" project, run within the framework of INTERREG Central Europe Programme. The project is one of key logistics and chemical industries' responses to expectations and goals as set in the EU Transport Whitepaper. Its main objective is the promotion of multimodal transport of chemical goods by the coordination and facilitation of cooperation between chemical companies, specialized LSPs, terminal operators and public authorities in chemical regions in CE.

The paper is organized as follows. Section 2 presents a literature review providing the theoretical basis of the analysis. Section 3 is dedicated to the method of research. Section 4 presents the results and its discussion. It is focused on chemical and logistics companies' approach towards modal shift, and discussing the toolbox's application in order to facilitate overcoming modal shift barriers in chemical freight transport. Conclusions and implications for further research and practice are in Section 5.

LITERATURE REVIEW

To meet the ambitious carbon reduction targets, governments, industry sectors and individual companies will have to implement decarbonization strategies over the next few years. The first stage, to develop a transport decarbonization strategy, is the refinement of the carbon measurement process. Having measured these CO_2 emissions, the next stage for companies is to develop strategies for reducing them. The article examines a range of standards and methods of emissions' measurement and emphasizes factors affecting CO_2 emissions calculation.

Factors influencing emissions' measurement

The implementation of green initiatives is generally influenced by a number of factors, which may accelerate or hinder the adoption of such initiatives. These drivers and barriers could be divided into external and internal factors. Among external factors affecting companies' behavior and decisions, the strongest ones are: demanding customers and their attitude towards pro-environmental products and services [Lieb & Lieb 2010] as well as the competition, which adopts different environmental initiatives [Lammgard et al. 2012]. Very important factors are also political, legal and environmental regulations, which force companies to perform CO_2 measurement and mitigation, and finally technology development which allows for better analytics, as well as for the improvement of energy efficiency with better infrastructure, and more eco-friendly vehicles and equipment. Among the internal factors crucial for emissions measurement and management are: sustainability strategy focused on eco-efficiency [Evangelista et al. 2017], which could be reactive (i.e. limited to just obeying the legal restrictions) or proactive (i.e. work-out new competitive advantages related to building up a green image), a company's culture towards green practices and the environmental awareness of its leaders [Lin et al. 2008], and the presence of procedures and methodology to manage environmental routines and technical solutions.

Standards and methods of emissions' measurement

There are numerous standards applied to CO_2 measurement, such as GHG Protocol Initiative, British standard PAS 2050:2011, different types of ISO standards, or EN 16258:2013. There are also numerous EU-wide studies on calculation and reporting of GHG emissions such as Greenhouse Gas Protocol [Ranganathan et al. 2004], McKinnon's Input and Output-based Measures [2007], Calculating GHG emissions for freight forwarding and logistics services in accordance with EN 16258 [CLECAT 2012], G4 Sustainability Reporting Guidelines [GRI 2013]. The analysis of these documents allows to draw two main approaches to CO_2 calculation:

- An activity-based method, a more general calculation method, which uses the average CO_2 emission factor per ton-km by transport mode, transport volume and average transport distance by transport mode.
- An energy-based approach, which estimates the actual amount of work done and the energy consumed per unit of output. The 'output' of freight transport operations is generally measured by energy consumption by liters of fuel or kilowatt-hours of electricity used per ton-km and fuel/energy CO_2 emission conversion factor.

The activity-based method of calculation is recommended for industrial companies that outsource transport operations and hence they have no direct access to energy or fuel consumption data. The companies can use average emission factors dedicated to a particular transport mode to calculate their carbon emissions in an easy and fast way. However, parameters of CO_2 emissions should be differentiated to the country according to broad international differences in the nature and efficiency of freight operations (i.e. the load factor, the share of empty running, the energy efficiency of the vehicle or train – diesel vs. electric locomotives), particularly in the average carbon intensity of the energy source (i.e. a source of electricity for rail transport or the nature of fuel types being obligatory used by vehicles – percentage of biofuels within the fossil fuels) and the condition of transport infrastructure [McKinnon 2007].

The energy-based calculation method is the more accurate way of CO_2 estimation, which is dedicated mostly for logistics or transport companies as they can collect their fuel consumption data and use the correct emission conversion factor. This method permits for much more accurate estimation of CO_2 emissions, however it may take even several years to migrate a company to use the energy-based method [McKinnon and Piecyk 2011]. Thus, McKinnon and Piecyk [2011] proposed a refined activity-based approach that is more precise but also demands closer collaboration between shippers and carriers. Logistics companies have to incorporate into the CO_2 calculation sample data on distances travelled, consignment routing, back loading and fuel efficiency provided by carriers, to permit the calibration of emission factors specific to the industry they are in. This could lead to operational, energy and carbon transparency between shippers and LSPs in the medium term, and encourage cooperation in management of transport emissions.

These three methods are useful to evaluate the potential of CO_2 emissions' mitigation in terms of modal shift from road to multimodal, rail, inland or short sea transport. However, it should be mentioned, that all three methods omit the CO_2 emissions of transhipment activities when intermodal is used [Tao et al. 2017], which may lead to an overestimation of the modal shift's potential influence on the CO_2 emissions' reduction.

The CO_2 emissions can be calculated ex ante and ex post transport activities. Ex ante measuring supports the planning and organizing of freights on functional and operational levels (i.e. decisions of transport modal shift, routes redesign and scheduling). The calculation of energy consumption and emission data of a worldwide transport chain can be done with the help of Internet platforms for CO_2 calculation. There are customized CO_2 calculators offered by consulting companies, as well as a few free-of-charge tools available on the market. Ex post emissions calculation, prepared mostly by the LSP, can be used to report and control CO_2 emissions. This method can enable managers to take strategic and tactical decisions related to the redesign of the logistics system and supply chain, modal split, determining factors of the logistics operator selection and conditions of cooperation in emissions management.

Initiatives to reduce the environmental impact of freight transport

To reduce the CO_2 emissions companies and managers can implement different types of green solutions, i.e. the set of actions and decisions necessary to mitigate the negative impact of transport on the environment, society and economy [Klassen and McLaughlin 1996]. These initiatives could be focused on a single company, through horizontal and vertical cooperation of business partners and competitors, to actions that consider an entire supply chain, its strategy and structure, as well as the stakeholders and policy makers involved [Evangelista et al. 2017]. The more partners involved in an initiative, the more challenging the process of its introduction is. Table 1 presents selected examples of initiatives described in the literature.

Table 1. Overview of selected initiatives to reduce CO_2 emissions from transport operations

Reference	Activities	Parties involved
M. Christopher [2016]	– reviewing product design – reviewing sourcing strategy – applying postponement strategies – reviewing transport options – improvement of transport utilisation	– Shipper – Shipper – Shipper – Shipper, LSP – Shipper, LSP
J. Mangan and Ch. Lalwani [2016]	– supply chains redesigning – using scale to reduce negative environmental effects – promoting various efficiency solutions for transport and handling goods	– Shipper – Shipper, LSP – Shipper, LSP
A. McKinnon [2010]	– modal split – redesigning supply chain structure – improvement of vehicle utilisation (loading, routing and scheduling) – improvement of energy/fuel efficiency (design, maintenance and driving) – revision of carbon intensity of energy	– Shipper – Shipper – Shipper, LSP – LSP, Vehicle manufacturer – LSP
Cefic and ECTA [2011]	– modal shift opportunities from road to "greener" modes of transport – supply chain management related opportunities, i.e. optimization of transport planning or logistics network optimization efforts – increasing vehicle utilization – increasing fuel efficiency of vehicles or reduction of fuel carbon intensity	– Shipper, LSP – Shipper – Shipper, LSP – Shipper, LSP, Vehicle manuf.
A. Woodburn and A. Whiteing [2010]	– transferring freight from roads to "greener" transport modes as rail and water – promoting freight transport modal shift and multimodality	– Shipper, LSP – Shipper, LSP
J. Woxenius and F. Bärthel [2008]	– applying intermodal road-rail freight transport	– Shipper, LSP

Source: own work

The authors see the need to review transport operations in order to reduce freight transport externalities. However, they look at the problem from different perspectives. McKinnon [2015] organizes its analysis around functional, strategic and commercial levels. A vehicle's fuel efficiency related to design, maintenance, the driving of a vehicle, as well as its loading, routing and scheduling, are examples of functional activities focused on managing CO_2 emissions from a single company's perspective. Strategic and commercial decisions could refer to a logistics system design of a single company or a supply chain structure. Supply chain perspective is also presented in Christopher's work [2016]. He indicates five steps which companies can take to decrease the transport-intensity of their supply chains. Mangan and Lalwani [2016] propose three ways to improve the sustainability of logistics and supply chain systems: redesigning supply chains, using scale to reduce negative environmental effects and promoting various efficiency solutions for transporting and handling goods.

According to Cefic and ECTA [2011], the majority of actions are the decision-making domain of industry companies. However, logistics service providers can play a proactive role in highlighting opportunities for CO_2 emissions mitigation, especially within logistics activities such as transport [Cichosz et al. 2017]. They can also have a direct impact on the fuel efficiency and loading factor as well as facilitate the switch from road to intermodal transport. These topics need further investigation.

METHODOLOGY OF THE RESEARCH

The research problem is analyzed on the basis of a literature review and structured, in-depth interviews conducted with twelve chemical companies operating in Poland and nine LSPs serving them. In the second part, the authors present the toolbox developed to facilitate chemical freight shift from road to multimodal transport. The research is part of the "Promotion of Multimodal Transport in Chemical Logistics" project, run within the framework of the INTERREG Central Europe Programme.

The ChemMultimodal project

The ChemMultimodal project is running from June 1st 2016 to May 31st 2019 with a budget of 2.388.840 Euro. 14 partners (regional authorities, chemical industry associations and scientific institutions) from seven countries (Austria, Czech Republic, Germany, Hungary, Italy, Poland and Slovakia) in CE are working together to improve safety and environmental protection of chemical transports on the one hand, but also to ensure competitively and economically feasible solutions on the other. The project is divided into three work packages (WP) (Tab. 2). Chemical companies are the object of the project, as they transport large volumes at long distances, being important stakeholders of transport and logistics companies. Besides, due to the hazardous nature of chemical products, the priority for chemical transport operations is safety and security, and that is why rail, including multimodal or intermodal transport, is more often the option.

Table 2. ChemMultimodal work packages

Work package	Time frame	WP description
WP1	6.2016 – 5.2017	Analysis & Tool Development **Output**: Tool for promotion of modal shift of chemical goods from road to intermodal transport
WP2	6.2017 – 5.2018	Pilot Testing **Output:** Pilot Projects and implementation in each country
WP3	6.2018 – 5.2019	Strategy and Action Plan **Output:** Transnational Strategy (1) and Action Plans (7)

Source: own work

Survey instrument development

A questionnaire for in-depth interviews was developed in English as a guide for the whole project, and was later translated into the Continental languages of project partners. The questionnaire included a mixture of open and multiple-choice questions. It comprised of the following sections:

- Relevance of CO_2 measurement,
- Importance and main routes of multimodal transport,

- Potential for modal shift,
- Drivers (advantages) and barriers (disadvantages) of modal shift,
- Potential internal and external improvements in modal shift (with emphasis on vertical and horizontal collaboration with supply chain partners).

A pilot test of the questionnaire was performed with an expert in the field of logistics and supply chain management in a chemical company, before the full sample of respondents were interviewed.

Data gathering

The questionnaire was sent out to 49 companies across Poland. Logistics and supply chain managers were approached as the most suitable informants. Twenty-one managers responded and interviews were performed by telephone and at-company sites, and lasted approximately one hour each. Statistical data was completed by e-mail. Finally, 21 questionnaires were collected: 12 from chemical companies (both producers and distributors) and nine from logistics companies (LSPs, carriers, rail and port operators). Both groups of respondents were rather diversified regarding their size. 58% of chemical companies were big players with more than 250 employees, 25% - medium, and 17% - small companies. The split of logistics companies was as follows: 45% - big, 22% - medium, and 33% - small players.

The ChemMultimodal toolbox development and beta-testing

The results from in-depth interviews delivered the list of obstacles preventing chemical and logistics companies from using multimodal transport, and provided the framework for a toolbox development. The toolbox is aimed to overcome obstacles and facilitate modal shift in chemical freight transports by creating awareness of multimodal transport importance and presenting possibilities of carrying it out. It consists of four elements: (1) consulting services, (2) planning guidelines, (3) IT visualization, and (4) CO_2 calculator (Tab. 3).

Table 3. ChemMultimodal toolbox elements

(1) Consulting Services • Data base with stakeholders' contacts • Marketing platform	**(2) Planning Guidelines** • Backbone of toolbox • National legal regulations re chemical transport
(3) IT Visualisation • Intermodal Links Platform • Visualize intermodal routes (frequency, available LSPs, information of pre-and post-haulage)	**(4) CO2 Calculator** • Calculation of CO2 emission based on EN 16258 and McKinnon • Create awareness for CO2 savings

Source: own work

Each and every part of the toolbox plays an important role in the process of modal shift. Consulting services are marketing a platform dedicated mainly for chemical companies to improve their share of multimodal transport. Planning guidelines is a list of criteria with regulative national differences, such as loading and driving restrictions, which are required for planning a route of chemical intermodal chemical transport. They are used by a facilitator who helps to develop a close cooperation between logistics and chemical companies to discuss current transport patterns, existing potentials, and possible actions to promote modal shift for chemical loads. The IT visualization platform is an easy Intermodal Links Planner [https://intermodallinks.com] offering companies the best intermodal connections between the place of origin and destination. And the last but not the least the CO_2 calculator [https://ifsl50.mb.uni-magdeburg.de/] which allows for evaluating the effects of the modal shift and estimating CO_2 savings.

When working on the CO_2 calculator, the research team aimed to establish a general but sufficiently precise method for the calculation of CO_2 emissions from freight transport operations, allowing the chemical and logistics companies to measure the CO_2 emissions of various transport routes and determine their transport carbon footprint. The activity-based calculation method was recommended for the use of chemical companies, as most of their transport operations are outsourced and they have no direct access to energy or fuel consumption data. The research highlighted difficulties in calculating emission values according to transport modes and freight destination. A challenging step in the approach was establishing the most appropriate freight emission factor for each transport mode and a particular country (in accordance with the EN 16258 standard). According to project assumptions and constraints, the same average emission factor, derived from international studies, was applied by chemical and logistics companies regardless of the carbon intensity of freight operations in a particular country. Another limitation of the CO_2 calculation methodology was disregarding the energy consumption of handling trans-shipment activities between road and rail or water transport modes which may cause the overestimation of potential of intermodal transport CO_2 emissions reduction. Despite these listed limitations, developing the standard calculation methodology is aimed to enable chemical companies to measure and compare CO_2 emissions across different modes of transport.

According to the project work plan, a peer review of the beta-version of the toolbox with the CO_2 calculator had been planned before the individual items were finalized and prepared for further testing in the project's pilots. The peer reviews took place in 2017. The peer reviews were carried out remotely as desk-based and required the participation of at least two people. The peer review itself required only a few hours of time, including the completion of a review form. For the peer review, an imaginary case example had been used, reflecting a chemical company existing in real life. When performing the peer review, one person acted as the project representative using the toolbox to give advice to the other person(s) who acted as a representative of the company.

RESULTS AND DISCUSSION

The section is arranged with a focus on: (1) presenting chemical and logistics companies' approach towards barriers and emissions measurement and management, as well as their attitude towards modal shift , and (2) discussing tests results of a beta-version of the toolbox used to facilitate modal shift in chemical freight transport.

Chemical and logistics companies' approach towards emissions' management

The in-depth interviews, conducted within the first stage of the research, have shown that measurement and management of CO_2 emissions from chemical freight transport operations are still at an early development stage in Poland. Most chemical companies (70% of those interviewed) do not measure emissions and half of them declared that they do not plan to do it in the nearest future. They admitted that "it's not their problem as they outsourced transport and logistics operations to LSPs", "they had already paid for it", "they did not have tools for it", and "they were not going to do it until it's required by regulations".

Their attitude towards decarbonization of transport operations is shaped by external and internal factors as well. Among the main external barriers respondents emphasized:

- lack of legal and social requirements forcing companies to measure and mitigate CO_2 emissions,
- lack of customers' requirements for pro-environmental freight (i.e. there is no pressure from customers to use more environmentally friendly transport modes and vehicles),
- lack of free access to tools (including IT tools) and emission calculators which could help companies to assess the pollution level they generate in an easy way, which could motivate them to care more about being greener,
- cost and inflexible rules of access to rail infrastructure and terminals, which in great majority are owned by Polish national infrastructure manager PKP PLK who, according to respondents' opinion, is not a customer-focused company with

insufficient communication systems, non-transparent processes and many managerial inefficiencies.

In most cases, transport activities are not included in Corporate Social Responsibility (CSR) strategies of chemical companies, which do not help in shifting road transport to rail. This is even the case for chemical companies that organize chemical freight transport on their own. This is mainly due to the fact that chemical companies focus on reducing emissions from their core business (i.e. production), which generates a large amount of their pollution. Those respondents, who outsource transport operations to LSPs, regard CO_2 measurement as the LSP's duty, however they do not require from LSPs measuring and reporting CO_2 emissions. Moreover, in most cases they do not specify pro-ecological criteria for LSPs regarding, for instance, transport mode selection, fuel used or loading factor. In addition, they do not take into account costs of transport externalities when estimating the cost of transport services. As a result, the main criteria for the selection of transport service providers are punctuality, reliability, and cost of service.

Critical internal factors, limiting shifting road transport to rail, are the habits of transport planners who are accustomed to applying door-to-door road connections because of their convenience, reliability of delivery, and significantly easier transport planning. Respondents admitted that development of multimodal connections, especially international ones, requires extra time and effort for extended planning and organizing operations and thus does not stimulate planners to change their habits and attitude towards modal shift, until timely delivery is assured. The research has showed that there is a strong need to change the mentality of operational workers as well as managers and their attitude towards the sustainability of transport solutions and measurement of CO_2 emission. Interviews reviled that IT tools visualizing different route options and calculating CO_2 emissions could facilitate the process.

On the other hand, the survey showed that logistics companies seem to pay more attention to environmental issues of chemical freight transport. Transport is their core activity and they see the potential of CO_2 emissions' mitigation by modal shift, and appreciate the advantages of multimodal solutions concerning reduction of transport externalities, which supports their CSR strategies. However, in Polish very proliferated market, the percentage of logistics companies who actually measure and manage CO_2 emissions is still very low (30% of those interviewed). Few of them offer their clients the option of measuring the carbon footprint of transport operations even ex ante or ex post. They provide access to CO_2 emissions' platforms and calculators, deliver emission data on invoices, or develop annual reports of transport operations' externalities. In most cases the information on emissions related to freight transport are available as a service at the offer of big logistics players. The interviews revealed that the market for eco-efficient logistics operations will be growing in the future, which can encourage logistics providers, intermodal transport companies and forwarders to invest in the extension of intermodal terminals (i.e. near chemical factories or sea ports) and to improve the quality of existing terminals and their capacity increase, create new multimodal connections and offer additional customized multimodal services dedicated to pooled small-size shipments, which are nowadays carried by trucks.

The infrastructure development and the improvement in quality of multimodal services should enforce chemical companies – LSPs cooperation on shifting chemical freight from road to rail. Survey results show that nowadays the main motivation for shifting chemical freight transport from road to rail is safety and security, as well as necessity to carry higher tonnages. In most cases logistics companies cooperate with chemical producers at arm's length what results from the fact that the logistics market in Poland is very fragmented as the majority of logistics companies are small players with very limited market power [Cichosz 2017].

Chemical and logistics companies' approach towards the toolbox with CO_2 calculator

The toolbox developed within the ChemMultimodal project was aimed to support chemical and logistics companies in cooperation on chemical freight transport shift from road to rail in order to manage transport chains' economic and environmental efficiencies. The toolbox includes a module dedicated to CO_2 calculation, however it is not limited to it. It consists of four elements (Tab. 3) which are important in managing transport chain reconfiguration when reducing CO_2 emissions. Within pre-tests of the beta-version of the toolbox, respondents evaluated every element of the toolbox on a scale of 1 (very useful) to 5 (not useful). Respondents were also asked to briefly explain how they applied the certain elements of the toolbox. The survey showed that the most appreciated element of the toolbox was the consulting services, which constitute a marketing platform integrating stakeholders of multimodal transport, such as chemical and logistics companies, terminal operators and others. Consulting services by definition are based on close cooperation, which is critical when companies share information on current transport patterns, existing potentials and possible actions to establish and promote modal shift.

At the other end of the convenience evaluation spectrum was the CO_2 calculator. Chemical companies felt it was not useful at all as in general, they are not interested in measuring and managing their transport emissions. This results from the fact that the transport emissions' measurement and management have not become obligatory yet. Moreover, during tests of the beta-version of the toolbox, chemical and logistics companies complained that the CO_2 calculator is not integrated with other transportation systems. Eventually, chemical companies considered it as a "nice-to-have" element of the toolbox, which can help in reporting emission savings. At the same time, logistics companies perceived the CO_2 calculator as a helpful tool, which could support them in convincing customers to shift chemical freight to intermodal transport, especially on the routes within European transport corridors.

Planning guidelines and IT visualization received, on average, scores between 2 and 3. Respondents appreciated planning guidelines but complained that it was not integrated with transport management systems. The IT visualization, provided by Intermodal Links Planner, which is an easy to use platform with more than 150 partners involved in providing and up-dating actual data on the scheduled railway connections, intermodal terminals, and their operators, was perceived as a helpful tool suggesting a range of connections between point of origin and destination. However, a disadvantage of the Intermodal Links Planner, highlighted by respondents, is the lack of specific information on the chemical freight handling equipment available at the intermodal terminals. Respondents admitted that this information would be received in quotation but they would appreciate to know it when selecting a multimodal route.

Summing up, the toolbox was recognized as a tool facilitating chemical freight modal shift, which still needs some improvement. Its improved version is being tested in five pilots across project member countries, i.e. Austria, Germany, Poland, Hungary, Italy, Czech Republic and Slovakia. It is a first step towards using the toolbox by chemical companies and this way increasing sustainability of its freight transport.

CONCLUSIONS

The results of the analysis show that in chemical freight transport in Poland, similarly to other European countries, there is still a need to reduce CO_2 emissions. The problem requires the strategic approach of both chemical and logistics companies as well. Chemical companies, even if outsourcing transport operations to logistics providers, should include sustainable transport in their CSR strategies. They should establish long-term strategic objectives for environmentally, socially, and economically responsible transport and logistics which should be translated into tactical and operational plans and metrics. Chemical companies, as buyers of transport and logistics services, could specify the environmental criteria such as the level of CO_2 emissions, source of energy, and others which give clear signal to logistics market that they prefer environmentally friendly LSPs as partners in their supply chains.

Conversely, logistics companies, especially big global players, in many cases have already had sustainable transport and logistics strategies. However, very often they give up on using multimodal solutions in accordance with their corporate goals as they try to please customers who are not ready to accept longer delivery times or take a risk related to load transfers in intermodal transport. As one LSP said, the concept of multimodality was great, there were just operational problems with convincing the customer and delivering it. Thus, significant changes are needed not just at the corporate level of transport management, but firstly the multimodality should be put into action at the EU and national levels by the multimodal infrastructure development (including ICT infrastructure) and the EU and national regulations' supporting more sustainable transport modes such as rail, inland and short sea transports. This way the EU would create equal market conditions for every transport mode.

The toolbox, prepared within the framework of the ChemMultimodal project and presented in the article, promotes multimodality and facilitates collaboration among different parties during the process of modal shift. This toolbox fulfills the gap for a tool, which is not just presenting railway connections with its transport time, frequency and number of transshipments, but integrates consulting services and planning guidelines with on-line platform visualizing available multimodal routes and CO_2 calculator. The toolbox is a complex solution. Project partners, who have developed it, are still working on its improvement. They are going to expand on-line version of Intermodal Link Platform and broaden its functionalities into cost analysis of different transport options.

However, with the technology development and hyper-connectivity becoming a reality, the future of efficient and effective intermodal chemical transport belongs to the solutions such as synchro-modality [Pleszko 2012, Cichosz et al. 2018]. Synchro-modality assumes that, based on prior client delivery requirements such as e.g. price, time, CO_2 emission factor, LSP can freely decide which transport mode to use and flexibly change its decision depending on the situation during the transport process itself. The synchro-modality aims at making the best use of an entire network of intermodal services. Well managed "synchronized intermodality" can deliver advantages for both: chemical and logistics companies as well.

This study presents some limitations. The main one relates to the small number of investigated companies who were asked about the barriers of multimodal transport, and those who tested the toolbox. To achieve empirical generalization, it would be necessary to increase the number of case studies. Moreover, further research is needed on effective operational suggestions and solutions to develop low-carbon chemical freight transport. It would be also interesting to investigate: case studies on the reconfiguration of global chemical supply chains to reduce transit distances and externalities related to it; the measurement of the energy consumption of handling or trans-shipment activities between road and rail or inland transport modes to calculate the overall CO_2 emissions' decrease of modal split, as well as safety and security of these activities; and finally the estimation of the modal shift influence on profitability of industry and logistics companies as well. However, in the authors' opinion with technological developments in the field of Internet of Things (IoT) as well as trends coming from the fourth industrial revolution (Industry 4.0) which strongly influence the field of transport and offer improvement opportunities in efficient transport management, the topic of freight transport measurement and management should be investigated in more detail.

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W JAKI SPOSÓB POPRAWIĆ ZARZĄDZANIE EMISJAMI W TRANSPORCIE TOWARÓW?

STRESZCZENIE. Wstęp: Chcąc walczyć ze zmianami klimatycznymi, UE zobowiązała się do realizacji ambitnych celów klimatycznych i energetycznych, tj. redukcji CO_2 o co najmniej 20% do 2020 roku i 80-95% do 2050 roku, w odniesieniu do 1990 roku. Celem tego artykułu jest spojrzenie na problem pomiaru i zarządzania emisjami w transporcie towarów w celu ograniczenia emisji CO_2. Artykuł koncentruje się na przemyśle chemicznym. Autorzy starają się odpowiedzieć na następujące pytania badawcze: (i) Czy firmy chemiczne i logistyczne w Polsce mierzą i zarządzają emisjami transportu towarowego? (ii) Gdzie widzą największe wyzwania związane z zarządzaniem emisjami i jak je adresują? (iii) Czy zestaw narzędzi ułatwiających zamianę gałęzi transportu, przyczyni się do zwiększenia wykorzystania transportu multimodalnego przez firmy chemiczne i logistyczne?

Metody: Problem badawczy jest analizowany dwustopniowo. Pierwszy etap to ustrukturyzowane, pogłębione wywiady przeprowadzone wśród firm chemicznych i logistycznych działających w Polsce. Wyniki tego etapu posłużyły do

przygotowania narzędzia ułatwiającego zamianę gałęzi transportu chemicznego. Drugi etap prezentuje wyniki testów beta wersji narzędzia wspierającego zamianę transportu drogowego chemii na transport multimodalny, które to testy przeprowadzono wśród firm chemicznych w Polsce w 2017 roku.
Wyniki: Autorzy dokonali diagnozy przeszkód uniemożliwiających firmom transport multimodalny oraz przygotowali i przedstawili narzędzie obejmujące: usługi konsultingowe, wytyczne do zmiany gałęzi, wizualizację IT rozwiązania multimodalnego oraz kalkulator CO_2. Celem narzędzia jest ułatwienie współpracy partnerów w zakresie zamiany transportu drogowego towarów chemicznych na transport multimodalny.
Wnioski: Ze względu na zmiany technologiczne, które mają znaczny wpływ na załadowców i dostawców usług transportowych oraz oferują możliwości usprawnienia zarządzania transportem, należy bardziej szczegółowo zbadać kwestię pomiaru i zarządzania emisjami transportu towarowego w celu ograniczenia emisji CO_2.

Słowa kluczowe: zrównoważony rozwój, transport multimodalny, transport intermodalny, redukcja CO_2, transport chemii, usługodawca logistyczny

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ORIGINAL PAPER

OWNERSHIP CONCENTRATION IMPACT ON FIRM FINANCIAL PERFORMANCE

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ABSTRACT. **Background:** Purpose of this study is to investigate the impact of ownership concentration on the performance of the firms operating in the financial and logistics sector of Pakistan. Impact of corporate governance practices on performance is under discussion for many years. Ownership structure has a significant effect on the performance of the firms either positively or negatively. Performance of the firms operating under the financial sector becomes more critical due to the reason that a well-functioning financial sector is vital for the economic development of any Country or Nation, in all areas especially in such crucial ones as logistics. The underline empirical study investigated the impact of ownership concentration on the performance of the firms operating in the financial sector of Pakistan, which has a strong influence on other sectors including logistics one.

Methods: There are 36 firms those have been considered for data collection process. These firms are listed on Karachi stock exchange (KSE) of Pakistan. Last five years' data from annual reports has been analyzed. Quantitative data descriptive statistics, correlation matrix and regression models are used for data analysis.

Results: Ownership concentration has a significant negative impact on ROA, Family-based ownership concentration has a significant negative impact on ROA, and Nonfamily based ownership concentration have a significant positive impact on Tobin's Q and ROA. Findings of this study are consistent with the agency theory.

Conclusions: Concentrated ownership can influence firm performance either positively or negatively. Study shows that the agency theory is applicable in the context of Pakistan. The power of decision-making is held by top shareholders in the concentrated ownership structure. Shareholders will make such decisions those are beneficial for them but not for the firm.

Key words: Financial sector, logistics sector, Ownership Concentration, Non-family based Ownership Concentration, Pakistan.

INTRODUCTION

How can concentrated ownership structure influence the performance of firms? It is a vital issue developing as well as in developed countries. It is impossible for the owner of the business to manage and control their business without expertise. Owners have to hire someone to manage the business on their behalf. Managers are not motivated to put their efforts because they have limited shareholding. Barely and Means are considered to be the first who discussed this problem. Through corporate governance, agency problem can be resolved. Concentrated ownership is an intimate way of governance.

Ownership structure plays an essential role in firms which are performing in a better way. When few people own a large number of shares, we can say ownership structure is concentrated while it is considered as dispersed when the majority of shareholders are there, and everyone has a small number of outstanding shares. In literature mixed results are available. Some researchers argued that agency problem could be resolved by

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concentrated ownership. Some authors argued that focused ownership becomes a reason for agency problem between majority and minority shareholders. A well-designed ownership structure can help to reduce the agency problem, and in this way, the performance of the firm will be increased. However, sometimes ownership structures can increase agency cost, and by doing so, the value of the firm will be reduced [Tryggvadóttir, 2011, Balsmeier, Czarnitzki 2015].

Large shareholders have the advantage to play their role in the management of the firm, by this way agency problem can be resolved. Shareholders can get the necessary information in a concentrated ownership structure. This can be helpful for the efficient monitoring system. Due to efficient monitoring system performance of the firm will be increased.

According to some studies conflict of interest arises due to the concentrated ownership structure [Anderson and Reeb 2003, Nagar et al., 2008, Vu, TuPhan, TuyenLe, 2018]. When the ownership structure is dispersed shareholder have less power to control managerial activities in this way the performance of a firm can be decreased. Now investors are more concerned regarding their investment decision. They want to invest in the firms which have good governance structure. Firms those have good corporate governance outperform the firms which do not have good governance structure. McKinsey and company [2002] surveyed to judge the perception of investors regarding corporate governance practices. According to the results of their study investors now considered the financial performance and corporate governance practices equally crucial to make an investment decision. Indeed, they are prepared to pay a premium for shares in well-governed companies as compared to poorly governed companies with similar financial performance. According to the results of the survey in US and UK firms people were prepared to pay a premium of 18%, for Italian firms it was 27% and for Indonesian firms 27% [Global Investors opinion survey].

Performance of the firms is fundamental as by performance firms can give return to the inventors otherwise they have to bear the losses. When we talk about financial sector performance becomes more critical because without an efficient financial sector it is impossible that the economy of the country will grow. It has also a big influence on logistics sector, which is an essential part of national economy. With the growth in economy living standards of people will also be increased. The development of any country is related to the economic growth of the country. Corporate governance is essential for the performance of the firm. Nations with the efficient financial system have the power to develop its economic growth more quickly Aurangzeb [2012]. Banks play a vital role in the economic development of a country. After the financial crisis in the 1990s need for a stable banking system rose.

Pakistani firms provide an ideal setting to investigate each of agency problems. Pakistan is a developing country where rules to protect shareholders are weak. Secondly, most of the listed firms have a concentrated ownership structure. Dr. Haq [1968] 66 percent of the business and corporations are under the ownership and control of 22 families in Pakistan. In Pakistan, most of the firms are owned and controlled by families. Javid and Iqbal [2010] top 3 shareholders have at least 50% of ownership rights in firms. In Pakistan, firms have very concentrated ownership structure. This study attempts to find how the performance of firms operating in the financial sector of Pakistan can be influenced by focused ownership structure. Because in existing literature the main focus of researchers was the impact of concentrated ownership on the performance of non-financial sector this was the motivation behind the choice of this topic. We measured the concentration of ownership by shares held by Top 5 shareholders. Then we segregate by shares held by directors who are also family members and percentage of ownership held by directors who are other than family members.

LITERATURE REVIEW

Corporate governance is a tool to reduce the agency cost of firms. There are more chances that publically listed firms have to face the agency problem because in this type of business shareholder have little or no direct control over management. Because of the separation between owners and managers' problem of collective action also arises. Managers operate business inefficiently because owners have less control over decision-making in listed firms. According to Adam Smith [1776] "The directors of such (joint-stock) companies, however, being the managers rather of other people's money than of their own, it cannot well be expected, that they should watch over it with the same anxious vigilance with which the partners in a private copartnery frequently watch over their own. Like the stewards of a rich man, they are apt to consider attention to small matters as not for their master's honor, and very easily give themselves a dispensation from having it Negligence and profusion, therefore, must always prevail, more or less, in the management of the affairs of such a company". He considered separation of ownership and control to be problematic for those firms in which managers are different from owners, and they would lack the incentives to operate corporations in the same manner as owner-managers.

AGENCY THEORY

The principal and agent theory emerged in the 1970s. In this theory, those problem has been discussed which aroused due to lack of control by owners. Berle and Means [1932] in modern corporations share ownership is widely dispersed due to this reason manager's start doing actions which are far different from those required to maximize shareholder returns. Separation of ownership and control has been characterized as an agency problem by [Jensen, Meckling 1976]. They described that managers are the agents who are hired to maximize the return to the shareholders who are the principals. As agents do not own the resources of corporations, they may commit moral hazards to increase their wealth in this way owners have to bear losses. In this way the concept of agency, cost arises. Agency theory also described some of the mechanisms which will reduce agency losses such as incentive schemes for managers through which managers will be rewarded for maximizing shareholder's interests. Jensen and Meckling [1976] the mechanisms which will be used to reduce the agency cost include issuance of shares at a low cost to the executives. In this way, the interest of executive's can be aligned with the importance of general shareholders.

STEWARDSHIP THEORY

Stewardship Theory describes the relationship between owner and managers were described differently. According to this theory, managers are individuals who are stewards their goals and objectives are aligned with the goals and objectives of owners [Donaldson 1991, Davis et al. 1997]. According to Stewardship, theory managers are trustworthy, and they give value to their reputation. By taking care of their reputation, they control their behavior and lust for money. Give value to their reputation. In market managers who have good standing can get higher compensation packages. Donaldson [1997] explained the relationship between owners and managers significantly depends on the behavior which they adopt.

STAKEHOLDER'S THEORY

Stakeholder theory deals with ethics and values used to control business. It was presented by Freeman [1984] in the book Strategic Management. A Stakeholder Approach helps to identify groups which are stakeholders of a corporation and provides ways by which interest of these groups can be protected. This theory deals with the "principle of who or what counts". Traditional owners or shareholders of the company were considered significant, and their needs were fulfilled at first. However, stakeholder theory considered activities of firms can influence other groups such as government, suppliers, business partner's society and sometimes competitors significant as the interest of these groups. Friedman [2007] corporate governance is a way to increase the profit of firms by following the basic rules of society. Wolfensohn [1999] stated that "Corporate governance is about promoting corporate fairness, transparency, and accountability".

CORPORATE GOVERNANCE HISTORY IN PAKISTAN

Awareness regarding corporate governance is not very old in Pakistan. In 1998 ICAP developed an outline for corporate governance in Pakistan. A code of corporate governance for firms operating in Pakistan was developed in 2002 with the cooperation of ICAP and SECP. In 2002 SECP published a Code of corporate governance for publicly listed companies. After this publication, it becomes an important area for research in Pakistan [Javaid, Iqbal 2010]. Corporations and commentators criticized the code. Some commentators believed that the Code was defective, outdated, and had benefit for stakeholders. However, due to the pressure by the regulatory bodies this code of corporate governance was made compulsory for a listing of firms in all stock exchanges in Pakistan. According to will enforce the-the requirements if a company failed to implement the code it will have to face punishment or de-listed from the stock exchange. Implementation of the code of corporate governance depends upon the fact how SECP will enforce the firms to follow this code as well as on companies and stakeholders who are aware of the advantages of compliance with the code.

OWNERSHIP CONCENTRATION AND PERFORMANCE

Concentrated ownership is a characteristic of ownership structure. Ownership structure weather concentrated or dispersed can influence performance either positively or negatively. Many studies have been conducted in Pakistan and other countries of the world as well on the Issue how concentrated ownership can influence performance. Mixed results are available in the present literature. According to some studies there exist a positive relationship but according to some researchers, a negative relationship exists between these variables. The first study was conducted by Jensen and Meckling [1976]. According to the results of their study concentrated ownership structure can influence performance in a positive way as in this type of ownership structure conflicts between owners and managers can be reduced. Morck et al. [1988] when ownership rights by managers are increased in the firm then they start working to increase their wealth in this way performance will be increased.

Stulz [1988] also examined how managerial control can affect a firm's value and policies. Similar results were found. Holderness and Sheehan [1988] studied the role of majority shareholders in publically listed firms on NYSE or AMEX for years 1978 - 1984. Shareholders are having more than 5% ownership were declared as majority shareholders. According to the results, significant shareholders cannot influence the performance of firms. McConnell and Servaes [1990] explored how ownership by shareholders can influence performance. Two samples have used a sample of 1,173 firms for 1976 and 1,093 firms for 1986. They found dispersed ownership structure can influence performance positively.

According to the results of a survey conducted by [Shleifer, Vishny 1997] concentrated ownership can influence performance in a positive direction. They used a sample of 1196 firm listed on different stock exchanges. Shahab-u-Din and Javaid [2012] examined how family ownership can influence the performance of firms listed at KSE 100 index. According to the results ownership concentrated by family members can influence the performance of firms in a positive direction. Data from 29 manufacturing firm from the year 2004-2009 was used for the study. A linear regression model was used. ROA, ROE and Tobin's Q were used as dependent variables while family ownership was used as an independent variable. Dividend, leverage, sales growth, Net income and the size of the firm were used as control variables.

Ahmed et al. [2012] attempt to find how concentrated ownership can influence the performance of the firms. Concentrated ownership has a negative influence on share prices while it has a positive influence on ROA. Sajid et al. [2012] concentrated ownership by shareholders and concentrated ownership by inside block holders cannot influence performance. Abbasi et al. [2012] also found a positive relationship between concentrated ownership and performance.

According to the results of the study conducted by Foroughi and Fooladi [2012] concentrated ownership structure can negatively influence performance.

Gonzalez et al. [2012] found that the performance of a firm can be influenced positively when family members are present on board. Alipour [2013] found that concentrated ownership has a positive impact on ROA. Most recently the relationship has been studied by Ahmad and Jusoh [2014] results indicates an increase in ownership rights by institutional investors performance will be increased because of efficient monitoring. Tahir and Sabir [2014] According to the results of the study Family-based firms outperform the non-Family based firm results were similar to the results of Shahab-u-Din and Javaid's study. Rashid and Nadeem [2014] according to results negative relation was found between families based concentrated ownership and performance. When a family member's performance concentrates, ownership will be decreased. In a recent study conducted by Parveen and Siddique [2014] concentrated ownership by government associated companies and managers cannot influence the performance.

Recently Ghamdi and Rhodes [2015] According to the results of the study concentrated ownership cannot influence the performance of firms but concentrated ownership by family members can have a positive influence on performance measured by Tobin's Q. Tobin's Q, ROA, and ROE will be used as a dependent variable. In the existing literature, these are the variables which are used by most of the researchers. Moreover, it is evident that these are the best measures of the performance of the firms.

TOBIN'S Q

Tobin' Q was introduced by James Tobin when he was in a try to find a relationship between Q value and investment. It is an essential measure of performance. Tobin's Q has been widely used by researchers as researchers consider it to be the best measure to calculate market performance. We used Tobin 's Q as the measure of the performance. When the value is greater than one, it means that the firm is performing well and it creates value for shareholders. To find out Tobin's Q, we used (book value of total assets – book value of equity + market value of equity) / book value of total assets. Mixed results are available in the literature.

RETURN ON ASSETS

It measures how much profit is being earned by a company by investing in their assets. The primary purpose of the assets of a company is to produce revenue. ROA indicated how profitable the assets of a company are. In this study, we measured ROA by dividing the Net Income after tax by total assets of the firm. Gonenc [2006] was unable to found a relationship between concentrated ownership and performance. According to most of the studies, ownership concentration can positively influence performance [Ghamdi and Rhodes 2015, Alipour 2013, Amran, Ahmad 2013, Isik, Soykan 2013, Shyu 2011]. Ibrahim and Samad [2011] found family-based ownership have a negative influence on ROA.

RETURN ON EQUITY

ROE is the ratio of net income divided by equity by shareholders during a year. It is an essential measure of the profitability of a company. It measures how much profit is being earned by a company from the investment of shareholders. The high value of ROE indicates that the company is generating profit for its shareholders. We divided the net income available to the common stockholder by total shareholder's equity in order to find out the ROE in this study.

OWNERSHIP CONCENTRATION

The concentration of ownership is % of shares held by top shareholders such as government, financial institutions, corporations, and individuals, or families. % of shares held by top 5 shareholders is used as a proxy for concentrated ownership. Shleifer and Vishny [1997] top shareholders can monitor the working of managers, and if managers are not working according to the contract, they can take legal action. They can use their power in order to get their benefits. According to Yeh et al. [2001], a highly concentrated structure by family members can influence performance positively. According to Johnson et al. [2000] in dispersed ownership structure with increase in ownership rights performance will be increased because the problem of free rider will be solved but when ownership rights by largest shareholders increase from a certain level than with the increase in ownership will become a reason to decrease the performance.

METHODOLOGY

Insurance companies, commercial banks, and leasing companies listed on KSE have been selected as a sample of this study, and their data has been collected for the five years. Firms which have the complete data of these five years have been included in the final sample. For analysis of quantitative data descriptive statistics, correlation matrix and regression models are generally used [Taani, 2013]. In statistical analysis, data can be analyzed by summarizing results to answer the research questions. Descriptive and inferential statistics are involved in this analysis. Descriptive statistics used in order to describe the behavior of variables. It reduces the extensive data set into bird-eye view by converting data into averages and percentages to better interpret it [Velnampy, Niresh 2012]. This is a descriptive study with empirical evidence.

THEORETICAL FRAMEWORK

The model shows the relationship of variables with each other. This model assumes that ownership concentration, family-based and non-family based ownership concentration can affect the performance of the firm.

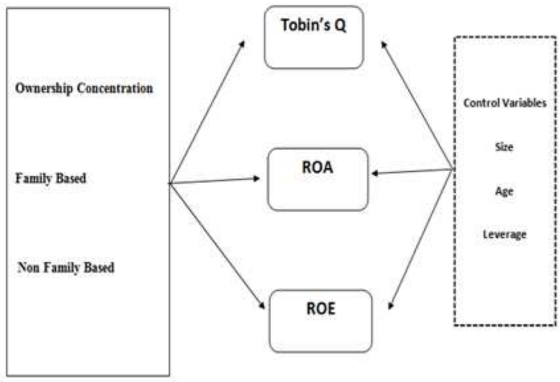

Fig. 1. Theoretical Framework

HYPOTHESIS DEVELOPMENT

H1: Ownership concentration has a significant impact on Tobin's Q.
H1a: Family-based ownership concentration has a significant impact on Tobin's Q.
H1b: Non-Family based ownership concentration has a significant impact on Tobin's Q.
H2: Ownership concentration has a significant impact on ROA.
H2a: Family-based ownership concentration has a significant impact on ROA.
H2b: Non-Family based ownership concentration has a significant impact on ROA.
H3: Ownership concentration has a significant impact on ROE.
H3a: Family-based ownership concentration has a significant impact on ROE.
H3b: Non-Family based ownership concentration has a significant impact on ROE.

RESULTS AND ANALYSIS

Table 1 shows the descriptive analysis of dependent, independent and control variables used in this study. The minimum value of the age of the firm is 4, the maximum value is 151, and 36.47 is the median which shows that on the average age of the firm is 37 standard deviations is 30.67 which shows that there is a significant deviation in the age of the firms included in the sample. The minimum value of a firm's size is 12.11; maximum value is 24 standard deviations is 2.184 which shows that value of firm's size deviates from average by

2.184%. The minimum value of the leverage ratio is -36.93 maximum values are 45.31, and the standard deviation is 8.60 which shows a substantial deviation from the mean. For ownership concentration minimum value is 8.54% and the maximum value is 98.99% while the standard deviation is 19.63% which shows that there is a significant deviation from the mean value.

Table 1. Descriptive Analysis

	N	Min	Max	Mean	Std.
AGE	180	3	151	36.47	30.607
LSIZE	180	12.1100	24.0000	19.188848	2.1844657
LEV	180	-36.9300	45.3100	7.538234	8.6048957
OWCN %	180	8.5400	98.9900	68.140449	19.6387270
FOWCN %	180	.0000	67.3200	5.631478	12.1096551
NFOWCN %	180	.0000	19.6690	1.583339	3.7782656
ROA %	180	-41.1200	46.7100	1.804389	6.9307642
ROE %	180	-460.8200	277.0000	8.733056	49.1691034
TBQ	180	.0370	1.8500	.947428	.2502053
Valid N (listwise)	180				

CORRELATION MATRIX

Correlation shows up-to which extent two variables are related to each other. This means that with the change in one variable up-to which extent another variable will be changed.

Table 2 shows a correlation between continuous variables. Concentrated ownership is insignificantly but positively correlated to Tobin's Q at 0.943% significance level. Concentrated ownership by family members is significantly but negatively related to Tobin's Q at 0.852% significance level. Concentrated ownership by non-family members is positively related to Tobin's Q at 0.299% significance level.

Table 2. Correlation Analysis

	Age	Size	Leverage	OWN	FOWN	NFOWN	ROA	ROE	Tobin's Q
AGE	1								
LSIZE	-.214**	1							
LEV	-.215**	.094	1						
OWCN %	.083	.327**	.192**	1					
FOWCN %	.071	.078	.011	.163*	1				
NFOWCN %	-.124	.074	.192**	-.191*	-.089	1			
ROA %	.274**	-.322**	-.133	-.230**	-.165*	-.128	1		

Concentrated ownership can influence ROA in the significant negative way. The value of the correlation coefficient is -0.230 at a significance level of 0.002%. Concentrated ownership by family members is significantly and negatively correlated with ROA. The relationship is significant at 0.027% level of the significant correlation coefficient is -0.165. ROA is significantly and negatively correlated to concentrated ownership by non-family members at a significance level of 0.088%.

HYPOTHESIS 1

The regression equation for this hypothesis is with control variables:

Tobin's Q $= \beta 0 + \beta 1\ (OWN) + \gamma 1\ (Age) + \gamma 2\ (Size) + \gamma 3\ (Leverage) + \varepsilon$ ……….. (1)

Without control variables:

Tobin's Q $= \beta 0 + \beta 1\ (OWN) + \varepsilon$ ………… (2)

H1: Ownership concentration has a significant impact on Tobin's Q

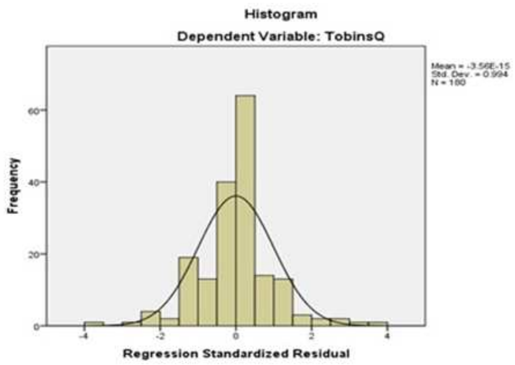

Fig. 2. Normality of Residuals for TBQ and OWCN

HYPOTHESIS 1A

Hypothesis H1a is regarding how concentrated ownership by family members can influence Tobin's Q. The regression equation for this hypothesis is with control variables:

Tobin's Q = β0 + β1 (FOWN) +γ1 (Age) + γ2 (Size) + γ3 (Leverage) + ε ……….. (1)

Without control variables:

Tobin's Q = β0 + β1 (FOWN) + ε ………. (2)

FOWN = Family based Ownership Concentration

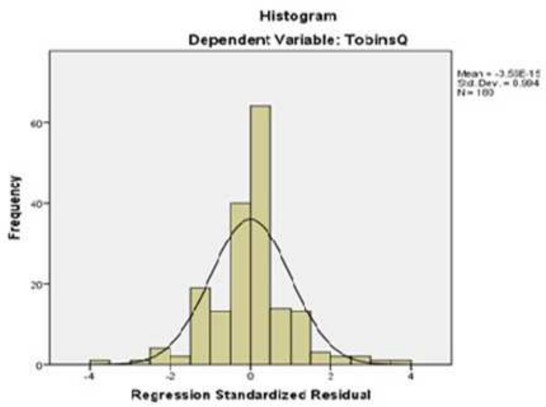

Fig. 3. Normality of Residuals for TBQ and FOWCN

HYPOTHESIS 1B

Hypothesis H1b is regarding how concentrated ownership by non-family members can influence Tobin's Q. Robustness of results has been checked by dropping control variables one by one. A strong correlation exists between control variables and dependent variables this is the reason that we take control variables into consideration

The regression equation for this hypothesis is with control variables:

Tobin's Q = β0 + β1 (NFOWN) +γ1 (Age) + γ2 (Size) + γ3 (Leverage) + ε ……….. (1)

Without control variables:

Tobin's Q = β0 + β1 (NFOWN) + ε …………….. (2)

NFOWN = Non Family based Ownership Concentration.

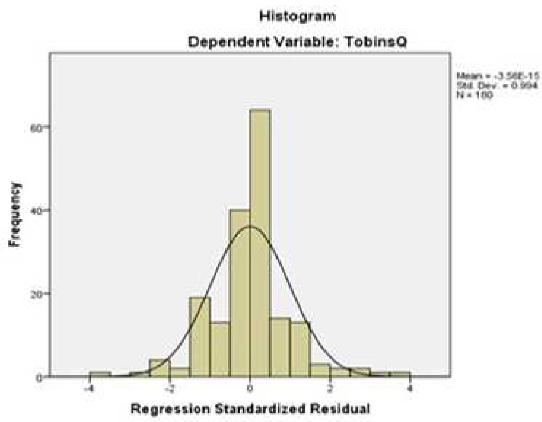

Fig. 4. Normality of Residuals for Tobin's Nonfamily Based Ownership Concentration

HYPOTHESIS 2

The regression equation for this hypothesis is with control variables:

ROA = β0 + β1 (OWN) +γ1 (Age) + γ2 (Size) + γ3 (Leverage) + ε ……….. (1)

Without control variables:

$ROA = \beta 0 + \beta 1 \, (OWN) + \varepsilon$ .... (2)

Here: OWN = Ownership Concentration

H2: Ownership concentration has a significant impact on ROA

HYPOTHESIS 2A

Hypothesis H2a is regarding how concentrated ownership by family members can influence ROA. The regression equation for this hypothesis is with control variables:

$ROA = \beta 0 + \beta 1 \, (FOWN) + \gamma 1 \, (Age) + \gamma 2 \, (Size) + \gamma 3 \, (Leverage) + \varepsilon$ .... (1)

Without control variables:

$ROA = \beta 0 + \beta 1 \, (FOWN) + \varepsilon$ ... (2)

Here FOWN = Family-based Ownership Concentration

Table 3. Regression Analysis Results Impact of FOWCN on ROA

Equation		B	Sig.	Tolerance	VIF	R Square	Durbin Watson
1	(Constant)	16.542	.000				
	AGE	.049	.003	.908	1.101		
	LSIZE	-.818	.000	.943	1.060		
	LEV	-.049	.391	.951	1.052		
	FOWCN %	-.091	.022	.985	1.015	.177	2.172
2	(Constant)	16.253	.000				
	AGE	.052	.001	.946	1.057		
	LSIZE	-.827	.000	.946	1.058		
	FOWCN %	-.092	.021	.986	1.014	0.174	2.148
3	(Constant)	.534	.586				
	AGE	.061	.000	.949	1.054		
	LEV	-.059	.317	.953	1.049		
	FOWCN %	-.105	.011	.994	1.006	0.114	2.038
4	(Constant)	21.260	.000				
	LSIZE	-.958	.000	.985	1.015		
	LEV	-.083	.145	.991	1.009		
	FOWCN %	-.080	.048	.994	1.006	0.0134	2.233
5	(Constant)	-.036	.964				
	AGE	.065	.000	.995	1.005		
	FOWCN %	-.106	.010	.995	1.005	0.109	2.010
6	(Constant)	21.225	.000				
	LSIZE	-.988	.000	.994	1.006		
	FOWCN %	-.080	.048	.994	1.006	0.124	2.205
7	(Constant)	3.128	.000				
	LEV	-.106	.075	1.000	1.000		
	FOWCN%	-.093	.028	1.000	1.000	0.211	2.034
8	(Constant)	2.335	.000				
	FOWCN%	-.094	.027	1.000	1.000	.027	1.996

Dependent Variable is ROA
Independent Variable is FOWCN

H2b: Non-Family based Ownership concentrations have a significant impact on ROA.

H3: Ownership concentration has a significant impact on ROE.

H3a: Family-based Ownership concentration has a significant impact on ROE.

H3b: Non-Family based Ownership concentrations have a significant impact on ROE.

CONCLUSIONS

Role of the financial sector is essential for the development of the whole nation. Highly concentrated ownership structure is the key issue as concentrated ownership can influence the performance of the firm either positively or negatively. It means that when ownership is not the concentrated performance of firms will be increased. By the findings, shares should be issued to individuals in a proper fraction to the moderate problem of concentrated ownership. Findings show that the Agency Theory is applicable in the context of Pakistan. In the concentrated ownership structure, the power of decision-making is held by top shareholders. They make those decisions which will beneficial for them but not for the firm. Large shareholders get benefited at the wealth of minor shareholders.

Concentrated ownership by family member's influences performance negatively. Family-based ownership is measured by the percentage of shares owned by directors who are also family members. In order to solve this issue a minimum possible number of family members should be present on the board. Results are consistent with agency theory. According to the theory when family members concentrate ownership structure, and they also have the managerial positions then they execute those policies which are right in the interest of family but not of the firm in this way performance of the firm will be decreased.

Nonfamily based ownership concentration has a positive effect on the performance of the firms. Firm-related factors such as Age, Size and Leverage Ratio of the firm can influence performance either positively or negatively.

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WPŁYW KONCENTRACJI WŁASNOŚCI NA FINANSOWĄ DZIAŁANOŚCI FIRM

STRESZCZENIE. **Wstęp:** Celem pracy była analiza wpływu koncentracji własności na sposób postępowania przedsiębiorstw, działających w sektorze finansowych i logistycznym w Pakistanie. Od wielu lat trwa dyskusji na temat wpływ praktyk sektora państwowego na działania przedsiębiorstw. Struktura własnościowa ma istotny wpływ na sposób postępowania firm, zarówno pozytywny jak i negatywny. Wpływ sposobu postępowania sektora finansowego ma istotne znaczenia dla rozwoju gospodarczego zarówno kraju jak i narodu we wszystkich sektorach, np. w tak istotnym sektorze, jakim jest logistyka. Prezentowana praca przedstawia badania pod wpływem koncentracji typu własności na działanie firm operujących w sektorze finansowych, co przekłada się również na działanie innych sektorów gospodarki, w tym logistycznego.

Metody: Badania przeprowadzono na losowej próbce 36 przedsiębiorstw. Przedsiębiorstwa te są zarejestrowane na giełdzie w Karachi, w Pakistanie. Analizie poddano okres ostatnich 5 lat, na podstawie raportów rocznych. Jako narzędzi do obróbki danych zastosowano statystykę opisową, macierz korelacji oraz modele regresji.

Wyniki: Koncentracja własności ma istotny negatywny wpływ na ROA, koncentracja własności rodzinnej ma istotny negatywny wpływ na ROA, natomiast koncentracja własności nierodzinnej ma istotny pozytywny wpływ na wskaźnik Tobin's Q i ROA. Otrzymane wyniki są spójne z teorią agencji.

Wnioski: Koncentracja własności może wpływać na działanie formy zarówno pozytywnie, jaki i negatywnie. Wyniki badań wskazują, że teoria agencji może być zastosowana w kontekście Pakistanu. W strukturze ze skoncentrowaną własnością, decyzje są podejmowane przez głównym udziałowców. Podejmują oni decyzje korzystne przede wszystkich dla siebie a nie zawsze dla całości firmy.

Słowa kluczowe: sektor finansowy, sektor logistyczny, koncentracja własności, koncentracja własności nierodzinnej, Pakistan.

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ORIGINAL PAPER

IMPRESSION MANAGEMENT DURING A CRISIS EVENT

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ABSTRACT. **Background:** With annual and integrated reporting becoming a standard practice, companies are disclosing more of their non-financial information to the public. As these corporate narratives are not regulated, they can become quite lengthy, thus, leaving room for impression management. Companies tend to present their performance in an overly positive way, resorting to various impression management strategies, especially pertaining to negative aspects. Such strategies are expected to be even more prevalent in companies faced with serious crisis events that can significantly tarnish their reputation. Thus, the purpose of this research is to analyse impression management techniques undertaken by companies in distress.

Methods: Building on existing research, a content analysis of the Volkswagen company's reports was conducted, selected as representative for analysed situation. The aim was to analyse the reporting before the emission scandal happened (2014), to see how the company positioned itself, and after the scandal (2015, 2016), to observe any changes in the annual reporting and analyse the company's communication about the scandal.

Results: The strong sustainability positioning Volkswagen has been building over the years was seriously tarnished by the emissions scandal, suggesting a high level of threat to the company's reputation. Thus, Volkswagen resorted to various impression management, the main ones being: competence enhancement, ingratiation, exemplification, apology, and redefinition of the event.

Conclusion: The impression management tactics employed by a company in distress are, to some extent, contingent on its positioning before the crisis event. Thus, a previously strong positioning on sustainability led Volkswagen to employ image salvaging tactics in an attempt to manage the public's impressions. This research sheds light on the disclosure strategies of companies in distress and contributes to existing studies of various impression management techniques used by such organizations. Potential avenues for future research could be extending the analysed corporate narratives, including press releases and other communication of the company, as well as evaluating the media's response and the public's reaction to the impression management strategies.

Key words: corporate narrative, crisis management, disclosure strategies, impression management.

INTRODUCTION

With annual and integrated reporting becoming a standard practice, companies are disclosing more of their non-financial information to the public. As these corporate narratives are not regulated, they can become quite lengthy, thus, leaving room for impression management. Impression management, sometimes used interchangeably with self-presentation, is defined by Hooghiemstra [2000] as a field of study dealing with the way people present themselves to be positively perceived by others.

The concept was first introduced by Goffman [1959], discussing the various communication and self-presentation techniques that individuals use to favourably influence others' impressions of them. It was later applied by other researchers in a corporate context, seeking to observe whether and how companies use impression management techniques in their reporting or communication with the public.

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The purpose of this research is to analyse impression management techniques undertaken by companies in distress, specifically Volkswagen during the recent emissions scandal. After scandals of such a high level that significantly tarnish the corporate image, companies may employ distinct manoeuvres in an attempt to salvage their reputation.

Volkswagen Group is a German automobile manufacturer with a worldwide presence. In September 2015, the Environmental Protection Agency (EPA) conducted an investigation into the company and discovered that its vehicles were equipped with a 'defeat device'. This software allowed the engines to detect when they are being tested and adjust the emissions to show better results [Hotten, 2015]. Volkswagen faced a severe backlash and threat to its reputation.

The company Volkswagen Group is a big and well-known company and therefore the analysis of its way to manage a crisis is a good basis for general conclusions in this area.

The next section provides a review of previous literature, followed by the research methodology used, a discussion of the findings and, finally, a conclusion.

LITERATURE REVIEW

Numerous studies have delved into the way companies present themselves to the public and the strategies they use. Oliver [1991] classified various strategic responses to institutional processes, from passive conformity to proactive manipulation. The researcher also used institutional factors in an attempt to predict the occurrence of the strategic responses and the extent to which companies are conforming or resisting institutional pressures.

Clatworthy and Jones [2003] looked into financial reporting of good and bad news, analysing impression management techniques in the chairmen's narratives. The objective was to observe whether companies with a declining performance report the news differently to companies with an improving performance. Findings reveal a similar self-serving approach in all companies, as they tend to emphasise the positive aspects and attribute the good news to themselves, while blaming the external circumstances for the bad aspects.

Hooghiemstra [2000] provides new perspectives into why companies engage in CSR reporting, discussing the legitimacy theory and the concept of corporate communication, focusing on corporate image and identity. The author also synthesizes previous literature and identifies four impression management tactics, applying those to the case of Royal Dutch Shell and its negative publicity in 1995.

With business model (BM) reporting deemed as essential for investors' analysis, Melloni, Stacchezzini and Lai [2015] set out to investigate whether companies use impression management (IM) techniques to manipulate the tone of their BM disclosures. Performing a content analysis on several reports, the authors found that companies do use BM disclosure as an IM strategy, with majority of the disclosures having a positive tone.

Merkl-Davies and Brennan [2007] researched the various disclosure strategies used by preparers of corporate narrative reports and how users of the reports react to them. The authors provide a comprehensive synthesis of the existing literature, classify the motivations for discretionary disclosure, and discuss the various impression management strategies undertaken by companies. The same authors [2011] also contribute to a better understanding of impression management in the corporate context by building a conceptual framework, including psychological, sociological, and critical perspectives. The purpose of the paper was to create a taxonomy of prior research, classifying it into distinct perspectives, and, thus, helping researchers to pinpoint their study within a particular perspective.

A study was conducted into rhetorical impression management in corporate narratives and aimed to observe whether the institutional environment of a company is reflected in the rhetorical style of the CEO's shareholder letter. Findings reveal three different linguistic styles, which proved to be more evident in US versus

UK companies [Yan and Aerts, 2014]. Rahman [2012] discusses the motivations behind impression management, the different strategies, and whether these affect the credibility of the message.

Tata and Prasad [2014] looked at CSR communication through an impression management perspective, proposing that companies are motivated to use CSR communication to bridge the gap between their current and desired CSR images. The paper introduces a model of four dimensions of CSR communication and impression management tactics.

Some studies are specifically focused on how companies manage impressions in a sustainability context. Hanh and Lüfs [2014] conducted qualitative research into corporate disclosures in sustainability reporting to observe the strategies used for legitimizing negative aspects. The authors found six different strategies and concluded that symbolic legitimation strategies are more prevalent in the analysed reports, as opposed to substantial strategies. The researchers also designed a model for reporting the negative aspects, aimed at improving the balance and fairness of sustainability disclosure.

A similar approach was taken by Sandberg and Holmlund [2015], researching impression management tactics that companies use in sustainability reporting. The authors performed a qualitative template analysis of two reports, identifying four specific strategies - description, praise, admission, defence, and four different writing styles - subjective, positive, vague, and emotional.

Researchers have also looked into impression management techniques of companies during crisis events or scandals, to observe the tactics they use to salvage their reputations. Van Halderen et al. [2016] discuss impression management in the oil industry, aiming to observe how firms' strategies change under extreme pressure. The researchers analysed the actions of two companies, suggesting that firms feel obliged to keep defending one specific view of themselves, their strategies changing only slowly.

A similar research into strategic manoeuvres and impression management was done by O'Connell et al. [2016], examining the communication approaches of an asbestos company during a crisis event. Based on Oliver's [1991] research into strategic responses, the authors analysed corporate disclosures, unveiling strategies of avoidance, defiance, manipulation, and compromise.

Ang and Ayoko [2008] set out to observe employee's emotional states during an organizational crisis, and their reactions to the impression management strategies used by the company. The authors built on the previous research performed by Benoit [1997], who introduced a model for image repair discourse, aiming to provide deeper understanding of corporate crises.

Coombs [2007] developed a Situational Crisis Communication Theory, which is an evidence-based framework for achieving maximum reputational protection through crisis communication. The author classified the types of crises into clusters, discussed the steps in analysing their threat level for the company, and provided crisis response strategies. The strategies are divided into primary – denial, scapegoat, excuse, apology, etc., and secondary – reminder, ingratiation, victimage. The secondary strategies can be applied to an impression management perspective, as well.

McDonnell and King [2013] researched the use of prosocial claims by companies that are the subject of social movement boycotts. To preserve their public image, firms may communicate their "commitment to socially acceptable norms, beliefs, and activities", the authors claiming that these prosocial claims serve as impression management tactics. The findings reveal that these claims do increase once boycotts against the firm are announced and the extent of the increase depends on the level of threat the firm faces.

Hakala [2017] did a similar study of Volkswagen's corporate narratives before and after the scandal occurred. The paper, however, focuses on sustainability reporting, analysing the ethos, logos, and pathos of the company's reports.

RESEARCH METHODOLOGY

The research methodology used was content analysis of Volkswagen's corporate narratives in three annual reports – 2014, 2015, and 2016. The aim was to analyse the reporting before the emission scandal happened (2014), to see how the company positioned itself, and after the scandal (2015, 2016), to observe any changes in the annual reporting and analyse the company's communication regarding the scandal.

The company's annual reports are divided into 5 sections: Strategy, Divisions, Group Management Report, Consolidated Financial Statements, and Additional Information. The "Divisions" section contains information about individual brands and business fields, and the key figures for each. A lot of the subsections from the "Group Management Report" include boilerplate information with minor adjustments to the specific year of reporting. Thus, for the purpose of this research, only relevant information was considered. This includes any information pertaining to the diesel scandal itself or to the company's stance on sustainability in general. Such information was predominantly found in the "Letter to Our Shareholders", "Goals and Strategies", and "Sustainable Value Enhancement" subsections. In the post-scandal annual reports, the company dedicated a separate subsection to the emissions issue, which was also analysed.

Seeing as crisis management and impression management are closely linked in the context of this paper's objective, the basis for this research was taken from literature related to both of the concepts. Jones and Pittman [1982] introduced five strategies for self-presentation from a social psychology perspective – ingratiation, intimidation, self-promotion, exemplification, and supplication. These have later been used in a corporate context by other researchers.

Allen and Caillouet [1994] researched impression management techniques in the external discourse of a company in crisis. Findings revealed that different strategies were directed at different stakeholders, and among these are ingratiation, intimidation, and denouncement.

Tierney and Webb [1995] analysed the press conference tapings of Exxon Corporation after the major oil spill scandal. Drawing from the work of Goffman, the authors identified four specific strategies followed by Exxon during the crisis – competence enhancement, information control, personalization of the event, and redefining the event.

Benoit [1997] identifies fourteen image restoration strategies, classifying them into denial, evasion of responsibility, reducing offensiveness of event, corrective action, and mortification.

These are the main previous studies based on which the research of Volkswagen's corporate narratives was conducted. Some strategies identified by the authors either overlap or have a similar meaning, the findings of the content analysis are discussed below.

RESULTS AND DISCUSSION

Before the Scandal

The content analysis of Volkswagen's 2014 Annual Report, before the scandal occurred, reveals the self-presentation tactics used by the company. The overall tone of the report is rather confident and optimistic, with a lot of praise of the company's performance, juxtaposed against the challenging and uncertain external environment. This is similar to the findings of Clatworthy and Jones [2003], except that Volkswagen doesn't blame the external circumstances for its performance, but rather uses it to elevate the company in the public's eye. The following statements are taken from Martin Winterkorn's, the CEO at that time, Letter to Shareholders:

"In addition, the automotive industry is currently experiencing fundamental change… But at Volkswagen, we do not see this transition as a threat, but rather as a tremendous opportunity..." [Volkswagen AG, 2015].

"Political and economic uncertainty dominated the situation in many regions of the world, and this also had far-reaching consequences for the automotive industry. Despite these headwinds, we successfully kept your Company on a strong, stable trajectory." [Volkswagen AG, 2015].

Worth noting is the choice of the pronoun in the last sentence – "your", rather than "our" Company. This is done with the aim to further engage the shareholders, elicit more involvement, and boost their loyalty and trust. The entire letter to shareholders, essentially, emphasizes the company's stellar performance, reassuring the shareholders that their trust and support of the company are not futile:

"This is another reason why I am convinced that your confidence in and support for the Volkswagen Group and its team will pay off. In every respect." [Volkswagen AG, 2015]

The report also reveals a great emphasis placed on the company's stance on sustainability. Its environmentally friendly orientation and the major goals it intends to achieve ecologically are discussed throughout the report, and referred to as "Strategy 2018". This strategy entails Volkswagen becoming the global economic and environmental leader, and is mainly discussed in the "Goals and Strategies" and "Sustainable Value Enhancement" sections, with a separate subsection titled "On the way to becoming the ecological leader". Even in its discussion of environmental strategies, the company still boasts of its superior capabilities:

"With its long history of commitment to protecting the environment, the Volkswagen Group is better equipped than most companies to meet these challenges" [Volkswagen AG, 2015].

There is also a significant accent placed on responsibility, transparency, and bringing benefits to all stakeholders. The company's goal to become an ecological leader is based on specific key areas, one of which is reducing the fuel consumption and CO_2 emissions of the vehicles.

The pre-scandal corporate narrative, in hindsight, is now marred with a rather hypocritical note, which underlines the severity of the issue. The strong sustainability positioning Volkswagen has been building over the years was seriously tarnished by the emissions scandal, suggesting a high level of threat to the company's reputation. Thus, it can be expected that Volkswagen will resort to various impression management tactics in its post-scandal reports, attempting to save its corporate image.

After the Scandal

The "Group Management Report" sections of both the 2015 and 2016 Annual Reports are longer than in the pre-scandal report, as the company dedicates a separate subsection to the issue, as well as mentions and refers back to it throughout the report. These subsections provide a clarification of the emissions issue and an overview of the conducted investigations. Both of the reports also repeatedly underline Volkswagen's cooperation in the investigations and the numerous steps it claims to be taking to fix the issue.

Interestingly, in the 2015 report, when talking about the scandal, the company uses phrases like "it has been alleged", "appeared to have been", and "potentially illegal". This choice of words creates an impression of the company not wanting to assume full responsibility. Another example is "we found slight discrepancies in only a very limited number of engine-transmission variants". This seems like the company's attempt at reducing the severity of the issue, although, Volkswagen does repeatedly state that it condemns infringements of law. In the 2016 report, such choice of words is absent, the company mainly emphasizing its work towards correcting the problem. Below are some impression management techniques that Volkswagen used in its post-scandal reports.

Competence enhancement. Tierney and Webb [1995] introduce this strategy as conveying an image of competence and an effective response to a crisis event. As previously mentioned, both of the reports repeatedly stress Volkswagen's key role in investigating and fixing the issue. Thus, this tactic is prevalent in the corporate narratives, accompanied by strong adjectives and adverbs:

"Volkswagen's reaction has been comprehensive and the Company is working intensively to clarify the irregularities." [Volkswagen AG, 2016]

"We are now working expeditiously to implement the technical solutions in the field." [Volkswagen AG, 2017]

This tactic is used by the company to reassure the public that it is adequately handling the issue, thus, boosting its corporate image. Another aspect of this strategy is putting an emphasis on the company's good traits, Benoit [1997] defining this as bolstering. Similarly, Jones and Pittman's [1982] strategy of self-promotion describes the pursuit for an attribution of competence.

This tactic is especially evident in the Letter to Shareholders, from Matthias Müller, the current CEO. The corporate narrative addresses the issue, but aims to draw more attention to the positive aspects, underlining the fact that Volkswagen still managed to perform well, despite the issue:

"… our operating business continues to be in excellent shape…"

"… the Group's unchanged robust financial strength, …" [Volkswagen AG, 2016].

In the same Letter from the 2015 report, Mr Müller also stresses the importance of Volkswagen's corporate identity not being reduced to the emissions scandal, neglecting its previous accomplishments. The 2016 Letter to Shareholders, again, emphasises the company's proficiency, boasting its title of best-selling automaker:

"For me it is important that you know there is much more to Volkswagen than this crisis. Our Group has qualities that did not vanish overnight, qualities on which we can also build for the future" [Volkswagen AG, 2016].

"… when we are still coping with the consequences of the crisis and have long since defined new priorities for the future – the headlines read: "Volkswagen becomes the world's best-selling automaker."" [Volkswagen AG, 2017].

There is an obvious attempt to revamp the corporate image, and remind the stakeholders of the company's core competencies. Considering the seriousness of the issue and its threat to the reputation, it is an expected strategy to be undertaken by Volkswagen, attempting to move the spotlight towards its positive qualities.

Ingratiation. According to Jones and Pittman [1982], ingratiation entails seeking an "attribution of likability" and, in the corporate context, Allen and Caillouet [1994] describe it as organizations expressing conformity to normative rules to obtain the audience's approval.

This tactic was also extensively used by Volkswagen throughout the reports, the company attempting to achieve likability in different ways. One of the ways was making sure the readers know that Volkswagen does not condone such behaviour, aiming to portray a sound corporate value system:

"Volkswagen does not tolerate any infringements of rules or laws. The irregularities that occurred contradict everything Volkswagen stands for." [Volkswagen AG, 2016].

In the following excerpts, another attempt at achieving audience's approval can be noted. By alluding to the fact that making mistakes is part of human nature, it seeks to achieve more likeability, especially as it expresses its readiness to learn from its mistakes:

"… we must above all learn from past mistakes and draw the right consequences so that something like this can never happen at Volkswagen again." [Volkswagen AG, 2016].

"We are working urgently to live up to our own standards again and restore our customers' and society's confidence." [Volkswagen AG, 2016].

Considering the high level of threat to the corporate reputation, there are many instances of Volkswagen ingratiating itself with the stakeholders. It is repeatedly asking for their trust, calling it its most important asset, and thanking them for their patience and loyalty:

"Now more than ever, that trust must be earned. And we are working on that. Which is why, this year, I am asking above all for your continued loyalty to Volkswagen…" [Volkswagen AG, 2016].

On behalf of our employees and in my own name I would like to thank you for your loyalty and support during a difficult time for your company [Volkswagen AG, 2017].

Exemplification. Jones and Pittman [1982] define this strategy as projecting "integrity and moral worthiness". This is quite similar to ingratiation, or, could be considered part of it, since having integrity also increases likeability and the audience's approval.

In response to the crisis, the company reminds the stakeholders of its strong convictions, painting an image of integrity. Also, after praising Volkswagen for becoming the best-selling automaker, the CEO states that pursuing such records is actually not what stimulates the company, but continuously perfecting itself is:

"However, our conviction remains unchanged: compliant behavior is a cornerstone of business success..." [Volkswagen AG, 2016]

"… chasing records is not what drives us. Our real mission is to make Volkswagen and its products better and better." [Volkswagen AG, 2017].

An attempt to further heighten itself in the public's eye can be seen in the following excerpt. Volkswagen not only states that it has already made major changes to its activities, but also sets a goal of becoming a role model for its integrity and the way it handled the crisis:

"The Group has substantially elevated its commitment to working ethically and with integrity. Volkswagen can and will set an example in the years ahead as to how a large, global company embodies and takes its social responsibility seriously" [Volkswagen AG, 2017].

Apology. Assuming responsibility and apologizing for the act is another strategy, Benoit [1997] classifying it under mortification. This, again, could be considered a part of ingratiation.

In the 2015 annual report, Volkswagen explicitly asked for forgiveness, Matthias Müller opening his first statement as CEO with an apology for the issue. In the 2016 report, however, the company mostly expresses its remorse, but doesn't explicitly apologize:

"On behalf of the Volkswagen Group I would like to apologize to you, our shareholders, that the trust you placed in Volkswagen has been broken" [Volkswagen AG, 2016].

"We deeply and sincerely regret the behavior that gave rise to the diesel crisis" [Volkswagen AG, 2017].

Asking for forgiveness in such a crisis is an obvious strategy for a company wanting to salvage its corporate image. Interestingly, it is only present in the 2015 report, as the 2016 one mostly draws attention to more positive aspects. This could be explained by Volkswagen wanting to move on from the issue and regain its positioning as a sustainable company by focusing on specific actions it is taking.

Redefinition of the event. According to Tierney and Webb [1995], companies may redefine the event to reduce the stigma and present the company in the best possible way. Volkswagen's use of this strategy was spinning the scandal and presenting it as an opportunity:

"… it is important we use this crisis as an opportunity: an opportunity to realign the Group in an automotive world..." [Volkswagen AG, 2016].

"Getting to the root of what happened and learning from it. Taking advantage of the opportunity for a fundamental realignment" [Volkswagen AG, 2016].

The company also used this as a chance to introduce its new Strategy 2025, building on the previous Strategy 2018. Seeing as the previous strategy of becoming an economic and environmental leader was heavily stained by the scandal, Volkswagen, essentially, rebranded it and presented it as a framework for its fundamental transformation and success:

"With its future program … Strategy 2025, the Volkswagen Group has launched the biggest change process in its history, laying the foundations for lasting success … and for its evolution into a globally leading provider of sustainable mobility" [Volkswagen AG, 2017].

CONCLUSIONS

Companies tend to present their performance in an overly positive way, resorting to various impression management strategies, especially pertaining to negative aspects. Such strategies are expected to be even more prevalent in companies faced with serious crisis events that can significantly tarnish their reputation. After conducting a content analysis of Volkswagen's post-scandal annual reports, five impression management techniques were identified – competence enhancement, ingratiation, exemplification, apology, and redefinition of the event. The severity of the issue and the previously strong positioning on sustainability led Volkswagen to employ image salvaging tactics to manage the public's impressions. The company mainly tried to present itself in the best possible light, by emphasising its competence and adequate problem-solving abilities. It also attempted to maintain an image of integrity, redefining the event into an opportunity for implementing significant change in the organization.

This research contributes to existing studies of various impression management tactics used by organizations in crises. The main limitations stem from the research method used, the findings being contingent on the subjective interpretation of the researcher. Potential avenues for future research could be extending the analysed corporate narratives, including press releases and other communication of the company, as well as evaluating media's response and the public's reaction to the impression management strategies.

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ZARZĄDZANIE WIZERUNKIEM W SYTUACJI KRYZYSOWEJ

STRESZCZENIE. **Wstęp:** Wraz z popularyzacją rocznych raportów publikowanych przez firmy, które to stają się standardem postępowania, coraz więcej informacji przedostaje się do wiadomości publicznej. Ponieważ sposób komunikacji nie jest poddany żadnej regulacji, zdarza się, że te komunikaty są na tyle długi, iż umożliwiają różną interpretację. Firmy mają skłonność do prezentowania siebie w pozytywny sposób, używając do tego różnych technik komunikacyjnych, szczególnie w przypadku negatywnych aspektów. Takie techniki uniku są szczególnie popularne w przypadku poważnych kryzysów, które mogą istotnie nadszarpnąć ich reputację. Celem tej pracy jest analiza technik zarządzania wizerunkiem przez firmy w sytuacji kryzysowej.

Metody: Analizie poddano oficjalne raporty firmy Volkswagen, wybranej jako reprezentatywnej dla badanej sytuacji. Celem było przeanalizowanie prezentowanych informacji emitowanych przed skandalem związanym z emisją (2014) oraz po skandalu (2015-2016) i na tej podstawie zaobserwowaniu zmian w sposobie prezentowania danych o sobie przez firmę.

Wyniki: Przez lata firma Volkswagen budowała wizerunek firmy o zrównoważonym rozwoju i zarządzaniu, który został zburzony przez skandal emisyjny. W związku z tym firma podjęła szereg działań ujmowanych jako zarządzanie wizerunkiem, wśród których najważniejsze to: poprawa kompetencji, pochlebstwo, zilustrowanie, przeprosiny, przedefiniowanie zdarzenia.

Wnioski: Metody zarządzania wizerunkiem przez firmę w czasie kryzysu, zależą od jej pozycji i wizerunku w okresie przedkryzysowym. W przypadku Volkswagen silnie podkreślany wizerunek firmy zrównoważonej umożliwił firmie odpowiednie zarządzanie jej wizerunkiem w czasie kryzysu. W pracy zaprezentowano różne techniki stosowane przez firmy dla zarządzania swoim wizerunkiem. Jednocześnie praca ta może być podstawą do dalszych badań w tym zakresie oraz do oceny odpowiedzialności mediów w obszarze zarządzania wizerunkiem przez firmy.

Słowa kluczowe: komunikacji w korporacji, zarządzanie kryzysem, strategie wyjaśniania, zarządzenie wizerunkiem

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ORIGINAL PAPER

BIOPLASTIC PACKAGING MATERIALS IN CIRCULAR ECONOMY

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ABSTRACT. **Background:** The European strategy for plastics focuses on adjusting the EU regulations to the fulfilment of circular economy tasks. Circular economy is an approach that will soon lead to considerable changes in numerous branches of modern economy. To a large extent, they will also affect the packaging industry.
Methods: A particular interest has been attracted by aliphatic polyesters such as polylactide (PLA) and polyhydroxyalkanoates (PHA). This work presents the bioplastic market and the selected examples of the latest solutions in bioplastic packaging materials. In the near future, the presented bioplastics have a chance to become some of the most desirable packaging materials
Results and conclusion: Bioplastics seem to be an alternative to conventional plastics used for packaging production. As the focus shifts to creation of sustainable environment and prevention of plastic waste disposal in the environment, the production of bioplastics has gained much attention due to their biodegradability.

Key words: bioplastics, packaging materials, circular economy.

CIRCULAR ECONOMY IN PACKAGING

The global production of plastics has been growing for years. Packaging applications are the largest application sector for the plastics industry. They represent 39.6% of the total demand for plastics, which generates the increase in their production [PlasticsEurope, 2016]. As a result, over the last 70 years, global plastics production grew from nearly 0.5 million tons in 1950 to over 365 million tons in 2016. In 2017, it reached about 348 million tons per year. Europe is the second largest producer of plastics in the world after China with around a 40% market share for packaging purposes [Plastics Europe, 2017].

Although the use of plastics has many advantages in comparison to other materials [Andrady, Neal 2009], their drawbacks are becoming more visible. Most materials used in the packaging industries are produced from fossil fuels and they are practically nondegradable [Nampoothiri et al. 2010]. Despite that, for many years, the need to recover raw materials was not acknowledged. However, recently it has become necessary to change the approach to the management of packaging and packaging waste. In December 2015, the European Commission adopted the EU action plan for circular economy. Therefore, recently the EU has enacted two legal documents related to the packaging industry and waste management: Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste and Directive (EU) 2018/852 of the European Parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste.

The EU regulations related to circular economy (CE) focus on packaging production and recovery of materials from waste.

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According to the European Commission, the potential for recycling plastic waste in the European Union remains unfulfilled. Europe generates 25.8 million tons of plastic waste per year but only 30% of it is recycled. Of 34 million tons of plastic waste, as many as 93% are stored on landfills and in the oceans [Pathak et al. 2014].

It is estimated that 100 million tons of polymers cause an ecosystem service damage amounting to approximately US$ 13 billion per year [United Nations Environment Programme 2014]. In circular economy (CE), products, materials and raw materials circulate as long as possible, which leads to minimization of waste. The main purpose of those actions is to increase recycling and limit the storage of packaging waste to 55% by 2025. Circular economy takes into consideration all stages of product life cycle, i.e. design, production, consumption and reuse of waste.

According to the European Union, CE has been introduced as a high-level strategy to move our societies beyond these limits [European Commisssion 2015]. Circular economy presents a solution to limit the excessive use of raw materials and makes it possible to reuse those materials that have already been used. However, only some types of materials can undergo repeated recycling or reuse. According to Ghisellini et al. [2016], CE will promote high value material cycles instead of recycling only low value raw materials as in traditional recycling). Furthermore, decomposition of plastics is known to be very difficult, and it involves high emission of CO_2 and many other toxic compounds [Emadian and Onay, 2017]. Many doubts are also raised by the fact that the majority of recycling methods cause an about 10% loss of material and material quality [Merrild et al. 2012]. Given the gigantic amount of plastics used for products, bioplastics may be a way to get a handle on our overwhelming waste problem. Recently the attention in the packaging industry regarding the use of bioplastics has been shifting from compostable/biodegradable materials towards bio-based materials [Nampoothiri et al.2010].

BIOPLASTICS MARKET

According to Mohanty et al. [2002], bioplastics are a new generation of plastics that limits environmental impact in terms of global warming and energy consumption. The term “bioplastics” is an umbrella term which describes several groups of materials: bioplastics from renewable resources, bioplastics from fuel resources, and bioplastics derived partially from renewable resources and partially from fuel resources. In terms of their susceptibility to disintegration, they can be divided into biodegradable materials, which include compostable materials, as well as non-biodegradable materials [Cooper 2013]. The non-biodegradable materials produced from renewable raw materials include, among others, polyethylene produced from bio-based ethanol. Materials that are biodegradable in the course of industrial composting but do not originate from renewable resources include, among others, PBAT or PCL, which may be obtained from natural products or petroleum. Biodegradable materials produced from renewable raw materials include PLA, PBS and PHA.

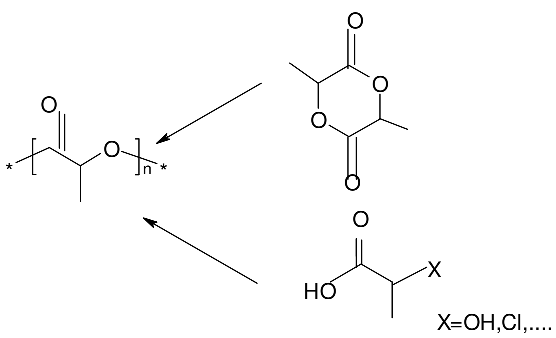
Biodegradable materials are undoubtedly eco-friendly but they have certain limitations such as high costs of production and low mechanical tendency. The decrease in the availability of gasoline and diesel due to higher costs exacerbates the shortage of resources, which promotes the need to create bioplastic materials [Thakur et al. 2018]. Therefore, natural polymers and polymers from renewable resources seem to be an alternative to conventional plastics. Their use is advantageous also from the economic point of view: their production requires less energy and does not result in toxic by-products.

The demand for bioplastics is constantly growing because they are applied in various contexts in order to manufacture more and more complex products. In 2017, the amount of biodegradable plastics produced at the global level was about 880 Gg [European bioplastics 2018], corresponding to less than 0.3% of the total amount of plastics produced that year (320,000 gigagrams). The demand for bioplastics is expected to grow to about 6 million tons per year.

The main recipient of bioplastics is the packaging industry. In the recent years, there have been developed many packaging materials based on starch, polylactide, polyhydroxyalkanoates, poly(glycolic acid) (PGA), aliphatic-aromatic polyesters, cellulose or lignin that are currently present on the market. Bio-based resources have a major role in the production of novel and bio-based materials [Brodin et al. 2017].

BIOPLASTIC PACKAGING MATERIALS

Bioplastic packaging materials, such as PLA and materials reinforced with natural fibers, have attracted particular attention over the past few years [Soroudi and Jakubowicz, 2013]. PLA is produced by conversion of corn, or other carbohydrate sources, into dextrose, followed by fermentation [Panseri et al. 2018] of polysaccharides or sugar, e.g. extracted from corn, potato, cane molasses or sugar-beet, into lactic acid [Murariu and Dubois, 2016]. PLA is produced as a result of ring opening polymerization and poly-condensation of lactic acid [Dubey et al., 2017] (Figure 1).



Source: Dubey et al. 2017

Fig. 1. Lactide and lactic acid monomer to form PLA

Studies show that PLA possesses good mechanical properties (high Young's modulus and tensile strength) and a high level of transparency. Similarly to conventional petrochemical plastics, it is easy to process [Auras et al. 2004]. The world literature presents many examples of PLA modification. One such solution was suggested by Przybytek et al. [2018], who combined polylactide (PLA), potato thermoplastic starch (TPS) and plant glycerin, and processed them by melt extrusion with epoxidized soybean oil as the reactive modifier. The presented studies have shown that it is possible to replace even up to 25% of PLA with mTPS. It will help to reduce product costs while retaining similar characteristics and compostability.

The addition of another biodegradable polymer-poly(ϵ-caprolactone) (PCL) changes the properties of PLA [Ostafinska et al. 2017] . The PLA/PCL combination was characterized by high rigidity (due to the presence of PLA) and hardness (due to the presence of PCL). The obtained material is promising as regards application in the packaging industry as well as other branches of industry. Spiridon and Tanase [2018] produced new poly (lactic acid)-lignin biocomposites. The addition of lignin to PLA in the amount of 7 to 15 wt% resulted in greater tensile strength. Biocompatibility studies evidenced that the addition of lignin to a poly (lactic aci d) matrix can allow for tailoring the final properties of the composites without inducing any significant changes in cell metabolic activity (compared to poly (lactic acid) itself).

Apart from PLA, the most commonly used biomaterials include starch. Starch has very favourable physical characteristics, such as high barrier properties and good rheological properties. Polymers combined with starch can be used without any limitations. The application of starch in the packaging industry dates back to the 90s. The first bags made from Mater-Bi became available in Germany in 1992 [Byun et al. 2014]. The studies carried out by Luchese et al. [2017] showed that corn and cassava starch may be considered promising alternatives for food packaging. The mechanical property values of starch based films were comparable to those of LDPE based film. The application of thermoplastic starch (TPS) offers numerous possibilities. Due to its characteristics, it may be processed in many ways, including casting, thermo-molding or extrusion and injection molding. As part of their studies, Sagnelli et al. [2016] produced starch-based bioplastic prototypes fabricated from an almost amylopectin-free starch synthesized directly in the barley grain. Also modified starch, including starch modified with citric acid, turned out to be a very promising biopolymer. That modification improves the thermodynamic stability of starch [Qian et al.2015; Ban et al.2006]. Domene-López et al. [2018] obtained interesting biodegradable materials as a result of combining potato starch/PVA with different concentrations of rosin. The addition of 8% rosin to starch/PVA blends led to tensile strength values higher than 10 MPa and elongation at break values close to 2000% in comparison to LDPE. The addition of 8% rosin to starch/PVA blends led to increases in maximum tensile strength and elongation at break by 72% and almost 400%.

Polyhydroxyalkanoates (PHA) are biopolymers of hydroxyl fatty acids that act as storage compounds during unbalanced microbial growth [Wijeyekoon et al. 2018]. We know such polyhydroxyalkanoates as PHB (poly(3-hydro-xybutyrate) and its copolymers: poly(3hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), poly[(R)-3-hydroxybutyrate-co-(R)-3-hydroxyhexanoate (PHBHx) and poly[(R)-3-hydroxybutyrate-co-4-hydroxybutyrate (P3HB4HB) [Gahlawat and Soni, 2017]. Polyhydroxybutyrate (PHB) bioplastics got the attention of the scientific community due to their low CO2 emission [Mostafa et al. 2015]. PHA polymers are fully biodegradable and compostable. Prokaryotes cause decomposition of PHA into carbon dioxide and water, which are consumed during plant growth. In addition, thermoplastic properties of PHA are similar to those of petrochemically derived polypropylene and polyethylene [Morgan-Sagastume et al. 2010]. To draw a comparison, polylactic acid (PLA) is compostable, but may remain in marine environments for up to a thousand years [DiGregorio, 2009]. However, the market size is still limited, mostly due to the elevated costs of PHA production, so many scientists are looking for manufacturing methods that require small outlays. For this purpose, PHA was produced with the use of such substrates as molasses, plant oils and fatty acids or microbes[Ntaikou et al. 2009]. Moreover, the use of waste substrates and/or mixed microbial consortia is of increasing interest as a strategy to reduce production cost [Burniol-Figols et al. 2018]. Challenges for PHA production include dependence on pure carbon sources, such as glucose; the requirement of organic substitutes for production of different types of PHA; the possibility of contamination; and the use of large amounts of solvents in downstream processing [Rodriguez-Perez et al., 2018]. One of the raw materials used for PHA production may be macroalgal biomass. This is exemplified by the studies conducted by Ghosh et. al. [2019], in which the authors evaluated the carbohydrate composition of 7 seaweeds to provide a carbon source for PHA produced by Haloferax mediterranei. Among the tested combinations, green macroalgae Ulva sp. had the best composition for the maximum yields of PHA. Sawant et al. [2018] proved that red algae Gelidium amansii can be used for PHA production without extensive hydrolysis.

Agro-industry waste has also been investigated as a low cost substrate for PHA production. Organic waste may be subjected to anaerobic fermentation or hydrothermal treatment to produce organic acid rich solutions. The volatile fatty acid rich liquors are an ideal feedstock for PHA production. Such a solution is illustrated in the work of S. Wijeyekoon et al. [2018]; the authors studied PHA production potential of substrates generated through subcritical wet oxidation (WO) of organic biomass. They presented two aspects of mixed culture PHA fermentation: first, the impact of a feed characterized by low carbon-nitrogen ratio, this being a natural characteristic of wet oxidized biomass conversion; and second, the influence of dissolved oxygen limitation as an alternative substrate limitation to enhance metabolism of carbon into PHA storage. The results of the studies showed that substrate feeding regime and oxygen concentration can be used to control the PHA yield and accumulation rate, thereby enhancing PHA production viability from nutrient rich biomass streams. The enzyme which produces PHA was extracted by Reddy et al. [2017] from two bacterial strains: P. pseudoflava and P. palleronii. As evidenced by the studies, P. palleronii showed higher PHA synthase enzyme activity than P. pseudoflava. It indicates the possibility of feeding the P. pseudoflava with cheap VFA rich fermented waste to produce PHA.

The scientific group of Bilo et al. [2018] obtained bioplastic from rice straw. Rice straw is considered agricultural waste, and its management is easy because it does not require separation from other waste [Dominguez-Escriba and Porcar, 2011]. The obtained bioplastic material exhibits good mechanical properties, with tensile strength and elongation at break equal to 45 MPa and 6.1% and 10 MPa and 63% for dried and wet dumbbell respectively. It proves that mechanical properties of bioplastic are comparable to those of polystyrene, while cast bioplastic in wet state is similar to plasticized poly(vinyl chloride). Moreover, the studies showed high mechanical performance of the newly obtained bioplastic both in dry and wet state.

Ramakrishnan et al. [2018] produced bioplastics with the use of chicken feathers followed by the mixing of different concentrations of glycerol. It was observed that the increased volume of glycerol reduced the time required for foil degradation. With 10 wt% glycerol content, the obtained foil disintegrated after 6 hours. This is the result of the poor strength and bonding between keratin and glycerol within the film [Ullah et al. 2011].

SUMMARY

Circular economy is one of the major principles of the economic policy of the European Commission. It is an approach adopted in order to tackle environmental challenges and support sustainable development. Circular economy promotes closing loops in industrial systems, minimizing waste, and reducing raw material and energy inputs [Stahel, 2016]. It pertains to industry, the entire economy and, to a large extent, the packaging industry. Circular economy introduces significant changes that have a huge impact on the future of the packaging industry. It is connected with the approach to environmental issues as regards composted polymer packaging materials that can minimize the increase of packaging waste currently generated from conventional plastics. In order to address those challenges, scientists all over the world are conducting studies to develop bioplastic materials whose properties will be similar to those of plastics. This article presents the results of the latest studies related to the development of bioplastic packaging materials with the use of such polymers as PLA, starch or PHA. In the near future, the bioplastic materials discussed in the text may replace plastics and become some of the most commonly used packaging materials.

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MATERIAŁY OPAKOWANIOWE Z BIOTWORZYW W GOSPODARCE O OBIEGU ZAMKNIĘTYM

STRESZCZENIE. Wstęp: Europejska strategia dotycząca tworzyw sztucznych skupia się na dostosowywaniu unijnych regulacji do realizacji zasad in circular economy. Circular economy to podejście, w ramach którego w niedługim czasie nastąpią znaczące zmiany w wielu gałęziach współczesnej gospodarki. Będą one dotyczyły w dużym stopniu branży opakowań.
Metody: Duzym zaniteresowaniem cieszą się poliestry alifatyczne jakie jak polilaktyd (PLA) oraz polihydroksyalkaniany (PHA).W niniejszej pracy przedstawiono rynek biotworzyw oraz wybrane przykłady najnowszych rowiązań w zakresie materiałów opakowaniowych z biotworzyw. Przedstawione biotworzywa w niedalekiej przyszłości mają szansę stać się jednym z najbardziej pożądanych materiałów opakowaniowych.

Wyniki i podsumowanie: Biotworzywa wydają się być alternatywą dla konwencjonalnych tworzyw sztucznych stosowanych do produkcji opakowań. Aby stworzyć zrównoważone środowisko i zapobiec utylizacji odpadów tworzyw sztucznych w środowisku, produkcja biotworzyw zyskała wiele uwagi ze względu na ich podatność na biodegradację.

Słowa kluczowe: biotworzywa, materiały opakowaniowe, gospodarka o obiegu zamkniętym

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ORIGINAL PAPER

LEAN AND AGILE PARADIGMS IN HUMANITARIAN ORGANIZATIONS' LOGISTICS AND SUPPLY CHAIN MANAGEMENT

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ABSTRACT. **Background:** Humanitarian organizations (HOs) have funding constraints, and pressure from donors and other stakeholders, on matters of accountability, transparency and efficient utilization of resources. Humanitarian organizations need to learn from the business sector and adopt strategies to address and resolve issues of inefficiency in resource consumption. In the HO sector, logistics and supply chain management is a critical area which consumes more than 80% of total relief budgets and therefore needs to be handled both effectively and efficiently. An integrated Lean and Agile management model, which has been successfully implemented in the business sector to achieve effective and efficient utilization of resources, is one strategy proposed for implementation by humanitarian organizations. To that end, this study carries out the important initial work of defining the boundaries between Lean and Agile operations in Humanitarian Organization Supply Chains in order to build a model that increases both effectiveness and efficiency.

Methods: The Lean & Agile Decoupling Point (LADP) model has been developed after researching the scope and thematic areas of 88 international humanitarian organizations. Seven humanitarian logistics and supply chain management (HL-SCM) professionals were interviewed at length to accurately identify key processes and establish optimal decoupling points in accordance with the priority and scope of each thematic area.

Results: Of the 88 HOs researched, 79 were doing both developmental and emergency work, so the LADP model is designed for such dual-purpose organizations. The LADP model is built on a flowchart for handling key processes, divided between developmental and emergency operations. Optimal decoupling points are identified starting from an organization's broad scope and extending to the details of HL-SCM. The model accurately reflects the experience and recommendations of the seven HL-SCM professionals consulted and is applicable to a wide variety of HOs.

Conclusions: The LADP model provides the critical groundwork that can renew and strengthen HO operations, leading to reliability in which donors, beneficiaries and other stakeholders will have confidence. This study is another step forward toward sustainable resource consumption that will save lives and serve disaster-affected people more effectively and efficiently.

Key words: Humanitarian Logistics and Supply Chain Management (HL-SCM); Lean and Agile boundaries, Lean and Agile Decoupling Point (LADP) Model, Efficiency and Effectiveness.

INTRODUCTION

Historically, provision of humanitarian services was closely associated with the political situation in the recipient country, with humanitarian services being provided more as 'vote catchers' than systematic provision of services. These services evolved into systematized Humanitarian Organizations (HOs) and eventually transformed into a formal professional humanitarian services industry [Davies 2014]. The primary goal of HOs has been to serve deprived and deserving community without any profitable motives [Doyle, Gorman, Mihalkanin 2016, Vojvodic, Dujak, Plazibat 2015]. HOs are recognized as professional bodies with disaster management skills and often extensive supply chain networks [Vojvodic et al. 2015]. The most crucial part of an HO's operations is logistics and supply chain management which utilizes 80% of an HO's budget [Van Wassenhove 2006a].

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Humanitarian Logistics and Supply Chain Management (HL-SCM) operations involve the processes of procurement of resources and goods, the curating and safe keeping of these goods, and the proper, efficient, effective and timely supply of these goods and services as and when required [Cozzolino 2012]. Supply chain management is a process of integration of departments, institutions, and stakeholders (government, donors, vendors and community) to meet the vulnerable and affected community's requirements, whereas, humanitarian logistics management includes the processes of planning, implementing, and controlling of the flow and storage of goods, materials, and information in an efficient and cost-effective manner from point of origin to point of consumption [Van Wassenhove 2006b].

The sudden onset of an emergency or disaster is the defining characteristic of the humanitarian logistics and supply chain problems faced by HOs but are not usually relevant to the long-term developmental operations of humanitarian organizations. With globalization, HOs have extended their services internationally and their operations scope have been expanded from disasters management relief services (food, shelter, health, etc.) to long-term developmental operations such as reconstruction and social development by the provision of education, infrastructure construction, and social and political awareness and capacity building programs. HOs long-term operations have very similar characteristics as are found in commercial and business organizations, with the significant exception of manufacturing operations that are not usually part of HOs operations. Like any organization, commercial, governmental or otherwise, humanitarian organizations are always under pressure to maximize their performance and to deliver the best results to justify and maintain their funding. Pressures come from various stakeholders, including donor agencies, government organizations', communities and business investors [Cairns 2005] who must be confident that their funds are spent efficiently and in a transparent and accountable manner [ChangeUp 2004, Eisinger 2002, Paton 2003, Wing 2004], and who must also be assured that the organizations which have tax exempt status are utilizing their resources conscientiously [Commission 1996, Hoefer 2000]. HOs need to adopt optimal solutions and strategies for efficient resource utilization in line with business organizations, without compromising the HOs vital role [Blumenthal 2003, Cairns 2005, Murray 2015] , being to provide services to more target groups with the utilization of fewer resources such as the effective management of costs and time.

According to Drew et al., [2016] both Lean and Agile management have proven to be successful approaches for businesses with significant improvements in profits, cash flow, customer satisfaction, and market share as a result [Drew, McCallum, Roggenhofer 2016]. Evidence for this supposition can be seen in several cases of successful businesses which have adopted Lean and Agile management techniques, e.g. Hewlett-Packard, Toyota, Zara fashion design and World Vision [Christopher, Towill 2001, Parris 2013]. There seems to be no reason to suggest that applying both Lean and Agile management techniques to HOs will be any less beneficial in the management of cost and time by reducing waste, increasing customer value and improving overall financial and production capacity of the HO, a position supported in [Cozzolino, Rossi, Conforti 2012, Oloruntoba, Kovács 2015] who suggest that, notwithstanding that Lean and Agile are different approaches, with clearly identified boundaries between the two paradigms, both can be applied to the same HL-SCM operations, in both disaster emergency relief operations and on-going developmental operations, projects and aid administration. The boundary between these is the point where the application of one paradigm, Lean or Agile, ends, and the other starts, which we have designated as the decoupling point, and have developed into the Lean and Agile Decoupling Point (LADP) Model. An important observation is that, while the existing studies present the Lean and Agile paradigms focusing on disaster management [Cozzolino et al. 2012, Oloruntoba, Gray 2006], the developmental operations of HOs remain largely ignored.

Given this discrepancy in the research, the purpose of this study was to develop an integrated Lean and Agile Management Paradigm framework based on the common elements found in the separate paradigms that would be applicable to both the emergency and the developmental operations of HL-SCM. The integrated framework was developed by identifying and prioritizing the HL-SCM processes and thematic areas. The HO thematic areas indicate the products (services, goods, and works) which are being offered by the HO for humanitarian reasons, such as education, health, livelihood support, disaster management, human rights recognition, women's empowerment, old age rights, child care, sustainability and poverty reduction. Organizational thematic areas were explored using the information provided on the websites of international humanitarian organizations. HL-SCM processes were identified and were optimized for LDAP model by interviews of HO professionals. The Lean and Agility paradigms, the decoupling points, are defined in broad terms, and then detailed, through two matrix models and the Lean and Agility Decoupling Point (LADP) model. The Lean and Agility framework that has been developed in our study will improve the effectiveness and efficiency of HL-SCM's resource utilization.

LITERATURE REVIEW

Humanitarian organizations (HOs) are different from private and public sector organizations inasmuch as they act autonomously, meaning that they do not need to seek government support or have economic power. As well, the nature of their workforce, which is usually and predominantly volunteer, rather than being attracted by remuneration, or being coerced, is an employment model different to private and public sector organizations.

In our literature review, we sought and identified information on the various aspects of interest, relevant to HO operations, to develop our LADP model these include:

- Humanitarian logistics and supply chain management (HL-SCM),
- Difference between Developmental, emergency, and business logistics & supply chain,
- Efficiency in humanitarian logistics and supply chain management,
- Effectiveness in humanitarian logistics and supply chain management,
- Lean management in humanitarian logistics and supply chain management,
- Agility management in humanitarian logistics and supply chain management,
- Leagility in humanitarian logistics and supply chain management,
- Decoupling models in humanitarian logistics and supply chain management.

Humanitarian logistics and supply chain management (HL-SCM)

Logistics and supply chain management is the backbone of humanitarian organizations' operations, which includes the processes of planning, implementing and controlling the efficient and cost-effective flow of goods, services, and information, and as well as the storage of goods, materials, and equipment from point of origin to point of consumption, sufficient to meet the beneficiaries' requirements [Vojvodic et al. 2015]. Humanitarian supply chain management includes the establishment of an integrated network of relationships among different actors e.g. suppliers, government, military, partner organizations and community, for the efficient and effective delivery of goods and services [Vojvodic et al. 2015].

Specifically, logistics is focused on moving something or someone from a point of origin to a destination, whereas supply chain management mainly focuses on the relationships among the actors that make such movement possible [Cozzolino 2012]. Logistics and supply chain management are both crucial to support a timely response to a disaster. Thus, the concept of HL-SCM is the provision of goods and services, maximizing cost efficiency and speed effectiveness, achieved by close and effective coordination of activities and supply. HL-SCM is a distinctive unit of any HO, and the success or failure of any humanitarian operation is highly dependent on this unit [Cozzolino 2012].

Difference between Developmental emergency, and business logistics & supply chain

In the main, HL-SCM functions are the same as the logistics and supply chain functions in any business organization that involve a range of activities, including preparedness, planning, procurement, transport, warehousing, tracking and tracing, and customs clearance. Normally HL-SCM deals with two types of operations; developmental humanitarian response operations and emergency response operations. Developmental operations refer to the development of education, health, environment, socio and economy system of a particular region, country and community, while emergency or disaster management operations deal with the fulfilment of urgent needs created by disasters, including search and rescue, food, water, sanitation, medicine and shelter [Bhimani, Song 2016]. Disasters can be further divided into two types; sudden onset disasters and slow onset disasters. Sudden onset disasters are usually natural disasters such as earthquakes, floods and tsunamis that are devastating events that occur with little or no forewarning. Slow onset disasters, on the other hand, include the occurrence of devastating events that develop over a period of time, slowly, and include droughts, heat waves, desertification, and more recently, land encroachment by rising sea levels.

Table 1. Difference between normal, emergency and business logistics & supply chain

No.	Distinctive point	Emergency HL-SCM operations	Normal HL-SCM operations	Business logistics and supply chain operations	Reference
1	Objectives	To help people and save lives without the objective of profit-making	To help and develop the people, environment, and nature without profit	To maximize profit	(Cozzolino, 2012; Ertem, Buyurgan, Rossetti, 2010)
2	Demand pattern	Unknown and irregular demand	Predictable with forecasting techniques	Predictable with forecasting techniques	(Christopher, Tatham, 2014; Ertem et al., 2010)
3	Supply pattern	Non-predictable mixed patterns with cash or kind, and in-kind donations	Predictable mixed pattern of cash or kind and in-kind donations	Predictable pattern with a specific product	(Christopher, Tatham, 2014; Ertem et al., 2010)
4	Flow type	Flow of fundamental resources, e.g. vehicles, peoples, food and shelter	Flow of fundamental and specific resources e.g. education, health and awareness	Flow of commercial products	(Cozzolino 2012; Ertem et al., 2010)
5	Lead time	Immediate demand with no lead time	Predictable lead time	Predictable lead time	(Christopher, Tatham, 2014; Ertem et al., 2010)
6	Delivery network structure	Dynamic structure, voluntary and ad hoc facilitator	Pre-established network with voluntary and ad-hoc facilitator	Pre-established network with location, warehouses and distribution centers	(Ertem et al., 2010; Scholten, Sharkey Scott, Fynes, 2010)
7	Inventory control	Challenging to maintain inventory level	Easy to manage, predetermined demand and supply	Easy to manage, have safety stock and demand patterns	(Ertem et al., 2010; Van Wassenhove, 2006a)
8	Technology and Information	Comparatively low technology, less use of software	Comparatively low technology, less use of software	Highly developed technology with software utilization	(Christopher, Tatham, 2014; Pettit, Beresford, 2009)
9	Performance evaluation	Time of response and number of lives saved	Time of response and number of people helped	Based on standard supply chain matrices, profitability	(Ertem et al., 2010; Scholten et al., 2010)
10	Equipment and vehicles	Robust equipment required	Both robust and ordinary equipment's are required	Ordinary equipment required	(Dufour, Laporte, Paquette, Rancourt, 2018)
11	Human resources	High-employee turn-over	Project-based high-employee turn-over	Stable, permanent respected career paths	(Kovács, Tatham, Larson, 2012)
12	Stakeholders	Donors, governments, military, community and partner NGOs	Donors, governments, military, community and partner NGOs	Shareholders, customers and suppliers	(Ertem et al., 2010; Nurmala, de Leeuw, Dullaert, 2017)

The functions imperative in disaster operations are more challenging than developmental HL-SCM operations, and also quite distinct from the logistics and supply chain management operations of commercial businesses. Some of the important distinctive points about emergency HL-SCM, Developmental HL-SCM and business logistics supply chain management, derived from the literature, are shown in Table 1.

HL-SCM studies found in the literature are mainly focused on the relevant operations demanded by natural and man-made disasters and discuss the processes involved in the disaster management cycle. Disasters impact directly on the life, infrastructure, and economies of communities and countries, and there seems to be a general perception that HO functions are only about disasters and disaster relief [Bhimani, Song 2016]. Developmental HL-SCM operations are often ignored and these have not attracted sufficient research attention, given their importance.

Efficiency in humanitarian logistics and supply chain management

Efficiency management in HL-SCM is the ability to minimize waste, avoid redundancy and duplication of activities, conserve energy, and maximize efforts, while minimizing both times taken and overall operational costs [Provan, Kenis 2008]. In other words, efficiency means "doing the thing right" that is applicable in Developmental HL-SCM operations. Efficiency in HL-SCM processes and actions can be achieved through the most common practices which are as much as 50% of the solution to any problem. Some of the common practices can be, have been, developed as a standard set of guidelines, training syllabi, certification processes and process alignment, especially with appropriate IT systems [PH Tatham, Spens, Kovács, Payne 2013].

HL-SCM efficiency means ensuring cost savings that can result in more supplies being available and delivered, resulting in more lives being saved and more people being helped [Cozzolino, 2012]. Efficiency can be achieved through standardization of processes and systems [Bhimani, Song 2016]. Thus, to bring both Effectiveness and Efficiency by the understanding of, and application of, both the Lean paradigm and the Agile paradigm, will enhance competitiveness, cost efficiency and time effectiveness in the overall HL-SCM processes [Gligor, Holcomb 2012, Ismail, Sharifi 2006].

Effectiveness in humanitarian logistics and supply chain management

Effective management in HL-SCM is defined as ensuring the quickest delivery of humanitarian goods, services, and other relief items, within the shortest time-frame [Cozzolino 2012]. Effectiveness means "doing the right thing" when an emergency situation arises, which is usually without warning, is sudden, and often devastating [Provan, Kenis 2008]. HL-SCM effectiveness is based on strong coordination between stakeholders, which includes donors, government, military, vendors, communities, and local community-based organizations [Tatham, Spens 2016]. To enhance stakeholder coordination and to meet the HOs common goal, many organizations have developed their clusters for cooperating and coordinating during a disaster, for the provision of humanitarian services. Some examples of such clusters are: the UN logistics cluster, the international search and rescue group (INSARAG), and the urban search and rescue group (USAR) [Tatham, Spens, 2016].

In HL-SCM operations, effectiveness must be a "Plug and Play" concept, meaning pre-determined, well-organised operations that can be put into place with immediate affect, which can only be possible through a well-coordinated, effective flow of information. HL-SCM effectiveness means significant savings in goods and services delivery time, which means that more lives are saved [Cozzolino 2012].

Lean in humanitarian logistics and supply chain management

Lean management is the provision of maximum customer satisfaction by reducing waste through optimum utilization of resources such as financial and human resources [Womack, Jones 2010]. Lean management also refers to doing more and better things with less utilization of resources when demand is relatively stable and predictable [Cozzolino 2012]. HOs have pressures from stakeholders to improve their performance and to deliver the best value for money. Stakeholders want to be able to assess whether or not their funds are being spent on the right people, in the right way, through the right source, at the right time, at the right cost, with effectiveness, accountability and according to best practice standards [Paton 2003]. They also want to know that funded organizations have the capacity to serve marginalized communities in an effective and efficient way [Eisinger 2002, Wing 2004]. Lean management is the optimization of resources which ensures that all the relationships among the actors involved are managed through an integrated approach to efficiently and effectively coordinate inter-organizational performance, eliminate redundancy, and maximize efficiency along the entire emergency and Developmental supply chain management.

A sustainable, successful, Lean adoption strategy requires maintenance of continuity between the existing and the evolving organizational cultures and management processes. Thus, for successful Lean management implementation, the LM qualifiers that have been identified are: positive organizational culture with improved processes, discipline, and committed leadership to overcome internal and external challenges [Lassiter 2007].

Agility in humanitarian logistics and supply chain management

Supply chain agility is the organizational ability to respond promptly to any uncertainty of future demand, or changes in current demand. Humanitarian organizations must be able to respond rapidly and effectively during disaster operations, and the major purpose of Agile supply chain management is to handle the external disruptions that almost inevitably occur, and to respond quickly to short term demands with flexibility [Lee 2004, Sheffi 2005]. In any disaster, the primary priority of HOs is to serve humanity, and to save the maximum number of lives in the disaster. To meet immediate and short term demands, Agile supply chain requires interim sources of supplies and employment, immediately available [Christopher, Towill 2002, Lapide 2006]. Agility can be achieved through stakeholder coordination and overall supply chain efforts with the utilization of the organization's redundant capacity [Christopher, Towill 2002, Cozzolino et al. 2012]. Agile management requires some qualifiers for achievement of successful results. These qualifiers in HL-SCM agility management have been identified as preparation of emergency plans, networking with suppliers, contingency stockpiling of equipment and goods, postponement of routine projects, low-cost stocks, creation of a stable network of third-party logistics services, and formation of a relief emergency implementation team [Christopher, Towill 2002]. As has been observed previously, Agility management has been the greater focus in recent academic research and in professional circles, due to increases in the number of disasters [Cozzolino et al. 2012]. In the disaster management context it is much more important to ensure timely (effective) delivery of goods and services, as distinct from the emergency and developmental operations context in which it is necessary to achieve efficient, cost optimized, delivery of goods and services as well [Cozzolino 2012].

Leagility in humanitarian logistics and supply chain management

Learning from the corporate sector for performance improvement, HOs are recommended to implement Lean and Agility management system together [Murray 2015, Scholten et al. 2010]. Lean management was developed in response of old strategies to reduce waste and unsatisfactory quality, while Agile was a response to continuous changes and fluctuations in customer demand and preferences. Some authors have considered agility to be associated with lean thinking and have been stated as the next step after lean principles implementation. Total logistics and supply chain management efficiency and effectiveness are based on a combined Lean and Agile paradigm. This combination is termed 'Leagility Management'. Within the Leagility Management paradigm, the Lean and Agile paradigms are separated by a strategic point which is called the "decoupling point", which delineates the boundary of Lean and Agile paradigm.

Lean and agile decoupling point models in humanitarian logistics and supply chain management

Agile management does not necessarily exclude Lean Management principles. Agile can be appropriate for Developmental HL-SCM operations, while Lean can also exist in emergency HL-SCM operations [Aitken, Christopher, Towill 2002, Christopher 2005, Scholten et al. 2010]. The boundaries between Lean and Agile are defined through the decoupling point approach, and postponement strategy has been applied when lead times are long and demand is unpredictable [Christopher 2005]. Leanness needs to be decoupled and Agility should be applied when the market is volatile or uncertain [Childerhouse, Towill 2000]. Apart from the decoupling point, some other techniques for defining the Lean and Agile boundaries have been considered: the Pareto curve approach and the separation of base and surge demands [Christopher, Towill 2001]. In HL-SCM, prioritization of needs is the most important factor for assessment of required resources, implementation of immediate solutions and to decide on the necessary shift from effectiveness (Agile) management to efficiency (Lean) management [Merminod, Nollet, Pache 2014a, Tomasini, Van Wassenhove, Van Wassenhove 2009]. Thus, humanitarian organizations need to prioritize these demands and to implement an immediate solution as per available resources [Merminod, Nollet, Pache 2014b, Tomasini, Van Wassenhove, 2009].

In the literature, HL-SCM Lean and Agile boundaries are considered in terms of being applied in emergency operations, within the disaster management cycle: mitigation, preparedness, response and recovery phases. The Lean and Agile paradigm boundaries are also applied to emergency supply chain management processes, while the normal or developmental scope of HL-SCM has been largely ignored [Cozzolino et al. 2012, Oloruntoba, Gray 2006]. Thus, this study is focused on drawing HL-SCM boundaries as a broad level concept, and as can be applied in detail in both emergency and normal, or developmental, types of operations. Data were gathered by survey and interview.

METHODOLOGY

Our study comprised two steps; the first step being the identification and justification of the need for the Lean and Agile paradigms in the HO sector. The second step was the development of the Lean and Agile paradigms in terms of the HO sectors particular requirements.

In Step 1, the potential for the Lean and Agile paradigms were determined by collecting, analysing and comparing the information from the websites of different HOs on the operational and thematic areas described or implied in those websites. The HOs included in the search included only International Non-Governmental Organizations (INGO's), 88 in all randomly selected from the results of a search on Google, and from the United Nations Organization website.

A comparative descriptive analysis was derived, based on the Lean and Agile qualifiers and enablers identified, together with the scope and thematic areas indicated. These were divided into two major categories; the developmental operations, and the emergency operations (see Table 2). Based on this analysis, the Lean and Agile paradigms particularly applicable to HOs were designed. These were then decoupled utilizing the two-matrix model approach and a broad level Lean and Agile decoupling model.

Second step of the study was development of Lean and Agile paradigms by mapping HOs logistics and supply chain management processes involved in both disasters/emergency supply chain management and developmental logistics and supply chain management. To map the HL-SCM processes, interviews and discussions were held with seven professionals experienced in HO logistics and supply chain management, who were selected on the basis of having more than 5 years' experience in these operational areas in international humanitarian organisations. Each professional was interviewed for up to an hour. The information elicited in these interviews regarding the development operations of the HO was characterised as, and divided into hard components and soft components, and the emergency operations were divided into sudden onset disasters and slow onset disasters.

Using the decoupling points approach, a detailed Lean and Agile Decoupling Point (LADP) model was developed. In this model, HL-SCM activities were identified in detail and the areas of HL-SCM that had been previously overlooked in the literature were highlighted.

RESULTS AND DISCUSSION

HOs scope and thematic areas

A thematic area or scope of a HO denotes all the products which may be included in the processes of delivery, both in the short term and long-term, of services, goods and works for the fulfillment of their humanitarian objectives. Traditionally, the scope and thematic areas of international HOs were limited to deal disaster (natural & manmade) responses in affected countries through the provision of relief supplies and services essential as basic life necessities (e.g. food, water, shelter and health) [Doyle et al. 2016]. With globalization, the scope and thematic areas have been extended toward non-disaster related development of deprived communities through education, infrastructure development, awareness of civil and political rights, and social capacity building.

The priority of the application of Lean or Agile thinking in the delivery of products and services can therefore be decided through the identification and categorization of thematic areas.

For identifying HOs scope/thematic areas, we carried out a survey of HOs websites, and relevant information was identified and categorized in (Table 2). The websites of organizations that we reviewed showed that at least 79 of the 88 organizations reviewed are engaged in both disaster management and long-term development operations. A sample of the information extracted from 10 or the 88 organizations is shown in Table 2.

Table 2. International HO's thematic areas

Name of HOs	Web address	Scope/thematic areas	
		Developmental	Emergency
Sight Savers	www.sightsavers.org	Protecting sight & fighting for disability	Not specified
SIF	www.secour-islamique.org	Providing people with the means to be independent	Responding to basic needs
Muslim.H	muslimhands.fr	Supporting communities in the long run	Providing immediate help
Relief Int	www.ri.org	Education, economic opportunity	Providing health and emergency basic needs
Action Against Hunger	www.actionagainsthunger.org	Supporting communities against hunger	Provision of basic necessities including food, water and shelter
Care International	www.care-international.org	Supporting in long-term development work including education, economic opportunity, gender ethnicity and equity and health	Responding to basic emergency needs and rehabilitate services for affected people
Concern world wide	www.concern.net	Protecting sight & fighting for disability	Not specified
Plan-international	plan-international.org	Providing people with the means to be independent	Responding to basic needs
World Vision	www.worldvision.org	Supporting communities in the long run	Providing immediate help

Our analysis shows that the role of HOs is not limited to disaster response but is extended to strategic partnerships for long-term development of society. Examples of strategic partnerships are the United Nations Organization (UN) partnership with HOs for the achievement of sustainable development goals and partnerships with corporate logistics companies for the enhancement of HOs' response capability (e.g. Agility, TNT and UPS) [Vojvodic et al. 2015]. The extension of the scope of operations into long-term and developmental operations now requires efficient (Lean) management rather than the traditional requirement for effectiveness (Agility). As discussed previously, Lean management is focused on reducing waste together with cost savings in the delivery of aid to the maximum number of people, whereas Agile management is more focused on the timely delivery of goods and services to the maximum number of people affected in an emergency. It can therefore be concluded that HOs should not be focused only on rapid (effective) delivery but also must focus on efficient delivery to satisfy fund donors.

Lean and Agile paradigms priorities based on HOs thematic areas

In disaster/emergency situations, Agility paradigms is required in terms of time effectiveness. In such situations, search, rescue and provision of basic life necessities with precise time management is essential. As well as involvement in emergency situations, HOs are now involved in developmental activities to uplift deprived (socially, economically) communities (Table 2), in this situation the Lean paradigm is required essential.

The major scope found on international HOs websites encompasses developmental projects e.g. education, poverty reduction, livelihood, child care, woman's empowerment, youth leadership, and support to disabilities. To achieve cost efficiency and sustainability in the HO's operation Lean management can play an important role through implementation of strategic partnerships and developmental projects. A two-matrix model to decide the paradigms between Lean and Agile is shown in Figure 1. This model explains that the emergency scope of HOs operations requires a high level of Agility, as presented in the Agile paradigm, whereas, developmental scope requires the substantial application of the Lean paradigm.

The requirement for Lean and Agile in both emergency and developmental HL-SCM operations is presented in detail in the LADP model.

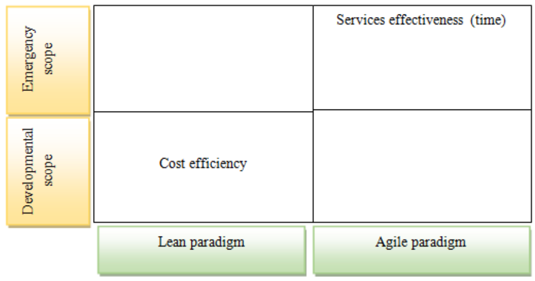

Fig. 1. Lean & Agility paradigms priorities based on two matrix model

Lean and Agile Decoupling Point (LADP) models

It is the decoupling point that recommends the most suitable supply chain processes and practices. When the priorities of the processes, and their boundaries, are well defined, the real opportunity of Lean and Agile strategies becomes apparent for employing hybrid Lean and Agile supply chain management [Christopher, Towill 2001], which has been termed in the literature as Leagility.

In our study we developed a decoupling model appropriate for both developmental and emergency HL-SCM operations in the broader terms of HOs' scope of operations, which is more detailed than the various HL-SCM processes which were identified from the information gained through the interviews that we conducted.

LADP model based on organizational scope in broader terms

Thematic areas/scope analysis found that about 90% of HOs are involved in both emergency and developmental activities. Following the prioritization of needs, the developmental thematic areas and emergency thematic areas, urgency of needs was considered as the basic yardstick. The decoupling of HL-SCM, as we propose in broad terms, is shown in Figure 2.

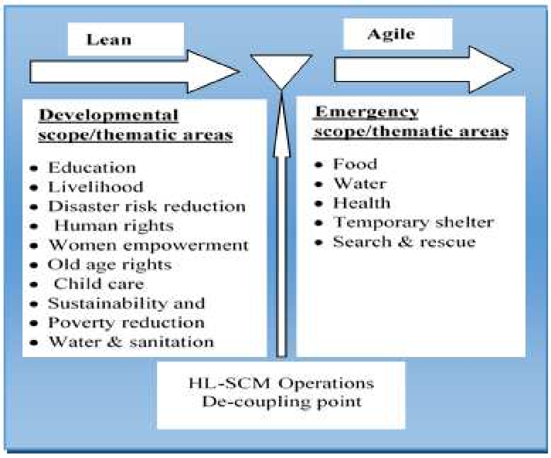

Fig. 2. Lean & Agility Decoupling Point (LADP) Model based on organizational scope

The boundary between emergency and developmental areas for Lean and Agile application is defined through the de-coupling point approach. For carrying out emergency operations Agile application is more appropriate, while, Lean management paradigms should be applied for developmental scope. While considering the broader scope of HL-SCM Lean and Agile application, the internal processes of both emergency and developmental scopes have not been explored in this part of model.

LADP detailed model based on HL-SCM processes

To map HL-SCM processes and identify efficiency and effectiveness priorities seven international HOs professionals were contacted and agreed to participate in interview. These professionals were rich in HL-SCM experience, having a minimum experience of 8 years and level of responsibility commensurate with their job titles. These are summarized in Table 3.

Table 3. Summary of the HO professionals' interviews

No.	Gender	HO experience in years	Position, title	Education relevant to Supply Chains
1	Female	10	Operation Officer	No
2	Male	11	Admin & Logistic Officer	No
3	Male	9	Supply Chain Officer	Yes
4	Female	8	Admin, Logistics and H.R Officer	Yes
5	Male	14	Director, operations	No
6	Male	12	Supply Chain Officer	Yes
7	Male	9	Senior Admin and Logistics Officer	Yes

From the discussions with these HOs professionals, the developmental and emergency HL-SCM processes of HOs were identified. Based on those interviews and discussions, the HL-SCM decoupling points were defined according to the urgency of each process. The HO professionals also explained the two categories of hard components and soft components. HL-SCM hard components include the obvious ad identifiable logistics and supply chain management processes and infrastructure that include the deliverables relevant to materials, equipment and other supplies. The soft components were explained as including those deliverables that are less visible and less physical, such as capacity building, policy making, human rights campaigns, education and health services etc., that have long-term impacts on the development of communities, Though, HL-SCM hard component processes are the same as soft components, with the addition of warehousing activities, as depicted in Figure 3.

Lean and Agile paradigms priorities placed on the HOs developmental operations by interviewed professionals was emphasized to brought efficiency management in supply chain components. The supply chain components defined by the professionals are includes: procurement, warehousing and fleet management. Due to time constraints, especially related to perishable goods, and considering the urgency of demands and minimizing warehousing costs, the distribution component of goods and services requires effectiveness, meaning a shift to the Agility paradigm. Thus, Lean (which gives efficiency) is proposed to be used for developmental processes from procurement to fleet management and transportation needs, after which it should be decoupled and Agile (which gives effectiveness) is applied to the subsequent distribution related processes (Figure 3).

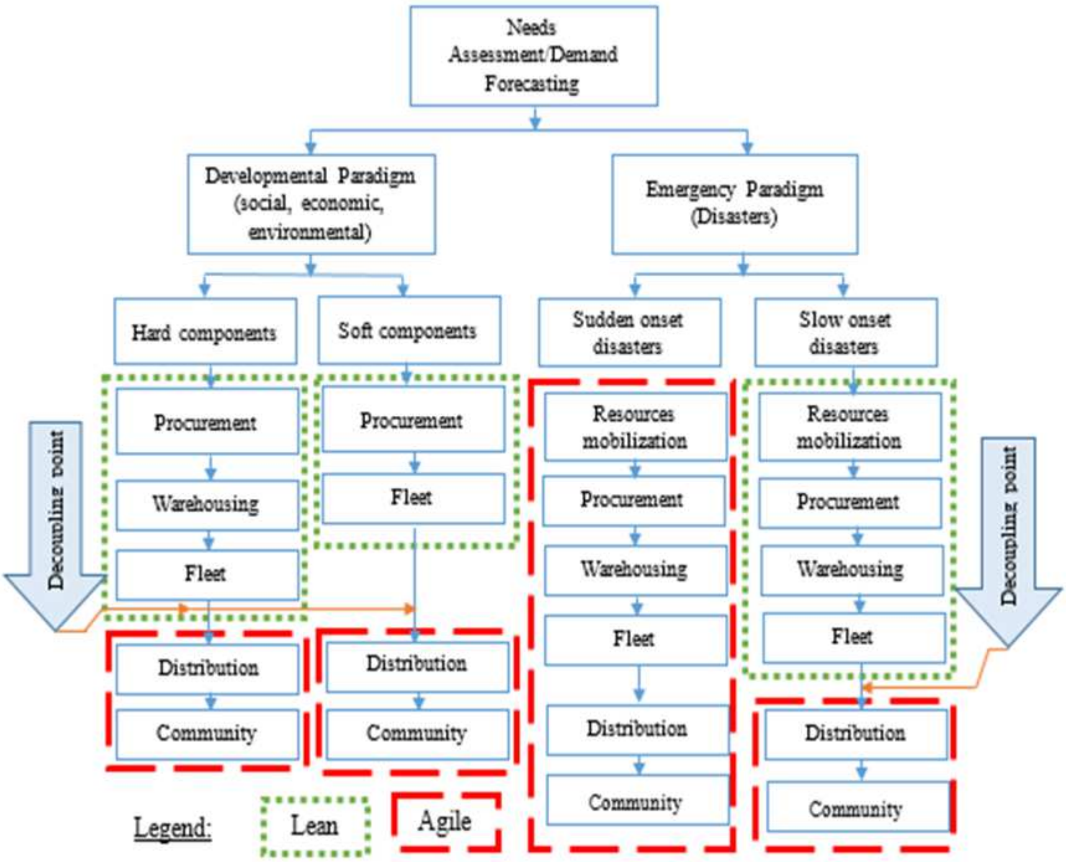

Fig. 3. Lean & Agility Decoupling Point (LADP) Model based on detailed HL-SCM processes

The emergency thematic area of HL-SCM processes was also divided by professionals into two categories sudden onset disasters and slow-onset disasters. Earthquakes, explosions, fire, landslides etc. are considered sudden onset disasters, whereas droughts, diseases, and climate change were suggested to consider as slow onset disasters. The HL-SCM professionals proposed that in sudden onset disasters, Agility is essential, especially in the initial 90 days, as the prime priority is timeliness of intervention, and cost considerations are not of interest. After the initial period of great urgency, the priority may change to allow application of the Lean paradigm for certain processes like procurement, warehousing and fleet management. Slow onset disasters, however, require the adoption of the Lean paradigm for the efficient management of transportation and fleet management prior to the commencement of the distribution process and community follow-up, in which case the shift to the Agility paradigm is appropriate.

A detailed Lean and Agile Decoupling Point Model was developed as a comprehensive model with recommendations on where HOs need to adopt the Lean strategy and where to adopt the Agile strategy, with the overall goal of this model being to improve the efficiency and effectiveness of the HO logistics and supply chain management operations (Figure 3).

CONCLUSIONS

Nearly 90% of humanitarian organizations (HOs) are involved in both developmental activities and emergency response. While the developmental scope is of greater importance to HOs than the emergency scope, it has been the latter that has received most attention from academics and researchers, and the developmental scope must be seen as a neglected area of research. It is in the development scope of operations, in the HL-SCM, that the Lean paradigm is considered to be most appropriate, whereas the Agility paradigm becomes prominent in the emergency scope/thematic areas, where the time is of the essence, and where immediate and effective measures are required.

The contribution of our research is that by identifying the boundaries between Lean and Agility, and the decoupling points between the developmental and emergency HL-SCM processes, we have provided a model that will enable HL-SCM operations to be more effective and useful. This model was developed using a two-matrix model and the decoupling point approach, in which the decoupling points are framed in the comprehensive LADP model.

We are confident that the appropriate application of the Lean management (cost efficiency) paradigm in the HL-SCM of HOs can bring many benefits and should be explored further to make HOs operations more efficient and sustainable. This study indicates the importance of comparing Lean with Agility and extracting a comprehensive Lean/Agile paradigm to fill the gap that is identifiable in the traditional approach to HO sector operations. The areas defined show where HOs should focus on Lean and to what point HOs should place importance on the Agile paradigm. We suggest that the practical implications of implementing the Lean paradigms in the HO sector, including the assessment of the readiness of any HO to adopt the combined paradigm, requires further studies.

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PARADYGMATY LEAN I AGILE W ZARZĄDZANIU ŁAŃCUCHEM DOSTAW I LOGISTYKĄ ORGANIZACJI HUMANITARNYCH

STRESZCZENIE. **Wstęp:** Organizacje humanitarne charakteryzują się pewnymi ograniczeniami w zakresie transparentności i efektywności wykorzystywania zasobów, wynikającymi z przyczyn ich istnienia, oczekiwań darczyńców lub innych udziałowców. Organizacje te powinny przyswajać wiedzę z sektora działalności komercyjnej w celu poprawy efektywności wykorzystywania dostępnych zasobów. W działalności charytatywnej, zarządzanie łańcuchem dostaw oraz logistyka są obszarami krytycznymi, które pochłaniają ponad 80% całego budżetu i dlatego też powinny cechować się efektywności i sprawnością. Zintegrowany model zarządzania Lean and Agile, które był z powodzeniem wdrożony w sektorze komercyjnym w celu poprawy efektywności zarządzania, jest strategią proponowaną dla wdrożenia również w organizacjach humanitarnych. Prezentowana praca jest początkowym etapem zdefiniowania granic pomiędzy operacjami Lean oraz Agile w łańcuchach organizacji hm unitarnych w celu zbudowania modelu zwiększającego efektywności i wydajność ich operacji.

Metody: Model Lean & Agile Decoupling Point (LADP) został opracowany po dokonaniu analizy obszarów wydzielonych tematycznie w 88 organizacjach humanitarnych. Przeprowadzono wywiady z siedmioma specjalistami z zarządzania łańcuchem dostaw z obszaru HL-SCM w celu precyzyjnego zdefiniowania kluczowych procesów oraz wyznaczenia optymalnych punktów rozdziału w zależności od priorytetów i zakresu każdego z obszarów tematycznych.

Wyniki: W obrębie 88 poddanych badaniom organizacji humanitarnych, 79 z nich prowadzą działalność zarówno kryzysową jak i zapobiegawczą, tak więc model LADP został opracowany dla organizacji o podwójnych celach działalności. Model LADP jest zbudowany w oparciu o schemat przepływu dla kluczowych procesów, podzielonych pomiędzy operacjami o charakterze zapobiegawczym jak i kryzysowym. Optymalne punktu rozdziału zostały określone począwszy od zakresu ogólnego i następnie do coraz bardziej szczegółowego. Model odzwierciedla dokładnie doświadczenia i rekomendacje siedmiu specjalistów, z którymi przeprowadzono wywiady. Jest on możliwy do zastosowania w wielu typach istniejących organizacji humanitarnych.

Wnioski: Model LADP dostarcza gruntownej bazy, która w istotny sposób może przyczynić się do przemodelowania i wzmocnienia działalności operacyjnej organizacji humanitarnych, zwiększając ich wiarygodność w oczach darczyńców oraz innych udziałowców. Praca ta jest kolejnym etapem wspomagającym wzmocnienie całego łańcucha zasobów przeznaczonych niesieniu pomocy poszkodowanych i potrzebującym w sposób jeszcze bardziej efektywny i skuteczny.

Słowa kluczowe: logistyka i zarządzanie łańcuchem dostaw organizacji humanitarnych (HL-SCM); ograniczenia Lean oraz Agile, model Lean and Agile Decoupling Point (LADP), wydajność i efektywność

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ORIGINAL PAPER

E-LOGISTICS AND E-SCM: HOW TO INCREASE COMPETITIVENESS

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ABSTRACT. **Background:** Recent technology development and the rise of e-commerce activities influenced changes in the logistics field and have "forced" companies to change their approach to logistics. On the other side, we are witnessing new developments in logistics service providers and their transformation. Competitiveness today doesn't depend only on price but also on customer service and delivery time. This can be influenced by the implementation of modern methods in logistics. Thus, logistics service providers in the global market are looked at as business partners and the relationship with logistics service company is considered as a partnership.

Because of the development in technology e-logistics concept has become more frequently used since it gives concepts for information sharing and information transparency within partners within supply chains. Thus, one of the important tasks of e-logistics is to share information with its partners and with that, it can have an influence on their competitiveness. The main aim of the paper is to show that the right logistics service provider in the modern supply chain can help companies to gain and maintain competitiveness and especially by using different modern digital tools in doing business.

Methods: Paper has been written based on the analyses of the reviewed literature together with determining potential influence e-logistics and e-SCM have on company's competitiveness. The case of DHL included in this study has been selected to present potentials which e-logistics have on creating a competitive advantage.

Results: Research results show that use of advanced logistics operator can help companies in increasing their competitiveness in today's market

Conclusions: Customer experience, new entrants, technology collaboration vs. competition are major characteristics of the new trend and logistics service providers will need to adapt to these changes. Improved running in one of the previously mentioned areas will create and maintain the company's competitiveness and as more modern technological tools and solutions will be used, companies will be able to have more benefits.

Key words: e-logistics, e-SCM, logistics service provider, competitiveness, DHL.

INTRODUCTION

Logistics activities represent an important part of the functioning of companies. The main goal of logistics is securing the availability of all necessary resources for the effective running of the production process. Logistics processes have undergone significant changes in recent years due to the increasing importance and creation of the integrated and strategic process. The modern logistics operations became a significant way of efficiency improving (material flow, reducing distribution costs) and at the same time development of modern, IT contributed to the logistics market expansion and to the promotion of logistics related technologies [Yu et al. 2016]. To maintain unchanged market position, logistics companies need to constantly make effort in gaining and retaining competitiveness in relation to other companies which are present in the market. This can be done by establishing business partnerships which are based on trust and adaptation to modern IT technologies [Vasiliev 2015].

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Companies need to properly understand logistics operations to be able to gain a competitive position in the market. Competitiveness in the modern global world can be gained through conduction of rational activities and by using modern logistics tools [Wieczorek 2017].

The main aim of the paper is to analyze the influence and connection of e-logistics and e-SCM processes to competitiveness and how the companies can apply different e-logistics and e-SCM tools and methods in gaining and maintaining their competitive advantage on the market. In the first part of the paper, we will define e-logistics and give its development since it was introduced. Then, it is followed by an examination of e-SCM and range of tools through which the e-SCM may be exercised. In the third part of our paper, we will analyze the connection between competitiveness and e-logistics and its tools. In the fourth part, we will analyze what DHL and its approach to e-logistics can do for the competitiveness of its clients. Finally, in the last part, we will give the conclusion of our research and give a proposal for further studies about this increasingly important part of the business.

E-LOGISTICS

Today e-commerce is fast-tracking the way the companies are managing logistics along the whole value chain and it represents one of the important megatrends. Shipment's size is shrinking, their frequencies are increasing, and the Internet's ubiquity is creating new challenges and opportunities for companies serving customers who are geographically dispersed, difficult to predict and sensitive to price and service levels [Wang et al. 2004]. Song and Hu [2004] studied the differences between traditional and e-logistics and the results of their research are presented in Table 1.

Presented differences between traditional logistics and e-logistics show challenges for companies which are involved in logistic processes if they want to create and maintain competitiveness in the market [Moroz et al. 2014]. E-logistics is presented as logistics concepts applied through Internet use and it means necessary processes for transferring goods which are sold online to their buyers (Figure 1).

Groznik [2008] stated that more sophisticated aspect of e-logistics is the wide-ranging topic of supply chain integration that eliminates intermediaries (such as wholesalers or retailers) and fosters the emergence of new players, like logistics operators who adapt traditional logistics chains to meet the requirements of e-business. Quirk et al. [2003] stated that e-logistics use Internet based technologies for supporting the acquisition of material, warehousing, transportation and enables distribution through routing optimization with inventory tracking. They conclude that e-logistics is the result of the introduction of e-commerce in logistics. E-logistics can be used for describing three main back-end processes needed to receive the order after the "buy" button is pressed until the bottom line: warehousing, delivery, transportation, and customer interaction. Last processes usually include call center communication where the customer has the possibility to ask questions, place orders, check his/her order status and if needed arrange returns of shipments. In the modern world on many occasions, different companies are handling each of these separate functions and managing them effectively and instantaneously requires a full understanding of each part of the process. And if the company wants to integrate them with companies' systems is even harder.

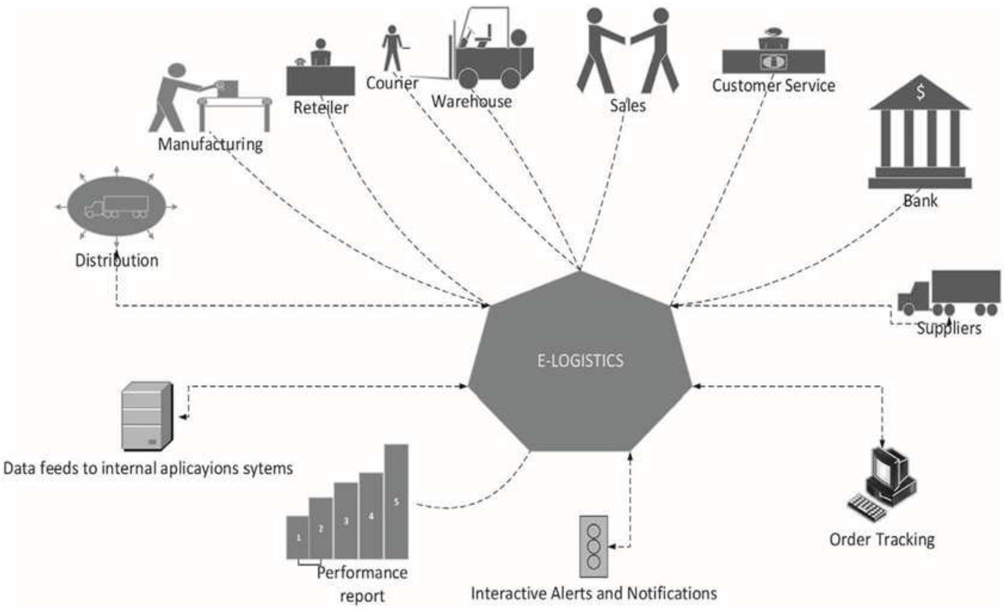
Wang and Pettit [2016] studied historical developments of e-logistics systems in the last 50 years through several characteristics (typical e-logistics system, emergent IT trends, integration focus, business application and supporting computer technology) while Merali, Papadopoulos and Nadkarni [2012] presented four-step changes in ICTs since the 1960s, which had a major influence on the e-logistics development:

- connectivity (between people, applications, and devices);
- capacity for distributed storage and processing of data;
- reach and range of information transmission;
- rate (speed and volume) of information transmission.

Table 1. Difference between traditional and e-logistics

	Traditional logistics	**E-Logistics**
Shipment type	Bulk	Parcel
Customer	Strategic	Unknown
Customer service	Reactive, Rigid	Responsive, Flexible
Distribution model	Supply-driven push	Demand-driven pull
Inventory / Order flow	Un-directional	Bidirectional
Destinations	Concentrated	Highly dispersed
Demand	Stable consistent	Highly seasonal, fragmented
Orders	Predictable	Variable

Source: Song and Hu 2004

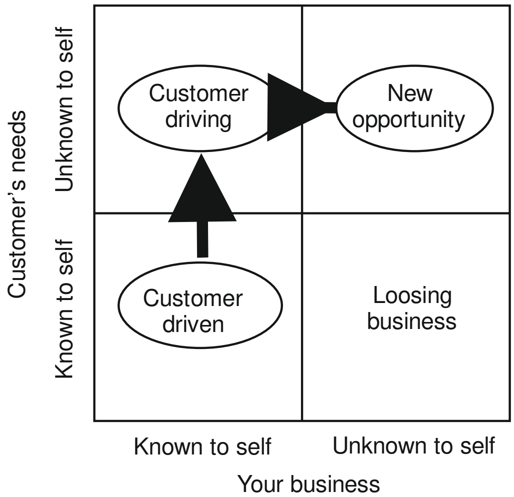


Source: Moroz et al. 2014

Fig. 1. E-logistics

Today's logistics has become one of the most important means of improving the efficiency of material flow, for reducing distribution costs in various industries. On the other side, the development of e-commerce contributed to the logistics market expansion and promoted the development of technologies related to logistics [Yu et al. 2016]. This has also influenced large numbers of studies related to the e-logistics [Bask et al. 2012, Masmoudi et al. 2014, Ramanathan et al. 2014]. Some studies examined logistics performance as a significant characteristic of e-commerce and last mile delivery [Agatz et al. 2008], while other studied the company's logistics capacity and its influence on e-commerce logistics performance [Joong-Kun Cho et al. 2008]. Bourlakis et al. [2018] presented a model which allows companies to determine if they are novice, intermediate or innovative e-commerce user. Based on their position in the model value chain companies can decide and take actions to succeed in cross border e-commerce space. Companies in e-commerce need to be more integrated, agile and flexible in their work. This is opening new opportunities to e-logistics companies in capturing new businesses and opening new revenue streams. The companies which will accept the new digital age to increase customers' service will be more competitive in the market.

Wang and Pettit [2018] proposed value generation model via e-logistics. For the starting point of the process, they pointed identification of the need and value generation from the customers perspective (Figure 2).



Source: Wang and Pettit 2018

Fig. 2. Value generation via e-logistics

The starting point is customer value which gives purpose to e-logistics managing. The bottom left quadrant stresses using the capability of e-logistics for fulfilling the current customer's need with minimum costs. Thus, for unlocking e-logistics potential it is necessary to move to the upper-left quadrant of the shown model. In this part of the model, e-logistics can be used for entering new markets and creating a new demand type. Upper right quadrant is unfamiliar areas where new and/or emerging technologies continues pushing the business expertise boundaries and can sometime have disruptive properties on current practices. A lower-right part is a place where no company wants to be. Value generation can be reached by improving current operational efficiency and/or offering innovative products and services. At this stage the company needs to build e-logistics capability for integration, building and reconfiguring internal and external competences for quick response to the changing environment. This capability will be then hard for duplication and imitation of its competitors. This capability needs integration of all the company's resources – processes, technology, and people.

E-SCM

The supply chain management (SCM) system encompasses all activities associated with the flow of resources, information, goods, and money among the entities along the chain. SCM focuses on improving the flow of products, information, and services as they move from origin to destination. The SCM is an integrated system consisted of interrelated subsystems; processes and activities that continuously should be improved to bring significant enhancement to all parties engaged in. SCM system is a predecessor of e-SCM.

The development of information and telecommunication technologies opens new challenges for the SCM. It leads to the creation of e-SCM, as an integral part of emerging e-business model of organization based on the use of electronic means to conduct business organization internally and externally [Bartels 2016]. E-SCM is the result of the synergy between the SCM and IT technologies. According to Luo et al. [2001], e-SCM is an "emerging business strategy which incorporates e-commerce into the physical supply chain to speed up information exchange, reduce transaction costs, streamline the manufacturing process and better satisfy customers' needs". Poirier and Baurer [2000] have defined e-SCM as the synergy of internet technology applications, intellectual resources of organizations and traditional SCM practices of the businesses. Handfield and Straight [2004] suggest that e-SCM is the use of internet technologies in the so called "5C" - Coordination, Content, Community, Commerce, and Communications. As key elements of e-SCM, Holten et al. [2002] have recognized: e-commerce, e-design, e-supply chain, e-planning, e-logistics, and e-production. Norris et al. [2000] provide more detailed definition and according to them, e-SCM is a collaborative use of technology to enhance business to business processes and improve speed, agility and real time control and customer satisfaction.

E-SCM TOOLS

A key driver to e-SCM is coordination and integration among all the participants in the supply chain, primarily through sophisticated information systems and management software. The efficiency and effectiveness of e-SCM are determined by the existence of information networks and interactive software. The primary types of information systems used in managing supply chains could be categorized in:

- Supply Chain Software,
- Web and mobile applications,
- RFID, and
- Emerging digital tools.

Supply chain software

Supply chain software is a tool that provides real-time analytical systems that manage the flow of information and goods through the supply chain network. The software solutions could be focused on individual or modular functions and processes of the supply chain or could offer solutions for integrated SCM systems within the Enterprise resource planning (ERP) systems.

ERP systems are developed like an integrated solution that provides the possibility for managing, controlling and tracking organizational resources [Monczka et al. 2009]. Reix et al. [2011] defined ERP systems as a computer application: configurable, modular and integrated, which aims to bring together and optimize management processes of the company by providing a single repository and relying on standard business rules. According to Gunasekaran and Ngai [2004] ERP are systems that connect different functions within an organization as well as an organization's supply chain partners (suppliers, distributors, third party logistics providers), enabling the various business partners and organizational entities to share information, such as order status, product schedules, sales records, as well as to plan production, logistics and marketing promotions. ERP as a cross-functional system is designed to improve organizational performance and competitiveness by streamlining business processes and eliminating duplication of work and data [Kwahk, Ahn 2010]. The SCM solution system can be developed and applied also as separate module software. SCM software plays a significant role in the ability of firms to reduce costs and increase the responsiveness of their supply chain [Chopra, Meindl 2015]. SCM software is information systems enable the coordination of information between internal and external customers, suppliers, distributors and other partners in a supply chain [McLaren et al. 2004]. SCM software creates the ability to transmit data in real time and helps organizations to transform supply chain processes into a competitive advantage. The companies use a real time data transmission system to assist in routing, tracking and delivering the goods. To be successful in the digital economy, companies need digital supply chains that are fast, agile and intelligent enough to profitably serve production on demand. It means the ability to produce any product in any quantity, with any modification and in any segments [SAP 2018].

Digital supply chains software tools open the opportunity for customization or to produce tailor-made products and services with predictive capabilities to anticipate potential jams and prevent against them. The new SCM software tools contribute to supply chain transformation. Due to, the digital supply chain becomes a fundamental function in today's digital economy. Today's trend of the digital economy is the direct selling and personalization experience which gives manufacturers more control and direct feedback from the customers. To respond to this new trend, the companies need responsive supply chain management that quickly adjusts and responds to the design, production and delivery services.

Web and mobile applications

Contemporary e-SCM strategy requests dynamic web application capabilities which will result in the customer – centric system oriented towards gathering and analyzing data and knowledge about customers; identifying collaborators to perform the functions needed in the supplying chain; moving the function to the channel member who will perform them most effectively and efficiently; sharing the knowledge about customers, available technology and logistics challenges and opportunities within the chain members; and developing products, services and executed the best logistics, transportation and distribution methods to deliver products and services to consumer. Web application technology consists of software platforms which relate the members of the chain. The software components of the platform consist of tools for providing services like trading, message, transaction, and other services [Verwijermeren 2003]. The upper level of digitalization of SCM is the mobile SCM. It means the use of mobile applications and devices to help the execution of supply chain activities and then support firms to obtain cost reductions, supply chain responsiveness and competitive advantage [Kurt et al. 2016]. Mobile technologies enable firms and users the flexibility to apply wireless technology to any supply chain function and extend existing SCM capabilities [Eng 2006]. Mobile technologies and applications offer an advanced level of efficient and effective communications among business partners in supply chains adding flexibility and greater visibility to the business processes. Stieglitz et al. [2015] made a distinction between mobile business apps that do not need any or only less customization and mobile enterprise apps that are developed for the specific firm and task. Yuan and Zheng [2009] stress four basic features of mobile enterprise apps: mobile notification, location tracking, navigation system and real-time assignment of tasks. Mobile supply chain management services and applications aimed at enhancing the performance of activities along the supply chain and facilitate collaboration with partners since information sharing can be conducted in real time. For example, mobile inventory applications alert suppliers if given stock of products or materials has fallen below a predetermined level, but also allow for remotely checking the availability of items in warehouse and reordering in case of unavailability [Jelassi, Enders 2014]. M-SCM architecture consists of three layers [Sathyan et al. 2013]:

- The terminal user level - encompass the end users of products, second-tier suppliers or distributors, retailers, or merchandiser, people working on products and maintaining warehouse or people in the sale
- The network layer - involved in the transfer of information. Mobile SCM apps enable information flow between different business functions throughout the supply chain.
- The system platform layer - manages the main areas in the supply chain like logistics, supply and marketing manufacturing, and inventory.

According to Muller-Versee et al. [2001], the main m-SCM applications are m-Inventory and m-Tracking. Ruhi and Turel [2005] have classified mobile application on the base of the activities in the company: logistics, operations, marketing and sales, and services.

RFID TOOLS

Another kind of mobile technology which rapidly leads to a redefinition of the supply chain processes is wireless product identification technology as a Radio Frequency Identification system (RFID). RFID chip is used for monitoring the stock level at the warehouses or store locations. RFID tags can be attached to products, pallets which carry goods, shelves, forklifts, mounted in freight and shipment pathways. The main idea of RFID system is as customers pick up the tagged product, signals are transmitted through the wireless network to the merchandise management system, which tracks the number in stock and issues alerts to clerks carrying Personal Digital Assistant (PDA) [Blau 2006]. The automatic notification of inventory management system by an RFID reader alert when inventory gets depleted below a certain level is an example of wireless technology application. It facilitates an efficient and streamlined process flows in warehouse and inventory management system [Taniar 2009]. RFID offers numerous benefits in the managing of the supply chain such as improved speed, accuracy, efficiency and security of information sharing, reduced storage, handling, and distribution expenses, increased sales through reduced stock outs and improved cash flow [Jones et al. 2004, Kakkainnen 2003]. Major retailers around the world such as Metro and Walmart rely on RFID as a solution to ensure inventory online in the store is seamless.

Emerging digital tools

The evolution and digital transformation of e-SCM are moving towards more connected, smart, responsive and predictive tools and systems. The new digital SCM solutions not only connects every aspect of internal operations but also enables real-time workforce engagement; supplier collaboration;

outcome-based consumer experience and other real-time operations engaging new technologies such as artificial intelligence (AI), Internet of Things (IoT) and Big Data.

New innovative web and mobile applications and software manage data from any source, integrate and extend business processes with an open digital platform. The cloud solutions offer a range of capabilities refers to digital business planning and digital logistics and order fulfilment.

E-LOGISTICS AND E-SCM FOR COMPETITIVENESS

Global market and need to be competitive influences companies connected to the logistics sector. Some online retailers have expanded their logistics services and offering. As result, they are reducing the use of external logistics providers but not completely. Others use different analyses of customer data to increase logistics efficiency. Companies like large grocery chains started to offer own logistics services and combine their two supply chains - brick-and-mortar and online. All included in logistics service will need to improve their businesses processes and technology they are using (robotics, drones, 3D printing) (Figure 3).

Source: Tipping and Kauschke 2017

Fig. 3. Complex competition

The previous figure presents a complex competition situation in logistics services and e-SCM in today's market. Customer experience, new entrants, technology collaboration vs. competition are major characteristics of the new trend and logistics service providers will need to adapt to these changes.

According to the research conducted by lharington group [Harrington 2018] companies (e-retailers, producers, etc.) will need to create a strategy for supply chain digitalization to access new technology and to establish a way to gain the benefits and stay in front of their competition. Most important areas of digitalization are big data analytics (73%), cloud-based applications (63%), the Internet of thing (54%), blockchain (51%), machine learning (46%) and sharing economy (34%). On the hardware side, the most important areas for gaining competitiveness in e-logistics are robotics (63% of respondents), AVs (40%), 3D printing (33%), and augmented reality and drones (both with 28%).

The ultimate objective of Supply Chain Management is to achieve a sustainable competitive advantage [Ling 2007]. The emergence of e-Business has influenced the coordination among different stages in the supply chain. Information technologies have changed customer contact mechanisms and information flows. It has enabled organizations to gain immediate feedback from customers and markets and share information with suppliers as well as collaborating decision making throughout the supply chain. E-SCM is considered as one of the milestones of e-Business. It is regarded as a critical element of successful e-business implementation [Croom 2005]. E-business applications and web-based information technologies have basically changed the way companies conduct their business and the way in which they compete [Sanders 2007]. Incorporating e-business approach in supply chain management has been proved as a competitive method for increasing value to be added and improving process visibility, agility, speed, efficiency, and customer satisfaction. Firms and their suppliers create highly competitive supply chains by collaborating, otherwise, it can result in inefficiencies like an increase in material cost, distortion of information or slow response to product design and development. All phases of the design, sourcing, manufacturing and distribution processes that are integrated within e-SCM tools helped the company to enhance its market position across sectors. Li et al. [2006] provide empirical justification that firms with high levels of SCM practices as e-SCM have improved the organization's competitive advantages through price/cost, quality, delivery dependability, time to market and product innovation.

If e-SCM is one of the crucial modules in e-Business, at the same time e-logistics is the critical function in the firm's supply chain because logistics directs the flow and storage of products and information. Successful e-SCM synchronizes e-logistics with other functions such as production, procurement, forecasting, order management, and customer services. Logistics elements that are integrated into the supply chain management need to assure smooth product flow. Due to, the e-logistic could be identified as a determinant of the overall supply chain performance and considered a crucial tool that provides a strong competitive advantage. The employment of emerging ICT technology – software, web, mobile, cloud, IoT, block chain solutions and AI will provide additional new value to e-Business, e-SCM and e-Logistics processes. It will be in the direction of achieving higher visibility into a network of partners and customers; track and trace the movement of raw materials and final goods across the network and get insights into the status of delivery. The critical value of e-SCM processes for the competitive advantages of the company was described by Barne [2006]. He stated that historically the competitive advantages of a company's supply chain were under-rated. Companies competed on products and services, not processes. But those days are over. The intensity of global competition is forcing companies to compete on the strength of their supply chains.

DEUTSCHE POST DHL

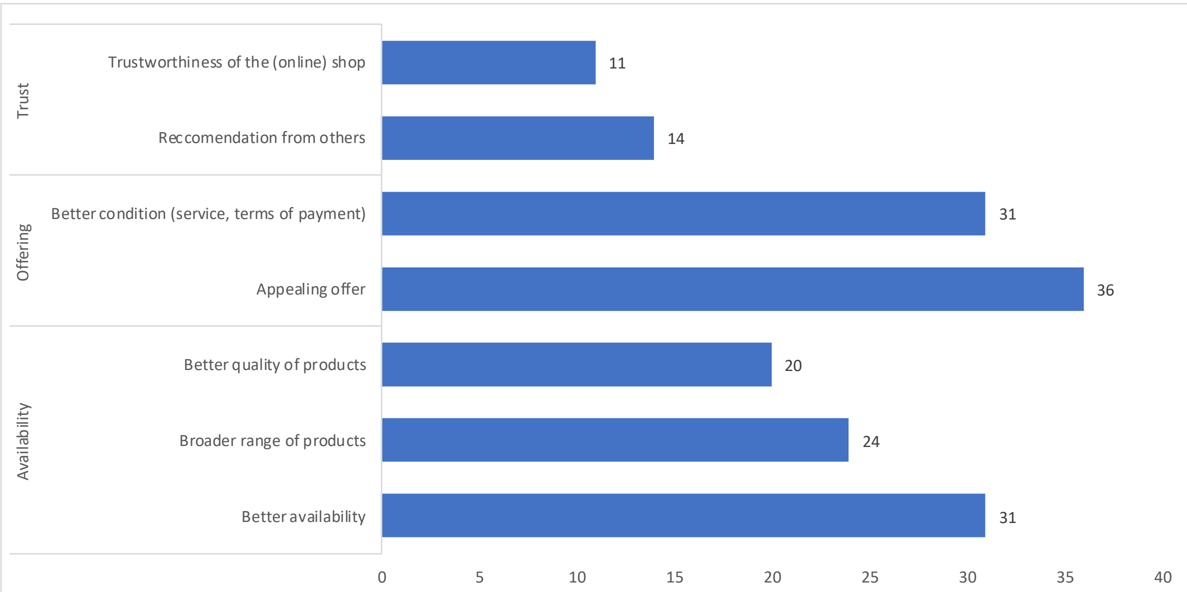
Deutsche Post DHL Group is one of the world's largest mail and logistics company. Company's focus is on being the first choice for customers, employees, and investors in its core business activities worldwide. They are making a positive contribution by connecting people and enabling global trade while being committed to responsible business practices, purposeful environmental activities, and corporate citizenship. The group is working under two brands Deutsche Post and DHL. The company is one of the largest 3PL logistics companies in the world. Based on DHL's understanding of global Internet and market, it provides different services in professional services in express, air freight and ocean shipping, ground transportation, and international postal service areas, etc. [Liu and Wen 2012]. Besides the delivery services, DHL offers contract logistics and enterprise solution services which are connected to the supply chain management and enterprise information solution.

In our paper, we will examine influence DHL Express can have on increasing the company's competitiveness being their e-logistics partner. DHL Express services cross-border premium e-commerce with its core Time Definite international product, supplemented by its deferred Day Definite solution. Delivering e-commerce shipments door-to-door through its international Express network that spans more than 220 countries and territories. Door-to-door Time definite international delivery services can allow retailers to reach customers quickly just about anywhere in the world without the need to establish warehousing or distribution chains; even where they have a centralized supply chain, it can also allow them to hold less buffer inventory. What this means for e-commerce customers is that they can open their web shop to a global market, where studies have even shown that offering an express solution will result in higher basket values, more returning visitors and increased sales.

DHL role in increasing competitiveness

DHL's express business is growing in demand due to the increase of international e-commerce and the increasing significance of SME's in international trade. Importance of DHL as an e-logistic partner can be seen in their 38% market share based on TDI deliveries and in the fact that 70% of all online purchases are made in international sites in 2017 which is an increase of 6% in relation to the previous year [DHL 2018]. DHL is working closely to buyers and sellers in the supply chain to deliver satisfaction for both sides through delivery experience and delivery options. They developed several services (i.e. On Demand Delivery) which are enhancing the customer's experience and supporting web merchants as they access new markets. The company uses their advanced market intelligence tools to identify web shops which receive traffic from abroad and with that describing potential international sales. DHL's customers (i.e. web shops, distributors, etc.) are then receiving different website engagement metrics which is helping them to reduce potential bounce rates in addition to a cross-border express delivery option. As part of the service, DHL is offering advice to the web shop owner how to optimize their online presence and how to create competitive advantage through offered shipping options.

DHL services are creating an opportunity for small businesses and entrepreneurs to open new markets for their products and services. This is creating a new trend in business – an accidental exporter [DHL, 2018]. Importance of this trend can be seen in the motivation of consumers for cross-border e-commerce (Figure 4).



Source: DHL, 2017

Fig. 4. Motivations of consumers for cross-border e-commerce shopping in %

Based on the previous research conducted by DHL and Google [DHL, 2017] it is possible to see that one of the motivators for visiting and purchasing at certain web shop is "better conditions (services, terms of payment)". This is the area where DHL comes as a characteristic for an increase of the competitiveness of merchants.

Once the customer comes to the international online shop and selects the products he would like to purchase, the next important decision is a shipping option which is everything but not simple. With the delivery options, e-retailers can gain and increase or completely lose competitiveness. Right and carefully selected delivery options and transporter in modern e-commerce creates an important competitive advantage. This was confirmed in research (DHL, 2017) where for the e-retailers the competitive advantage comes through an e-logistics partner. Customers noted that guaranteed delivery time (22% of the respondents), the speed of delivery as the most important logistics need (37% of the respondent) and transparent trace and track possibility (17% of the respondents) represents significate parts of formula which create a competitive advantage for e-retailers. Additionally, for the customers and e-retailers stated logistics related characteristics as the biggest challenge in e-commerce with most significant barriers in high shipping costs (74% of all respondents) and complex logistics (67% of all respondents). The previous data shows the importance of having good e-logistics partner as DHL is for creating and maintaining competitiveness in the market.

A possibility which offers DHL – premium shipping – represents a gold standard for some product categories (i.e. medium to high priced fashion) and this creates a competitive advantage for the e-retailers which offer time definite shipping. In the same time, this is maybe not attractive for other product categories or lower-priced products since the trade-off between price and speed is not clear in these categories. Although for them premium shipping is important addition since customers like having choices and with that e-retailer can have a competitive advantage just for having it in its delivery possibility – without it, the customer can change mind and leave web shop and buy somewhere else. This is another benefit which DHL gives to their partners in creating a competitive advantage for them and based on their data [DHL, 2017] almost 20% of international sales are shipped with an express option and e-retailers who offered express (premium) shipping grew 60% faster than the companies offering only standard shipping option.

Further influence of e-logistics on the competitiveness and DHL as the provider can be seen in the further development of digitalization since it has a significant influence on the supply chain and operations. Companies (e-retailers, producers, etc.) will need to create a strategy for supply chain digitalization to access new technology and to establish a way to gain the benefits and stay in front of their competition [Harrington, 2018]. The digitalization process will include DHL as their respected partner who is already applying digital technology in their current business footprint which delivers extraordinary customer experience with increasing efficiency for their customers. The company is already using digitalization as augmented reality tools in their warehouse operations which is increasing efficiencies in picking times. This is shortening the time employees need for packaging service and with that, it is possible to lower the price of the service and consequently, DHL's customer (web retailer) can be more competitive on the market.

Another field in which DHL is increasing competitiveness for its clients is the use of artificial intelligence (AI). Today's AI systems are more accessible, less expensive, and more powerful than ever. By including AI into the company's core process, the company can invest more in strategic growth imperatives to modernize or eliminate legacy application systems. This will increase the efficiency of current assets and infrastructure and at the same time, it will provide time for the workforce to improve their skills and capabilities. AI in logistics enables new value creation models with increased use of AI with digital and physical logistics networks, support through self-learning systems and back office automation, forecasting and intelligent logistics. AI can help logistics with renewing of operating model i.e. from reactive to the proactive and forward-looking tactic. This move will have a significant impact on different activities and sectors in logistics such as customer contact activities, operations, and back office and resulting in increased efficiency and competitiveness.

CONCLUSIVE REMARKS

Companies serving modern customers need to invest in new technologies and start creating and using its e-logistics and e-SCM applications. They are equipped with Internet and cloud computing and have access to global factories and global supply chains. So, the only differentiator in being competitive in the market is to understand and satisfy customer needs. Companies need to be more customer-centric and not only customer-aware. This is where e-logistics and e-SCM can help companies in creating and maintaining a competitive advantage.

Developing technology allows companies to offer more customized services – ordering, pick-up, and delivery options. To be able to meet their customers need and keep them from going to the competition, they need to offer and/or use services with embedded digitalization in all areas of business. Companies can create their services with the use of supply chain software, web and mobile applications, RFID and different emerging digital tools. Companies need to adapt to a complex competition situation in logistics services and e-SCM in today's market.

Customer experience, new entrants, technology collaboration vs. competition are major characteristics of the new trend and logistics service providers will need to adapt to these changes. Improved running in one of the previously mentioned areas will improve the company's competitiveness and as more modern technological tools and solutions will be used, companies will be able to have more benefits. E-logistics needs to support company's process with information sharing within the company and within the supply chain. Thus, companies can create and maintain their competitive advantage through their e-supply chains strengths. Applying of e-logistics and e-SCM tools can improve the supply chains total reaction and as a result, make a new foundation for competitive advantage.

The presented case of DHL is showing how one company (a part of supply chain) as 3PL (or 4PL) can help companies in creating and maintaining a competitive advantage in today's globally competitive market.

To further increase knowledge about how e-logistics and e-SCM can increase competitiveness we propose further research:

- To monitor e-logistics and e-SCM users (i.e. DHL's customers) to find how DHL's activities influence their competitiveness
- To quantify possible reductions in running a business by using e-logistics and e-SCM tools.

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E-LOGISTICS I E-SCM: JAK ZWIĘKSZYĆ KONKURENCYJNOŚĆ

STRESZCZENIE. Wstęp: Rozwój technologii, który postępuje w ostatnim czasie oraz wzrost aktywności związane z e-commerce, wymusza zmiany w obszarze logistyki jak również podejście wielu firm do obszaru związanego z logistyką. Z drugiej strony można obecnie zaobserwować rozwój dostawców usług logistycznych i ich przekształcenia. W obecnych czasach konkurencyjność nie polega jedynie na cenie ale również na jakości usług oraz czasie realizacji. Wpływa to również na wdrażanie nowoczesnych metod w logistyce.
W związku z rozwojem technologii, koncepcja e-logistyki jest coraz częściej wdrażana, umożliwiając wymianę informacji oraz jej przejrzystość dla wszystkich uczestników łańcucha dostaw. Dlatego też jednym z najważniejszych zadań w-logistyka jest przekaz informacji pomiędzy partnerami, co wpływa na ich konkurencyjność. Celem tej pracy jest zaprezentowanie właściwej postawy dostawcy usług logistycznych we współczesnym łańcuchu dostaw, która może pomóc uzyskać firmom przewagę konkurencyjną poprzez między innymi stosowanie najnowszych rozwiązań technologicznych.
Metody: Na podstawie przeglądu literatury dokonano analizy obecnej sytuacji, następnie określono wpływ e-logistyki oraz e-SCM na konkurencyjność firmy. Na przykładzie firmy DHL zaprezentowano potencjalne korzyści e-logistyki dla podwyższenia przewagi konkurencyjnej.

Wyniki: Otrzymane wyniki wskazują na uzyskanie przewagi konkurencyjnej przez operatora logistycznego, stosującego zawansowane rozwiązania technologiczne.
Wnioski: Doświadczenie klienta, nowi użytkownicy, współpraca w zakresie używanych technologii versus konkurencyjność to główne elementy charakteryzujące nowy trend, który muszą wdrożyć do swojej praktyki dostawcy usług logistycznych. Poprawa w którymkolwiek z powyższej wymienionych obszarów stwarza możliwość do utrzymania konkurencyjność firmy. Wraz ze wzrostem stosowanych nowoczesnych rozwiązań technologicznych, firmy uzyskują więcej korzyści.

Słowa kluczowe: e-logistics, e-SCM, dostawca usług logistycznych, konkurencyjność, DHL.

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TABU SEARCH AND GENETIC ALGORITHM FOR PRODUCTION PROCESS SCHEDULING PROBLEM

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ABSTRACT. **Background:** The paper deals with production process scheduling problem. In large companies, the decision-making process about operators' work, machines availability and production flow is a very difficult task, which is often being done by employees. Thus, not always the decision made is optimal in terms of cost, production time, etc.
Methods: As a solution, two intelligent methods: Tabu Search and the genetic algorithm have been analyzed in field of production scheduling. The aim of this work was to examine the possibility of improving presented decision-making process that is being performed when scheduling, using Tabu Search and genetic algorithms. As a result of experimental re-search, it has been confirmed that the use of appropriately selected and parameterized intelligent methods allows for the optimization of the analyzed production process due to its du-ration. The research was case of study performed in cooperation with company that produces components for automotive industry.
Results: Basing on collected and analyzed data, considered methods can be more or less successfully used in production process scheduling. Comparing both used algorithms, Tabu Search twice proposed worse solutions, the average operational time was 1.63% shorter than the actual one. In this case, better results were reached by using genetic algorithm – potential operational time was always shorter than the actual one, and it was reduced by 6.3% in total on average.
Conclusion: Using algorithms allowed to achieve lower workload of employees and to reduce of operational time, which were the evaluation criteria in performed research. Managers of the analyzed company were pleased with the proposed solution and declared interest in developing these methods for future. This shows that intelligent methods can find, in relatively short time, the solution that is close to the optimal and acceptable from the problem point of view.

Key words: production process scheduling, Tabu Search, genetic algorithm, heuristic methods, intelligent methods in manufacturing.

INTRODUCTION

Nowadays, not only the low cost is important for customers, but also the quality of products and as quick delivery as possible [Musiał et al. 2017, Kotowska et al. 2018, Zwolińska at al. 2017]. That is the reason why companies that want to be competitive need to perform complex solutions in production scheduling area. This process should include aspects like analysis of available machines and their effectiveness, operators' availability and possibilities, organizational restrictions etc. This is a very difficult task, that usually is being performed by one person or small group of employees. Even if companies use computer programs to schedule, the process of decision-making is often fraught with error caused by human factor, frequent and quick changes in production process. A solution of this problem is, among others, an application of intelligent methods (heuristic and metaheuristic), which can find in relatively short time, the solution that is close to the optimal and acceptable from problem point of view.

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The practice confirms that heuristic methods can be successfully implemented in production processes [Kotowska et al. 2018, Górnicka et al. 2018, Burgy and Bulbul 2018, Paprocka et al. 2017]. The use of intelligent methods and algorithms in production and logistic processes are shown in many publications. Algorithms are being used in process optimization, for example in transport management [Bożejko et al. 2017], scheduling [Chen et al. 2018, Shishido et al. 2018, Bożejko, et al. 2008, Kumanan et al. 2006, Grajek and Zmuda-Trzebiatowski 2014], delivery synchronization [Gdowska and Książek 2017] or planning and helping in decision-making [Ahmad et al. 2017, Kazemi et al. 2009].

RESEARCH PERFORMED IN INDUSTRY

The research was performed in a company that produces components for the automotive industry. Because of the components character, most of the operations performed in the company there are welding and sealing.

Production process

The products manufactured by the analyzed company are car seats, produced in four variants. The production plans of all variants assume mainly the use of the same machines. Production processes take place in the same production cell and there are differences between single operations. In the analyzed area of production, there are 17 machines in total, and each of them needs one operator. In the production of all four variants the unit times are the same. Data about production process flow is shown in the fig.1.

The company works in the two-shift arrangement, with 8-hours lasting workday. 15 minutes are intended to start and 15 minutes to finish the shift. Workers have two breaks, 10 and 20 minutes (fig. 2).

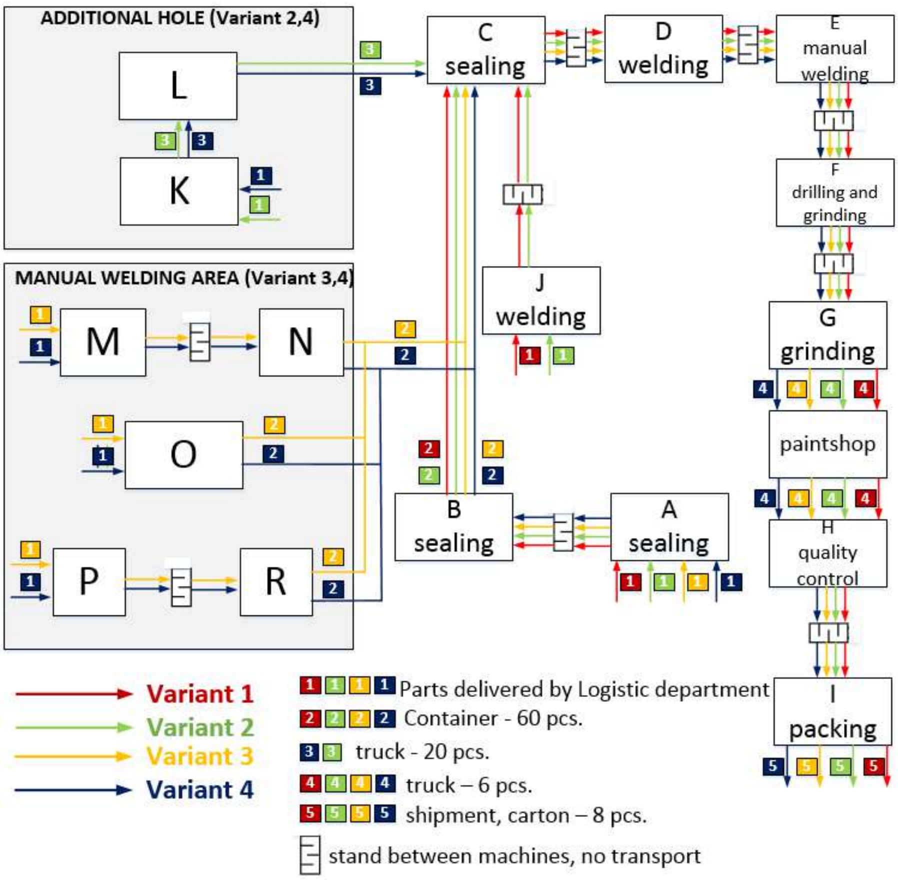

Fig. 1. Production process flow

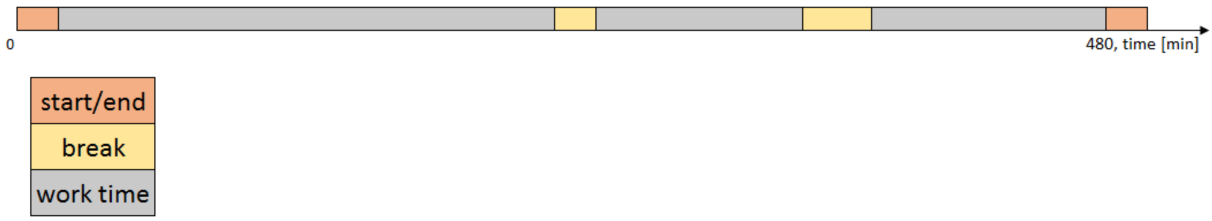

Fig. 2. Shift schedule

That means, that on one shift, the company has 420 minutes of operational time. In addition, they keep a stock of 5 pieces next to each machine with no transport before.

Production scheduling process

Based on accepted orders, the logistic department elaborates the production plan of each shift. Then planning department calculates the operators demand, based on the sum of all unit times necessary to realize the production plan. Amount of available operators on one shift may differ than planned, because of sickness, random events or the need of using operator to help in production processes for other products. Moreover, the total amount of operators is always lower than number of machines used in production process. Each operator is allowed to work with each machine. The foreman divides the work between the operators, based on the production plan, the real number of workers and other factors. With the aim of production continuity, some workers need to operate few machines in a proper sequence. Main limiting factors taken under consideration are: limited number of employees, specified number of machines and the required operation order for each product. The scheduling process is not computer aided and it's being done in two steps. The first step is to assign operators to machines, to the load for each machine to be as even as possible. The second step is making the decision about operations sequence (if one worker operates few machines) to ensure, as far as possible, that the work flows continuously. The main aspect that determines fulfilling the schedule is the foreman experience.

OPTIMIZATION METHODS

Formulation of the problem

In the selected manufacturing cell, $w = 4$ product variants from the set $W = \{1, \ldots, w\}$ are being produced. There are $m = 17$ machines from the set $M = \{1, \ldots, m\}$, in which $o = 17$ from the set $O = \{1, \ldots, o\}$ operations are being executed. Each machine performs only one operation. For i-th operation, where $i \in O$, the operation time t_i is given. The technological process for each product is given as the sequence relation showed in the fig.1. For k-th machine, where $k \in M$, the initial workplace buffer bk is given. On the j-th shift from the set $S = \{1, \ldots, s\}$, for v-th variant where $v \in W$ the production plan is given as a number $p_{v,j}$ from the set $P_{v,j} = \{1, \ldots, p_{v,j}\}$ of pieces of each variant to be produced and a number e_j of available employees.

For i-th $\in O$ operation and lv,j-th $\in P$ piece two parameters have been determined for objective function calculation:

- start time $t_{si,l(v,j)}$ – time, when the i-th operation for lv,j-th piece starts,
- end time $t_{ei,l(v,j)}$ – time, when the i-th operation for $l_{v,j\text{-th}}$ piece ends.

The objective is to generate the work schedule for employees, specifying the beginning and end of all operation executions to minimalize the entire production time.

The objective function is given as the set of two conditions:

1. Operation orders for all pieces have to be prevented.
2. End time value of the last operation for the last piece has to be as small as possible. (for all variants the last operation is "packing" on machine I).

In case of 100 pieces, the measurement of objective function is time, when machine I finishes last 100th operation).

te17,p -> min

Selected algorithms

The research results indicate that there are many types of decision-making problems that can be solved with use of the meta-heuristic algorithms [Burduk, Musiał 2016, Górnicka et al. 2018, Ho et al. 2010, Kotowska et al. 2018, Musiał et al. 2017, Gola Kłosowski 2018, Kalinowski, Skołud 2017]. They are being increasingly used as supporting methods because they allow finding a near-optimal solution in a reasonable time and do not need the transformation into mathematical formulations [Antosz, Stadnicka 2014, Dorigo 1992, Krenczyk, Skołud 2014]. The intelligent methods are applicable to both simple and NP (nondeterministic polynomial) optimization problems [Bożejko et al. 2016, Burduk and Musiał 2016, Musiał et al. 2017]. Although their application does not guarantee finding the optimal solution, the proposed solutions can be fully acceptable from the company point of view [Bentley and Wakefield 1998, Tuncer and Yildirim 2012], because of time, labour input and human errors reduction. For the considered problem of decision-making process in scheduling it was decided to use intelligent methods. For the examined case, the Tabu Search algorithm and the genetic algorithm were considered as well known, advanced and modifiable algorithms appropriate to the investigated issue. In the Tabu Search method, it is possible to modify the sequence of tasks performed by employees. In genetic algorithm there are various selection methods that may affect speed and quality of the result. The Tabu Search algorithm has been implemented by OpenTS - a java tabu search framework. Genetic algorithm has been used with Matlab program.

Tabu Search algorithm

Tabu Search algorithm is widely used because of ease of its implementation and high quality of generated solutions. It belongs to the group of local search algorithms.

The main advantage of Tabu Search algorithm is the possibility of avoidance of stucking in local minimum.

```
Algorithm Tabu Search (S0, var S, max_m, max_it)
 Set S = S0 and n_iter = 0
 Repeat
    m = 0
    best = 0
    it = it + 1
         Repeat
             m = m+1
             Execute Check_the_neighboring_solution (S,Sm)
             Execute Check_Tabu_list (S,Sn)
                 if (f(Sm) > best then (best = f(Sm) and
                 (m2= m))
         until (m = max_m)
    Execute Add_to_Tabu_list (S,Sm2)
    S= Sm2
    If best > solution then solution = best
 Until n_iter = max_it
```

Fig. 3. Basic Tabu Search algorithm pseudocode

In figure 3 the Tabu Search algorithm pseudocode has been shown. The general concept based on searching neighboring solutions and going to the best of them. To protect from sticking on local optimum the tabu lists are used and the solution once find is not taken under consideration in further searching. Moving in unacceptable solutions (solutions that do not give a valid operation order) is risky from optimization point of view. These solutions are tabu – not visited again. Among solutions that give a valid schedule a tabu list length equal to 7 has been applied. It means that 7 last moves are tabu and tabu list is refreshed after each movement. Additionally, the longtime memory of objective function value has been used to prevent from turning around.

Genetic algorithm

Genetic algorithm is an example of an algorithm analyzing many samples in each step, in contrast to Tabu Search based on a simple sample analysis. Genetic algorithm belongs to class of evolution algorithms. Main limitation of a genetic algorithm are instability - lack of convergence in the absence of good schemes and premature convergence. Adjustment of parameters in a specific case may solve these problems. A scheme of genetic algorithm has been presented in the figure 4.

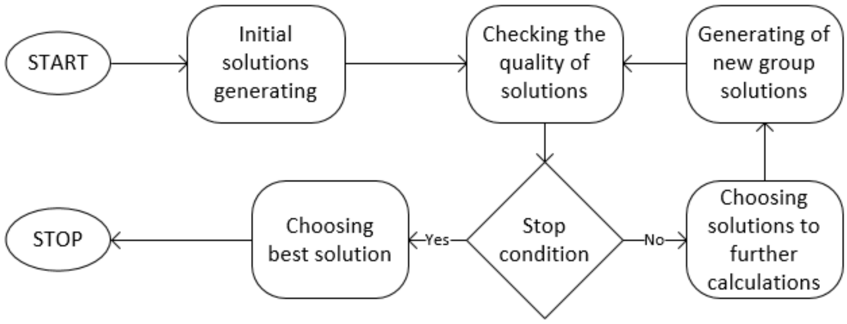

Fig. 4. Scheme of genetic algorithm

Process of genetic algorithm solution searching consists of several steps. First, called initiating, generates an initial population – initial groups of solutions. In next step, these solutions are evaluated in terms of acceptability and quality in accordance with defined objective function. Chosen solutions can be used to next population generating – next group of solutions. The algorithm is finished after knowing the stop condition, for example: after determined number of cycles or after finding the accepted solution.

Algorithms in investigating issue

In the following example, the Tabu Search algorithm and the Genetic algorithm have been used to solve task of allocation technological operation to proper employees and establishing the order of operation execution. Order of operation will be accepted if:

1. All executed operations will be included with amount equal to number of produced pieces of each variant.
2. Given sequence of operation executing will be preserved for each piece of product.

Basing on the real process of allocation operations to employees, the Tabu Search algorithm had been used in two stages. First, to allocate employees to machines to keep the employees occupancy as equal as possible. That way, 3 best solutions have been chosen. Next, basing on solution chosen in first stage, to find the best possible sequence of executed operation for each employee. Genetic algorithm also has been used in two stages. First, to allocate employees to machines to optimize their occupancy. Next, based on 3 best solutions the operation sequences for employees have been generated.

Comparison of methods results

The results obtained with use of both analyzed methods compared with actual results of the company are illustrated in the diagrams (fig. 5 and 6).

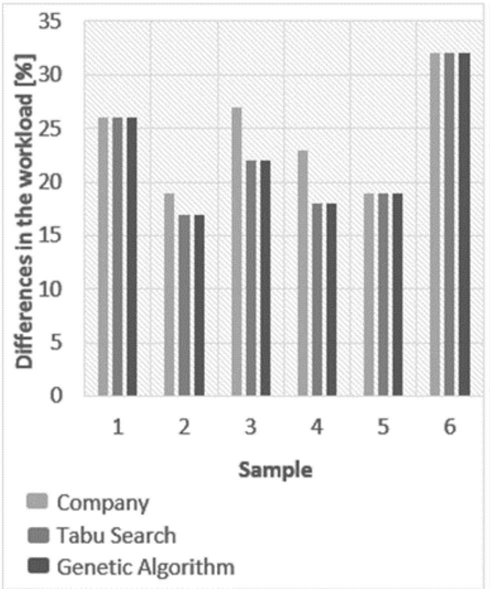

Fig. 5. Differences in the workload of employees

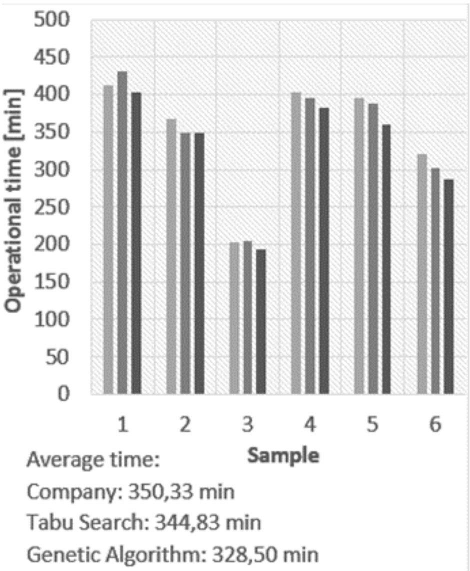

Fig. 6. Operational time of orders execution in analyzed samples

Analysis of the results obtained after the first step in solving the optimization task indicates that this task is performed by the brigadier with a very good result. In about half of the analyzed cases, the foreman assigned the machines to the employees in the same way as the algorithms proposed. In other cases, the result of the foreman was the second or third best solution proposed by the algorithms. This step was solved by both algorithms in all cases identically. Analysis of the results obtained after the second step indicates that the genetic algorithm proposed better solutions than the Tabu Search algorithm. The Tabu Search algorithm has twice proposed worse solution than the foreman and in all studied cases showed solutions only on average 1.63% better than the actual ones. Based on the data collected, in each of the analyzed samples, the genetic algorithm suggested a solution better than the real one – potential operational time was in each case shorter, in total on average by 6.3% than the real one.

CONCLUSIONS

In the presented work the decision-making problem in production scheduling has been considered. As a solution an intelligent scheduling system with the use of the Tabu Search method or the genetic algorithm have been proposed. The research has been carried out on an example of a company, which is a producer of components for automotive industry. The results obtained by both considered methods show that only the genetic algorithm can be successfully used for solving considered problem. By using the genetic algorithm it is possible to reduce an operational time, guaranteeing the execution of all accepted orders and minimizing the resources usage. The obtained results demonstrate high potential of the genetic algorithm usage that can be successfully used for solving similar or even more difficult problems. Therefore, further works on this method have been planned.

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TABU SEARCH I ALGORYTMY GENETYCZNE W HARMONOGRAMOWANIU PROCESÓW PRODUKCYJNYCH

STRESZCZENIE. Wstęp: Artykuł opisuje problem harmonogramowania procesów produkcyjnych. W dużych przedsiębiorstwach proces podejmowania decyzji dotyczących pracy operatorów, maszyn, dostępności zasobów i przepływu produkcji jest bardzo złożonym zadaniem, często wykonywanym przez pracowników. W związku z tym podjęte decyzje nie zawsze są optymalne w kontekście kosztów, czasu produkcji itp.

Metody: Jako rozwiązanie, przeanalizowane zostało użycie, w obszarze harmonogramowania produkcji, dwóch metod inteligentnych: Tabu Search i algorytmów genetycznych. Celem pracy było zbadanie możliwości doskonalenia procesu podejmowania decyzji, który jest wykonywany przy harmonogramowaniu produkcji, przy pomocy Tabu Search i algorytmów genetycznych. Jako wynik eksperymentu przeprowadzonego podczas badań, potwierdzono, że użycie odpowiednio wybranych oraz sparametryzowanych metod inteligentnych pozwala na optymalizację analizowanego procesu produkcji. Badania zostały wykonane we współpracy z przedsiębiorstwem zajmującym się produkcją komponentów dla branży motoryzacyjnej, jako studium przypadku.

Wyniki: Zgodnie z zebranymi i przeanalizowanymi danymi, wybrane metody mogą być z mniejszym bądź większym powodzeniem stosowane w procesie harmonogramowania produkcji. Porównując zastosowane algorytmy, Tabu Search dwukrotnie zaproponował rozwiązanie gorsze od aktualnego podejścia przedsiębiorstwa, jednak czas produkcji został skrócony średnio o 1.63%. W tym przypadku, lepsze wyniki pozwoliło osiągnąć zastosowanie algorytmu genetycznego – potencjalny czas produkcji był zawsze krótszy od aktualnie stosowanego rozwiązania, a średni czas produkcji został zredukowany o 6.3%.

Wnioski: Zastosowanie algorytmów pozwoliło na osiągnięcie niższego obciążenia pracą operatorów oraz zredukowanie czasu operacyjnego, co stanowiło kryteria oceny w przeprowadzonych badaniach. Kierownictwo analizowanego przedsiębiorstwa było zadowolone z zaproponowanych rozwiązań. Zdecydowali się na stosowanie omawianych metod w codziennym harmonogramowaniu produkcji oraz zadeklarowali zainteresowanie rozwojem stosowania metod w przyszłości. Metody inteligentne pozwalają znaleźć, w relatywnie krótkim czasie, rozwiązanie bliskie optymalnemu i akceptowalne z punktu widzenia analizowanego problemu.

Słowa kluczowe: harmonogramowanie procesów produkcyjnych, Tabu Search, algorytm genetyczny, metody heurystyczne, inteligentne metody w wytwarzaniu

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ORIGINAL PAPER

THE ROLE OF IT IN THE LOGISTICS SECTOR: THE IMPACT OF DUPONT MODEL ON THE PROFITABILITY OF IT COMPANIES

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ABSTRACT. **Background:** The information technology (IT) is presented in all levels of the supply chain, from the communication with suppliers, through the manufacture process and until the delivery to clients. Moreover, IT has a positive effect on the performance of the supply chain. In this context, it is important for the IT sector to register a positive evolution, in other words it is important that the IT companies to be profitable and to continue to exist on the market ensuring the provision of the necessary tools for the logistic sector. Therefore, the objective of this paper was to analyze the profitability of the IT companies and to identify which factors impact it. The importance of our study in the context of the logistic sector can be sustained by the fact that technology information constitutes a crucial strategic aspect for the logistics service providers and it is important to maintain a positive evolution of the IT sector.

Methods: There was used a regression analysis which started from the factors of the DuPont model and afterwards supplemented by one factor identified based on the Stepwise method.

Results: The results show that the profitability of the Romanian IT companies is influenced by the Net Profit Margin, the Asset Turnover, the Financial Leverage and the Sales Growth.

Conclusions: More exactly, the profitability of these companies is impacted by the capacity to generate net income based on the sales performed (and indirectly by the management of the costs), the efficiency with which the assets are used in order to generate revenues, the financing source of the assets and by the growth of the sales volume. Our results may present importance for the financial management, investors and researches offering insights about the factors which should be observed in order to improve the profitability of an IT entity from Romania. The importance of this study for the logistics sector can be interpreted as following: knowing which is the evolution of the IT market from a country and which factors impact the profitability of it represents an asset from the point of view of the logistics aspects, as there can be provided insights in case that the continuity for the tools needed is uncertain. Future research direction may imply the analysis of the correlation between the evolution of the IT companies and the logistic sector. Considering the fact that, as far as we know, no similar study was performed at the level of the Romanian IT industry, the novelty and originality of the research is represented by the performance of the research at the level of this market.

Key words: profitability, IT market, Romania, DuPont model, ROE, supply chain.

INTRODUCTION

In the economic world from today, companies are facing with a significant competition and are put in the situation in which they should improve their portfolio of products and services in order to be attractive on the market. In this context, companies are facing with various difficulties in relation to the administration of the information flow throughout the supply chain. As a consequence to this situation, and in order to make the logistic operations easier, entities use the technology information tools. Therefore, the information technology is presented in all levels of the supply chain, from the communication with suppliers, through the manufacture process and until the delivery to clients. Moreover, from the point of view of logistics, the information technology contributes to the improvement of certain processes among the supply chain, as well to the reduction of labor costs, improvement of

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the customer services and of the management of the transportation channels [Miraldes et al., 2015, Wieczerniak, Cyplik, Milczarek 2017]. Other researchers consider that IT has a positive effect on the performance of the supply chain [Yee, 2005]. Furthermore, the authors concluded that IT represents a tool which allows companies to face a dynamic market, improving their relationship with the customers.

Given all the above, there can be considered that the improvement of the supply chain at the level of companies depends on the technology and evolutions from the IT market. In this context, it is important for the IT sector to register a positive evolution, in other words it is important for the IT companies to be profitable and to continue to exist on the market ensuring the provision of the necessary tools for the logistic sector. Therefore, there was found interesting to analyze the IT market, as a vehicle for the improvement of the supply chain, and to determine which factors influence the profitability of the IT companies.

Determination of factors which impact the level of the profitability recorded by entities has became, during the time, one of the most analyzed topics in terms of financial management. Moreover, after reviewing the literature in this domain, there was observed that studies are performed at the level of various industries, but no study was performed in order to identify the factors which influence the profitability of the companies from the IT sector, at least not at the level of Romania. Given this, the aim of this paper is to determine those factors which impact the profitability obtained by the Romanian IT companies. The Romanian IT market was chosen, as during the time this industry recorded a significant evolution, becoming an attractive market for investors and also an important pylon for the development of the Romanian economy. Therefore, it was considered that the novelty and originality of the research is represented by the performance of the research at the level of the Romanian IT market. Moreover, the originality of the paper could be sustained by the fact that in order to identify the determinates on the profitability, the research started from the DuPont model, followed by the identification of additional factors, in this respect being applied the Stepwise method. Therefore, the research objectives of this paper were as follows: first, to identify how the DuPont factors impact the profitability of the Romanian IT companies and second, to identify other additional factors that could influence the profitability of these companies. Going further, the main aim of the paper was to contribute to the finding of a model that could be used in order to perform a prediction of the profitability recorded by the Romanian IT companies.

The novelty and originality of the paper are also represented by the results of the research. The most important result which contributes to the scientific researches on the IT market is represented by the fact that in this industry is not important the experience on the market in order to be profitable, but the efficiency in which the assets are used. In other words, it could be interpreted that, in order to be profitable on the IT market, an entity should be up-to-date with the modern technology.

The results of this paper could be beneficial for the future researchers who intend to investigate the profitability of companies that operate on the IT market, in the sense that it could represent a starting point for identifying other determinant factors. In addition, this research could present importance for the financial management and also for investors, offering insights about the factors which should be observed in order to improve the profitability of an IT entity from Romania.

The importance of the study in the context of the logistic sector can be sustained by the fact that technology information constitutes a crucial strategic aspect for the logistics service providers [Sauvage, 2003].

The paper is organized as follows: the presentation of the literature review based on which were developed the research hypotheses, the description of the data and methodology used (sample and data description and presentation of the research model applied), the illustration of the results obtained and, in the end, the presentation of the conclusions followed by future directions for research and by the limits of the research.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The recent literature analysed the profitability recorded by companies from different countries and markets, using in this respect indicators like the financial return [Padachi, 2006], the return on assets [Deloof, 2003; Narware, 2010] or the return on equity [Avdalović, 2018].

According to Raza and Farooq [2017], the most important factor that should be used in order to assess the profitability of an entity is the return on equity (ROE). Regarding the studies performed in relation to ROE, part of them are based on the DuPont model [Burja and Marginean, 2014; Kharatyan et al., 2017; Raza and Farooq 2017]. According to the DuPont model, considering that ROE represents the ratio between net income and equity, it could be decomposed as follows:

$$ROE = \frac{Net\ Income}{Equity} = \frac{Net\ Income}{Sales} * \frac{Sales}{Assets} * \frac{Assets}{Equity}$$

Where:

$\frac{Net\ Income}{Sales}$ = Net Profit Margin. This indicator measures the capacity of an entity to generate net income based on the sales performed.

$\frac{Sales}{Assets}$ = Asset Turnover. This indicator shows the efficiency with which an entity uses its assets in order to generate revenues.

$\frac{Assets}{Equity}$ = Financial Leverage. This indicator illustrates the way in which companies finance their assets.

Simplifying, starting from the DuPont model, ROE could be decomposed as follows:

*ROE = Net Profit Margin * Asset Turnover * Financial Leverage*

Kharatyan et al. [2017] performed a study, at the level of the 90 largest nonfinancial entities that are part of the NASDAQ-100 index, investigating the factors that impact the level of ROE. The authors applied the ordinary least squares method and starting the analysis from the DuPont model. They concluded that irrespective of the industry sectors the most important factors that influence the level of ROE are the operating margin, the asset turnover, the financial leverage, the interest burden and the tax burden.

Avdalović [2018] performed a study at the level of a sample of industrial grinding companies in order to analyse the impact on ROE of the following factors: number of stocks, size, years of firm existence, financial leverage and book value per share. The author concluded that only the financial leverage, number of stocks and book value per share influence the level of ROE, while the other factors do not have a significant impact on ROE. Delen et al. [2013] studied the impact of certain financial ratios on ROE and concluded that the level of ROE is affected by indicators such as the financial leverage, the net profit margin and the sales growth ratio.

Denčić-Mihajlov [2013] analysed the impact of the account receivables on the profitability obtained by 108 companies listed on the Belgrade Stock Exchange. The results showed that there is a positive, but no significant relation between the profitability and the account receivables. Mbula et al. (2016) concluded that there exists a positive correlation between the financial performance of companies funded by government capital in Kenya and the accounts receivables. Ikechukwu and Nwakaego [2015] investigated the factors which affect the profitability of building materials entities from Nigeria using in this respect a multiple regression method. The results of their study show that the accounts receivables have a positive and significant impact on the profitability.

Akinyomi and Olagunju [2013] analysed the impact of the firm size on the profitability and concluded that firm size has a positive effect on the level of the profitability obtained by the manufacturing companies from Nigeria. According to Mulchandani [2016], the size of a firm has a positive impact on the level of ROE. Vintila et al. [2014] measured the size of a firm through the annual average number of employees.

Pervan at al. [2017] conducted a dynamic panel analysis on a sample of Croatian companies operating in the food industry. The results of their research reveal that the age of a firm negatively affects the performance of a firm. However, according to Akben-Selcuk [2016] the younger entities start with a decline in profitability and become profitable at an old age.

Moreover, according to some researchers, the factors which impact the profitability of companies can change among countries and industries [Hatem, 2014; Raza and Farooq 2017]. Given this, and in a first instance, having as a starting point the DuPont model, we found interesting to analyse how the financial indicators from this model impact the level of ROE recorded by the Romanian companies which operate on the IT market. Therefore, we expected to find that the indicators from the DuPont model (i.e. Net Profit Margin, Asset Turnover and Financial Leverage) positively influence the level of ROE, the aim of the paper being to observe the measure in which each of the three indicators influence ROE.

Furthermore, considering the results of the research studies described above, we also found interesting to analyse if those results could be validated also on the Romanian IT market. In this context, we established the following research hypotheses:

Hypothesis 1: Indicator Size influences the level of ROE.

Hypothesis 2: Indicator Age influences the level of ROE.

Hypothesis 3: Indicator Account Receivables influences the level of ROE.

Hypothesis 4: Indicator Sale Growth influences the level of ROE.

DATA AND METHODOLOGY DESCRIPTION

Sample and data description

We analysed the impact of the above mentioned factors on the level of ROE over the year 2016 (i.e. the most recent year for which we identified data). The sample used in this research is represented by the Romanian companies which operated in the IT industry during 2016. The search of these companies was performed within the Amadeus database, online version, number 289. In order to select our sample we applied the following criteria in the Amadeus database:

- we selected only companies located in Romania;
- we selected only active companies. The main purpose of applying this criterion was to eliminate those companies which are inactive, in insolvency or in bankruptcy. We considered that the inclusion of these companies in the sample could distort the results of the research, and therefore we selected only the active companies;
- as a last criterion, we selected those companies which operate in the IT industry, having the following NACE Rev. 2 codes: 6201 - Computer programming activities; 6202 - Computer consultancy activities; 6203 - Computer facilities management activities; 6209 - Other information technology and computer service activities.

The Amadeus database returned a number of 228 active companies which operate on the Romanian IT market. Due to the fact that for a part of the companies the Amadeus database did not contain all the financial information needed in order to perform our research, we included in the sample only 145 companies (i.e. those companies for which all the necessary data is available).

After we identified the research sample we applied a regression model. The variables included in the regression model are presented in table 1 below.

Table 1. Measurement of variables

Variables	Measurement
1. Dependent variable	
ROE	ROE was computed as the value of the net income divided by the value of the total equity.
2. Independent variables	
2.1 Variables from the DuPont model	
Net Profit Margin	This indicator represents the ratio between the net income and the value of the sales.
Asset Turnover	We computed this variable by dividing the value of the sales to the value of the total assets.
Financial Leverage	This variable represents the ratio between the total assets and the total equity.
2.2 Other independent variables	
Size	We considered that the size of a company is given by the number of its employees.
Age	This indicator represents the years of experience on the IT market of a company (i.e. the years between the date of incorporation and the date of this research).
Account Receivables	This indicator was computed as the value of the sales divided by the value of the account receivables.
Sales Growth	The Sales Growth measures the volume with which the sales of a company increased in 2016 compared to 2015.

Source: Authors` processing

Empirical methods

In the first step of the research we tried to confirm our expectation regarding the fact that the indicators from the DuPont model positively influence the level of ROE. Moreover, in this step we tried to achieve the first objective of the research (i.e. to observe the measure in which each of the three indicators influences ROE). Therefore, in order to do this we applied the following multiple linear regression model:

ROE = β0 + β1 x Net Profit Margin + β 2 x Asset Turnover + β 3 x Financial Leverage + ε, *(1)*

where ROE is the dependent variable, Net Profit Margin, Asset Turnover and Financial Leverage are the independent variables, β are the coefficients of the regression and ε represents the error.

After applying this model we tried to achieve our second research objective, respectively to identify other factors that could be included in the research model (other factors which could influence the level of ROE) and also to see if the research hypotheses could be validated. Therefore, in order to do this we created the following new multiple linear regression model, including as independent variables the Size, Age, Account Receivables and Sales Growth:

ROE = β0 + β1 x Net Profit Margin + β 2 x Asset Turnover + β 3 x Financial Leverage + β4 x Size + β 5 x Age + β 6 x Account Receivables + β 7 x Sales Growth + ε *(2)*

The statistical software used in order to analyse the above research models is SPSS (Statistical Package for the Social Sciences).

The main tests/ methods applied in SPSS were as follows:

- The significance test in ANOVA – for this test we used the output table of the ANOVA analysis from SPSS to check whether there is a statistical significant difference between our group means. We considered a confidence level of 95% and a significance threshold of 5% (100% - 95%);
- Shapiro-Wilk test – we used this test in order to check if our dependent variable (i.e. ROE) is normally distributed;
- Stepwise method – through this method we determined the statistical significant predicators in the regression equation. This method looks into the correlation matrix and chooses the independent variable that has the largest Pearson correlation with the

dependent variable and puts it into the regression analysis creating a first model. After that, it looks for the next highest predictors of the dependent variable, sequentially creating new models, until it finds a non-significant predictor;
– Enter method – through this method we determined the statistical significant predicators in the regression equation forcing all the independent variables into the multiple regression equation, irrespective of their statistical significance;
– Pearson correlation- this statistic tool was used in order to test if all our independent predictors are multicollinear.

EMPIRICAL RESULTS

Descriptive statistics

Table 2 presents the descriptive statistics for all the variables included in our empirical research.

Table 2. Descriptive statistics

Variables	N	Minimum	Maximum	Mean		Std. Deviation
				Statistic	Std. Error	Statistic
ROE	145	.003	2.535	.377	.0286	.345
Net Profit Margin	145	.000	.679	.108	.0086	.104
Asset Turnover	145	.003	7.886	1.85	.1025	1.23
Financial Leverage	145	1.001	72.711	4.228	.771	9.281
Size	145	1	3635	241.480	42.081	506.725
Age	145	4	28	15.960	.519	6.244
Account Receivables	145	.009	124.888	5.765	.890	10.718
Sales Growth	145	.191	24.489	1.398	.173	2.084

Source: data from SPSS

As could be observed from the above table, the average profitability indicator (ROE) of the companies from our sample is of 37.735%. Moreover, these companies have an average of 241 employees and an average experience on the IT market of 16 years.

The average sale growth on the IT market during 2016 was of 139.760%. The high average value of the asset turnover shows that companies which operate on the IT market used their assets, during 2016, in an efficient way, in order to generate revenues. On the other hand, the high average value of the Financial Leverage shows that the assets used by the companies from the IT industry are financed from debts rather than from equity. Regarding the Net Profit Margin, during 2016, the companies from our sample generated an average net income of 0.108 EUR for every euro of sales. Looking at the average value of the account receivables there can be assumed that in the IT sectors companies are performing sales based on credit.

Results of the regression model

A. Regression model including the factors from the DuPont model

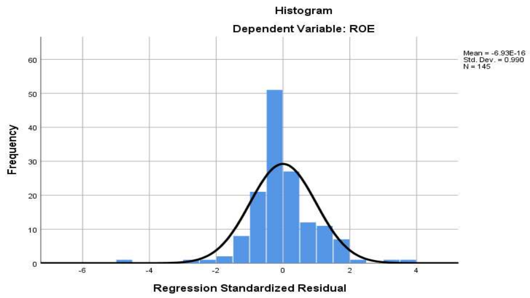
As we already mentioned, through this multiple regression we tried to analyse how the financial indicators from the DuPont model influence the variance of the profitability indicator (ROE). Thus, for this multiple regression analysis we selected three predicted variables and one dependent variable.

First of all, we checked if the dependent variable is normally distributed. In this respect, table 3 presents the results of the Shapiro-Wilk test which show that the non-statistically significant P-value is 0.811. Given this, we can assume that the dependent variable is normally distributed.

Table 3. Test of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.
ROE	.811	145	.000

Source: data from SPSS



Source: data from SPSS

Fig. 1. Histogram

Moreover, to have another confirmation of the fact that the dependent variable is normally distributed, we generated from SPSS the above histogram for ROE, presented in figure 1. The histogram also shows that the values of ROE are normally distributed.

In the next step, we tested if all our independent predictors are multicollinear. Looking into the Pearson correlation results from the table 4 we can see that there is no value above 0.7 which means that all our predictors are independent.

Table 4. Matrix Correlations

	Variables	ROE	Net Profit Margin	Asset Turnover	Financial Leverage
Pearson Correlation	ROE	1.000	.587	.288	.061
	Net Profit Margin	.587	1.000	-.168	-.203
	Asset Turnover	.288	-.168	1.000	-.175
	Financial Leverage	.061	-.203	-.175	1.000

Source: data from SPSS

Table 5. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.758[a]	.575	.566	.227099

Notes: Predictors: (Constant), Financial Leverage, Asset Turnover, Net Profit Margin; Dependent Variable: ROE

Source: data from SPSS

Further on, based on the Model Summary output from the table 5, there can be observed that R Square value is 0.575 which means that 57.5% of the variance in the dependent variable (ROE) is explained by the predictor variables (Financial Leverage, Asset Turnover and Net Profit Margin).

Moreover, looking in the ANOVA results from table 6, considering the statistical significance P-value (which is well below the P-value significance threshold of 0.05) and also the F-statistic we can conclude that our model is statistically significant. Therefore, the regression model is valid and the results of the regression are not accidental. More exactly, the impact of the analysed factors (Financial Leverage, Asset Turnover and Net Profit Margin) on ROE is significantly different from the role of chance.

Table 6. ANOVAa

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9.827	3	3.276	63.512	.000[b]
	Residual	7.272	141	.052		
	Total	17.099	144			

Notes:
a. Dependent Variable: ROE
b. Predictors: (Constant), Financial Leverage, Asset Turnover, Net Profit Margin
Source: data from SPSS

Table 7. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.164	.047		-3.511	.001
	Net Profit Margin	2.402	.191	.723	12.600	.000
	Asset Turnover	.128	.016	.460	8.054	.000
	Financial Leverage	.011	.002	.288	5.016	.000

Notes:
a. Dependent Variable: ROE

Source: data from SPSS

The table 7 presents the results of the regression model applied. In the coefficients output from this table is presented the significance levels for all of the mean differences in ROE score between the constant and the predictor variables. Given that the statistical significance (P-value) for all of these variables is below 0.05, we can create three statistically significant relationships.

Based on the above results, we go further to confirm our expectation regarding the influence of the DuPont model on ROE. In order to do this, we applied the "t-test". Considering that the t test value of our independent variables is higher than the t critical value (1.645), and more than that the significance threshold of these variables is lower than 0.05, our expectation was confirmed. This means that the profitability obtained by the Romanian entities operating in the IT industry is influenced by the financial indicators from the DuPont model (i.e. Net Profit Margin, Asset Turnover and Financial Leverage).

Furthermore, the results show that the Net Profit Margin is significant and positively correlated with ROE. This means that the level of the profitability indicator is impacted by the capacity of an entity to generate net income based on the sales performed and as a consequence, indirectly by the management of the costs.

Going further, the Asset Turnover is positively correlated with ROE. Therefore, the efficiency with which an entity, which operates on the IT industry, is using its assets in order to generate revenues has a positive impact on the level of the profitability indicator (ROE in our case). More exactly, taking into account that the main assets for an IT entity are represented by the IT equipment and the software tools used, there can be concluded that the way in which are used these assets impact the profitability level. Based on this, there can be associated an efficient use with the existence of up to date software tools and modern IT equipment and can be concluded that the use of a modern technology can leads to an increase in the profitability level. However, this is only an assumption based on the results of our research and the validation of it needs a more deeply analysis.

Regarding the Financial Leverage, we can observe that there is a positive but small correlation between this indicator and the level of ROE. Therefore, the way in which companies from the IT sector are financing their assets impacts only in a small proportion the level of the profitability indicator.

The results obtained in relation to the impact of the Financial Leverage, Asset Turnover and Net Profit Margin on the level of ROE comply with the results of other researchers (Kharatyan et al., 2017; Avdalović, 2018 and Delen et al., 2013).

In the end, based on the results obtained, there can be created the following regression equation which can be used in order to predict the value of ROE for given values of our predictor variables:

$$ROE = -0.164 + 2.402 \times \text{Net Profit Margin} + 0.128 \times \text{Asset Turnover} + 0.011 \times \text{Financial Leverage} + \varepsilon \quad (3)$$

B. Regression model including the factors from the DuPont model and other factors

Given the fact that based on the previously research model we found that 57.5% of the variance of ROE can be explained by the three independent variables (i.e. Financial Leverage, Asset Turnover and Net Profit Margin), the difference being explained by other variables, we tried in the next step of the research to identify those other factors which can influence the level of ROE. In this respect, in addition to the Financial Leverage, Asset Turnover and Net Profit Margin we included in the regression analysis the following four factors: Sales Growth, Account Receivables, Size and Age of the company.

As we already tested the normal distribution of the dependent variable, we did not test this aspect again. Therefore, we applied the Stepwise method in order to determinate the statistical significant predicators in the regression equation. More exactly, through this method we tried to identify which of the four additional factors can be considered as a significant predictor in the new regression analysis. The results of the Stepwise method are presented in table 8 below.

Table 8. Stepwise method

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.587[a]	.345	.341	.279826
2	.706[b]	.499	.492	.245660
3	.758[c]	.575	.566	.227099
4	.781[d]	.610	.599	.218120

Notes:
a. Predictors: (Constant), Net Profit Margin
b. Predictors: (Constant), Net Profit Margin, Asset Turnover
c. Predictors: (Constant), Net Profit Margin, Asset Turnover, Financial Leverage
d. Predictors: (Constant), Net Profit Margin, Asset Turnover, Financial Leverage, Sales Growth

Source: data from SPSS

As can be observed from the above table, only one additional predictor was added to the existing model (i.e. Sales Growth). The introduction of this new independent variable determines an increase of the R Square at 0.610. This means, that 61.10% of the variance in the dependent variable (ROE) is explained by the predictor variables (Financial Leverage, Asset Turnover, Net Profit Margin and Sale Growth). The other three independent variables (Account Receivables, Size and Age) were excluded from the model as their statistical significance P-value is above 0.05 (according to the information included in the table 9 below), this meaning that these variables do not impact the level of ROE. Moreover, the introduction in the regression analysis of the Sales Growth independent variable is also sustained by the coefficients table (table 10) according with the statistical significance P-value for this variable is below 0.05 and also by the fact that the t test value for this variable is higher than the t critical value.

Table 9. Excluded Variablesa

Model	Variables	Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
4	Size	.007[e]	.130	.896	.011	.876
	Age	-.066[e]	-1.227	.222	-.103	.953
	Account Receivables	.106[e]	.973	.332	.082	.236

Notes:
a. Dependent Variable: ROE
e. Predictors in the Model: (Constant), Net Profit Margin, Asset Turnover, Financial Leverage, Sales Growth

Source: data from SPSS

Table 10. Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
4	(Constant)	-.156	.045		-3.476	.001
	Net Profit Margin	1.989	.216	.599	9.197	.000
	Asset Turnover	.122	.015	.437	7.912	.000
	Financial Leverage	.010	.002	.268	4.829	.000
	Sales Growth	.037	.010	.224	3.584	.000

Notes: a. Dependent Variable: ROE

Source: data from SPSS

Therefore, our hypotheses according which ROE is dependent on the size of an entity, its experience on the market and the ratio of the account receivables were rejected, but the hypothesis according with ROE is impacted by the evolution of the sales growth was accepted (these results complying with those obtained only by Delen et al., 2013 and Pervan at al., 2017). More exactly, the level of ROE is not impacted by the number of employees from an IT entity, the experience on it on the IT market and the ratio of the account receivables, but it is impacted by the evolution of the growth sale.

Based on the results obtained, after the introduction of the Sales Growth in the regression model there can be created the following regression equation which can be used in order to predict the value of ROE for given values of our predictor variables:

ROE= -0.156 + 1.989 x Net Profit Margin + 0.122 x Asset Turnover + 0.010x Financial Leverage + 0.037x Sales Growth + ε *(4)*

Going further, we found interesting to analyse how the financial indicators from the DuPont model and also the additional factor identified impact the profitability (ROE) registered by the IT entities from Bucharest versus the profitability (ROE) recorded by the IT companies outside Bucharest.

As could be observed from the table 11 all the four independent variables positively influence the level of ROE for the IT companies from Bucharest. Moreover, for these companies 66.8% of the variance in the dependent variable (ROE) is explained by the four predictor variables (Financial Leverage, Asset Turnover, Net Profit Margin and Sale Growth). Regarding the companies located outside Bucharest, as could be observed, the Sales Growth do not statistically influences the level of ROE, but the other three variables explain in a proportion of 55.8% the variance of ROE. Therefore, the inclusion in the regression model of the Sales Growth indicator is justified only for the IT entities from Bucharest.

Table 11. Results of regression: Bucharest vs. non-Bucharest

Variables	Bucharest		Non-Bucharest	Sign.
	Coefficients	Sign.	Coefficients	
(Constant)	-.183	.012	-.101	.111
Net Profit Margin	2.520	.000	1.703	.000
Asset Turnover	.122	.000	.126	.000
Financial Leverage	.010	.000	.010	.003
Sales Growth	.028	.037	.000	.996
R Square	.668		.558	
F-Statistic	36.274		19.907	

Source: data from SPSS

DISCUSSION AND CONCLUSIONS

The aim of this paper was to investigate how the profitability of the Romanian IT companies is influenced by certain factors. The results of the regression applied confirm our expectation regarding the fact that the indicators from the DuPont model (i.e. Net Profit Margin, Asset Turnover, and Financial Leverage) impact the level of ROE recorded by companies subject to our research. Moreover, all these factors are positively correlated with ROE, the factor which has the highest impact being Net Profit Margin. Interpreting the results obtained from a financial analysis point of view, there can be concluded that profitability of the Romanian IT companies is influenced by the capacity of these entities to generate net income based on the sales performed and as a consequence, indirectly by the management of the costs. Going further, the level of the profitability is impacted by the efficiency with which an entity, which operates on the IT industry, is using its assets in order to generate revenues and also by the way in which companies from the IT sector are financing their assets.

In the next step of the research, we used the Stepwise method in order to identify additional factors which could influence the level of ROE. We found only one additional factor in this respect, namely the Sales Growth. However, we observed that this additional factor is significant only for the IT companies localized in Bucharest. There was surprising to find that the experience on the IT market does not influence the level of the profitability recorded by the companies. Correlating this result with the previous result obtained, according with the profitability is impacted by the efficiency with which an IT entity uses its assets in order to generate revenues, we assumed the fact that the experience on the market does not matter as long as there is used a modern technology (we considered that a modern technology could be used more efficient in order to generate revenues compared with an older one). We also found that the number of the employees and the Account Receivables do not impact the level of ROE recorded by the Romanian IT companies.

Considering the fact that, as far as we know, no similar study was performed at the level of the Romanian IT industry, the novelty and originality of the research is represented by the performance of the research at the level of this market.

Regarding the limits of our research, there can be mentioned the fact that our analysis was performed at the level of a single year. Therefore, other future research directions may imply the expanding of the research for more years and maybe at the level of other countries and also by the inclusion of other factors in the regression model (for e.g. starting from the expanded version of the DuPont model).

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ROLA IT W SEKTORZE LOGISTYCZNYM: WPŁYW MODELU DUPONTA NA RENTOWNOŚĆ PRZEDSIĘBIORSTW IT

STRESZCZENIE. **Wstęp:** Technologia IT jest obecna we wszystkich obszarach łańcucha dostaw, od komunikacji z dostawcami, poprzez proces produkcyjny aż po dostawy do klientów. Dodatkowo, IT ma pozytywny wpływ na pracę łańcucha dostaw. W tym kontekście ważne jest, aby sektor IT przeżywał pozytywną ewolucję, to znaczy, aby firmy IT były zyskowne oraz kontynuowały swoją działalność na rynku i były w stanie dostarczać potrzebnych narzędzi dla sektora logistycznego. Celem niniejszej pracy była analiza zyskowności przedsiębiorstw IT oraz identyfikacja czynników na nią wpływających. Istotność tych badań w kontekście sektora logistycznego opiera się na fakcie, że informacja technologiczna jest kluczowym aspektem strategicznym dla dostawców usług logistycznych i dlatego ważnym jest utrzymanie pozytywnej ewolucji sektora IT.

Metody: W pracy zastosowano analizę regresji, wychodząc od czynników modelu DuPonta a następnie uzupełniając o czynnik zidentyfikowany przy użyciu metody Stepwise.

Wyniki: Wyniki wskazują, że na zyskowność rumuńskich przedsiębiorstw IT ma wpływ marża netto, wskaźnik rotacji, dźwignia finansowa oraz wzrost sprzedaży.

Wnioski: Zyskowność badanych przedsiębiorstw jest uwarunkowana zdolnością generowania dochodu netto w oparciu o realizowaną sprzedaż (oraz pośrednio przez zarządzanie kosztami), wydajnością wykorzystania posiadanych zasobów, źródłem finansowania zasobów oraz wielkością sprzedaży. Prezentowane wyniki są istotne dla zarządzania finansowego, zarówno dla inwestorów jak i naukowców, oferując informacje na temat czynników, które należy kontrolować w celu uzyskania zyskowności przedsiębiorstwa IT w Rumunii. Istotność uzyskanych wyników dla sektora logistycznego należy zinterpretować następująco: znajomość ewolucji rynku IT w kraju oraz czynników wpływających na zyskowność daje przewagę z punktu widzenia aspektów logistycznych i dostarcza niezbędnych informacji w sytuacjach niepewnych. Dalsze badania powinny obejmować analizę korelacji pomiędzy ewolucją przedsiębiorstw IT oraz sektora logistycznego. Biorąc pod uwagę fakt, że jest to pierwsza tego typu praca dotycząca poziomu przemysłu IT w Rumunii, nowość i oryginalność prezentowanej pracy jest reprezentowana poprzez jej realizację na poziomie tego rynku.

Słowa kluczowe: rentowność, rynek IT, Rumunia, model DuPont, ROE, łańcuch dostaw

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ORIGINAL PAPER

EDI SYSTEM IN LOGISTIC MANAGEMENT OF AN ENTERPRISE

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ABSTRACT. **Background**: Currently, many IT tools are used in every field. Therefore, the management of enterprises want modern IT solutions to also include logistic applications in various and diversified business profiles. It is also related to the minimization of operating costs. The EDI system makes it possible to achieve such goals. For this reason, research was carried out in selected Polish and Russian enterprises and the results were presented together with the conclusions regarding the use of the EDI system.

Methods: The comparision of small enterprises in Poland and Russia were conducted. For that purpose a random sample of 100 enterprises, i.e. 50 enterprises in Poland and 50 enterprises in Russia was selected. The data were collected by the use of specially prepared questionnaires.

Results and conclusions: EDI system is used in both Polish and Russian enterprises although the scope of application of this system varies and depends on the concept of its use by the management of enterprises. Polish enterprises is mainly focused on the optimization of inventory management, minimization of costs and productivity of the enterprise, while in the case of Russian enterprises, activities are aimed at improving relationships with partners, the quality of the company's operations and productivity.

Key words: EDI, IT, IT tools, IT solutions, logistic applications.

INTRODUCTION

The EDI system is necessary to achieve the set goals, as it allows shortening the time of customer service completion. It is well known that the longer the customer service time, the longer it takes to freeze the company's financial resources [Cyplik, Zaborowski, Shvartsburg 2017]. As a consequence, it may result in a lack of financial liquidity and lead to perturbation in the company's operations. For this reason, it is important to analyze the EDI system in an enterprise that produces goods [Cyplik, Zaborowski, Shvartsburg 2017]. It is therefore necessary to test the EDI system used in business management. It improves customer service and significantly improves the quality of this service [Leung 2012, Cadle, Paul 2010].

These activities can significantly help Computer Science. It should be remembered that an IT system is a tool used to integrate data from multiple sources and which are distinguished by identifiers and transformed into a specific stream of information [Naraynan, Maruchek, Handfield 2018, Hoc-Hai, Bernard, Kwak-Kee 2015, Fiaidhi, Mohammed, Mohammed 2017]. This information is then collected in the database and is the result of the implementation of the main planning processes and implementation of processes [Bradley et.al 2018, Cyplik, Zaborowski, Shvartsburg 2017, Blecker, Kersten, Ringle 2014].

An interesting solution is the integration of the IT system with the telecommunications system leading to the creation of an ICT system, which allows access to the computer

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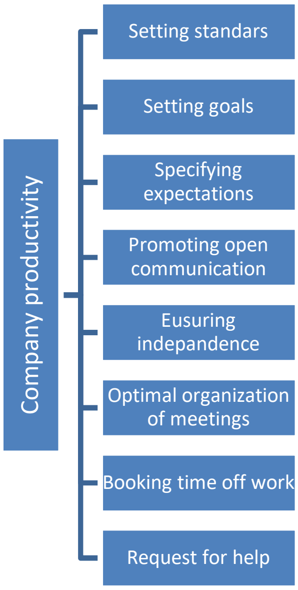
system of every enterprise to the telecommunications network [Vesela 2017, Fiaidhi, Mohammed, Mohammed 2017]. This leads to integration between the IT and ICT systems, enabling the processing of information and placing them in the cloud, which becomes a place and computing power related to enterprise servers [Fiaidhi, Mohammed, Mohammed 2017, Han, Dong 2017, Neise, 2017].

Thanks to this solution, every employee can work on documents in real time. This enables electronic data exchange (EDI) in a closed group of users [Cyplik, Zaborowski, Shvartsburg 2017] and allows you to use its main advantages (Fig. 1- 6).

The factors of individual elements listed in Figs. 2-6 illustrate how the EDI system works. They are also the basis for carrying out tests of the occurrence of these elements in individual enterprises. In this way, it is possible to assess to what extent the EDI system or its components are installed and used in the surveyed enterprises to influence the effectiveness of their functioning.

Source: own study

Fig. 1. Advantages of the EDI system



Source: own study

Fig. 2. Productivity as part of the EDI system

MATERIALS AND TEST METHODS

The research covered small enterprises in Poland and Russia, while for comparisons, a random sample of 100 enterprises, i.e. 50 enterprises in Poland and 50 enterprises in Russia, which deal with the production of machinery and equipment was established.

Selected companies were directed to specially developed questionnaires in which they explained what they are used for and what is the purpose of the research.

Responses were received from 24 enterprises, in 12 enterprises from Poland and 12 companies from Russia, which accounts for 24% of the surveyed enterprises. The results of the obtained tests were subjected to statistical analysis using the Statistica program for this purpose.

Respondents answered questions related to the EDI system and the use of individual elements of this system, which are presented in Figure 2-7. The results of these tests are presented in the following drawings.

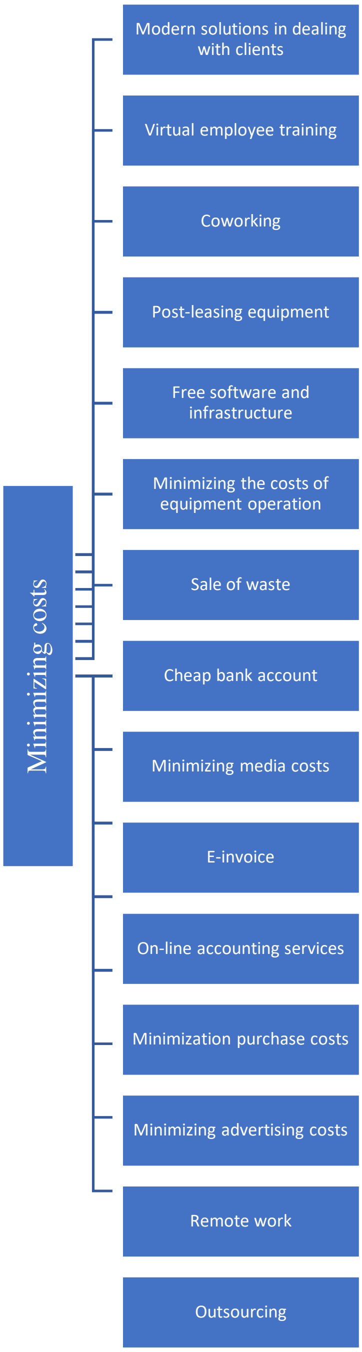


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Fig. 3. Minimization of costs as an element of EDI

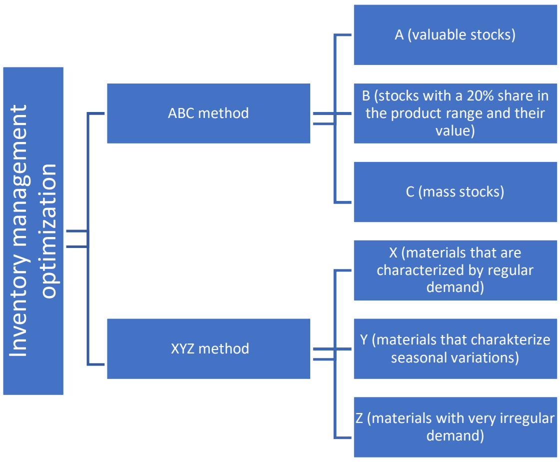

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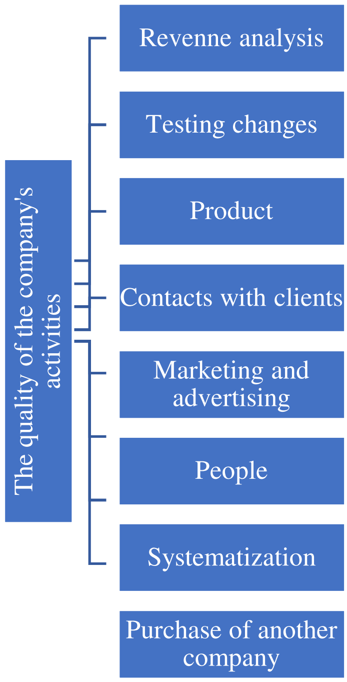
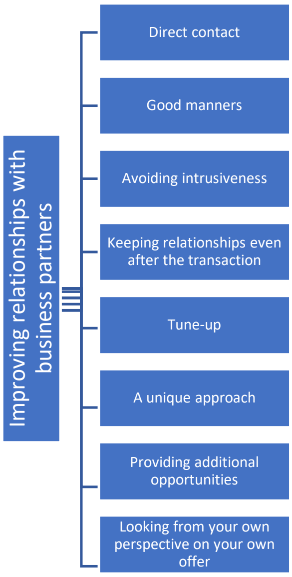
Fig. 4. Optimal inventory management as an element of EDI



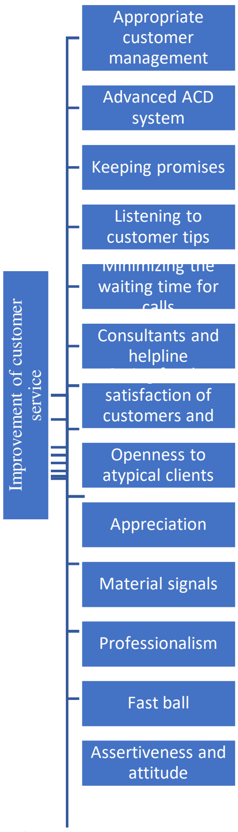
Source: own study

Fig. 5. The quality of the company's activities as a component of EDI



Source: own study

Fig. 6. Improvement of relations with partners as a component of EDI



Source: own study

Fig. 7. Improvement of customer service as an EDI component

FINDINGS

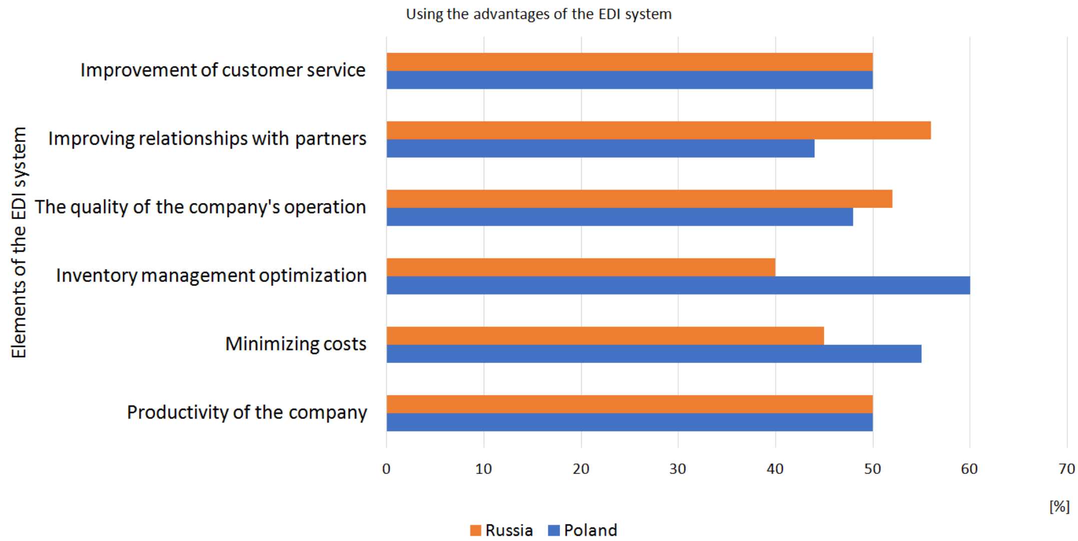
Research on using the advantages of the EDI system showed (Fig. 8) that cost minimization is used in Polish enterprises in 18% more than in Russian enterprises, while the optimization of inventory management is 33% higher than in Russian enterprises. However, quality activities in Russian enterprises are higher by 7.3% than in Polish enterprises and the improvement in relations with partners is higher by 21% in Russian enterprises.

It should be noted that the elements of individual components in the assessment of the surveyed enterprises are of great importance for the entire EDI system. Therefore, the results of research on individual elements included in the productivity for Polish enterprises are presented (Fig. 9) and for Russian enterprises (Fig. 10).

Comparing individual elements within the productivity of enterprises (Figure 9, Figure 10), it can be seen that the following elements dominate in Polish enterprises: promoting open communication 8.4%, optimal organization of meetings 9.67%, request for help 24.42% they are bigger than in Russian companies. On the other hand, Russian companies have an advantage in setting standards by 37.25%, setting goals by 61.9%, specifying expectations by 13.2%, ensuring independence by 14.6% and booking time off from work by 68.51%.

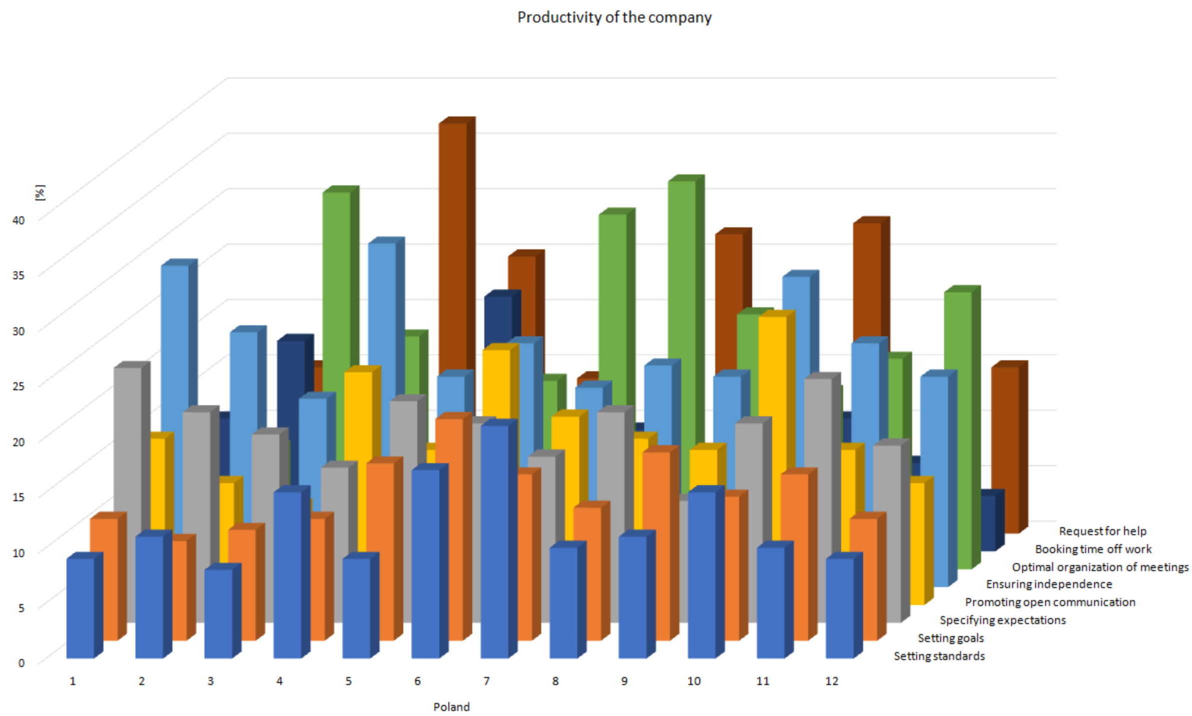
The research results indicate a different approach in the surveyed enterprises towards the EDI system. Skillful use of setting standards and setting goals gives the Russian company a greater perspective in the area of EDI production and use.

In the case of minimization of costs by an enterprise, elements of this component of EDI for the surveyed enterprises also differ, which is illustrated in Fig. 11, Fig. 12 and Fig. 13. The research results indicate that there are groups of elements in the surveyed enterprises, which in one case are beneficial for Polish enterprises, and in other cases for Russian enterprises (Fig. 13).



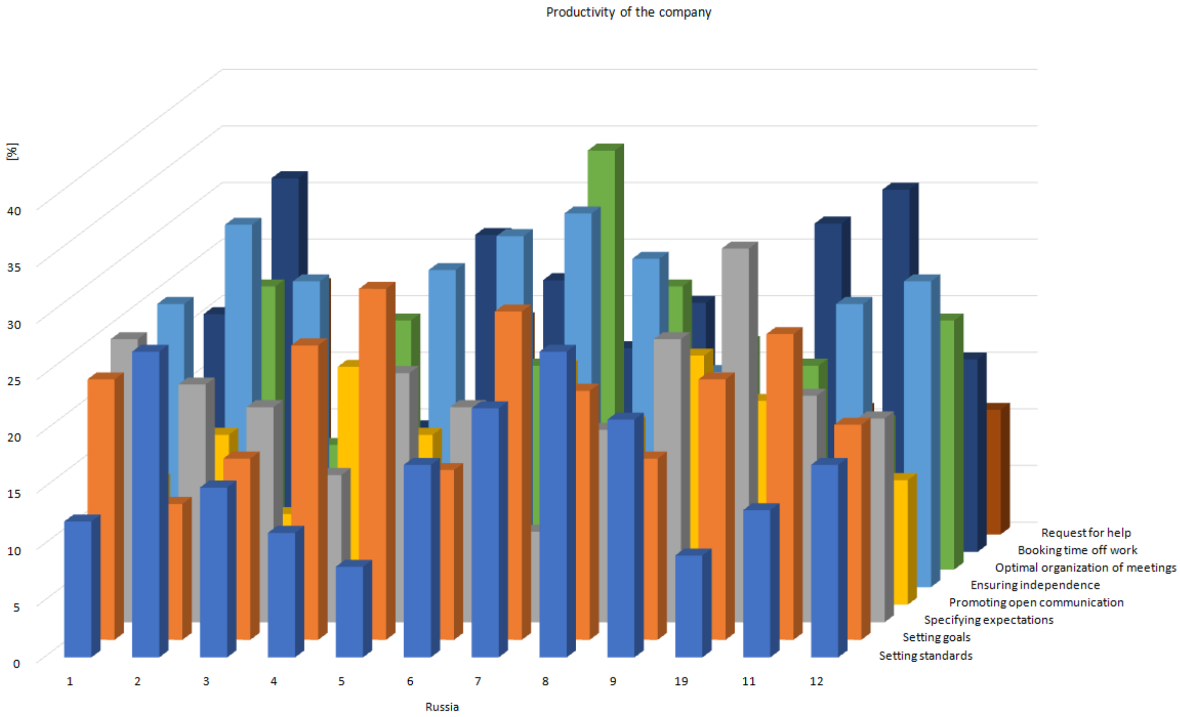
Source: own study

Fig. 8. Components of the EDI system used by Polish and Russian enterprises



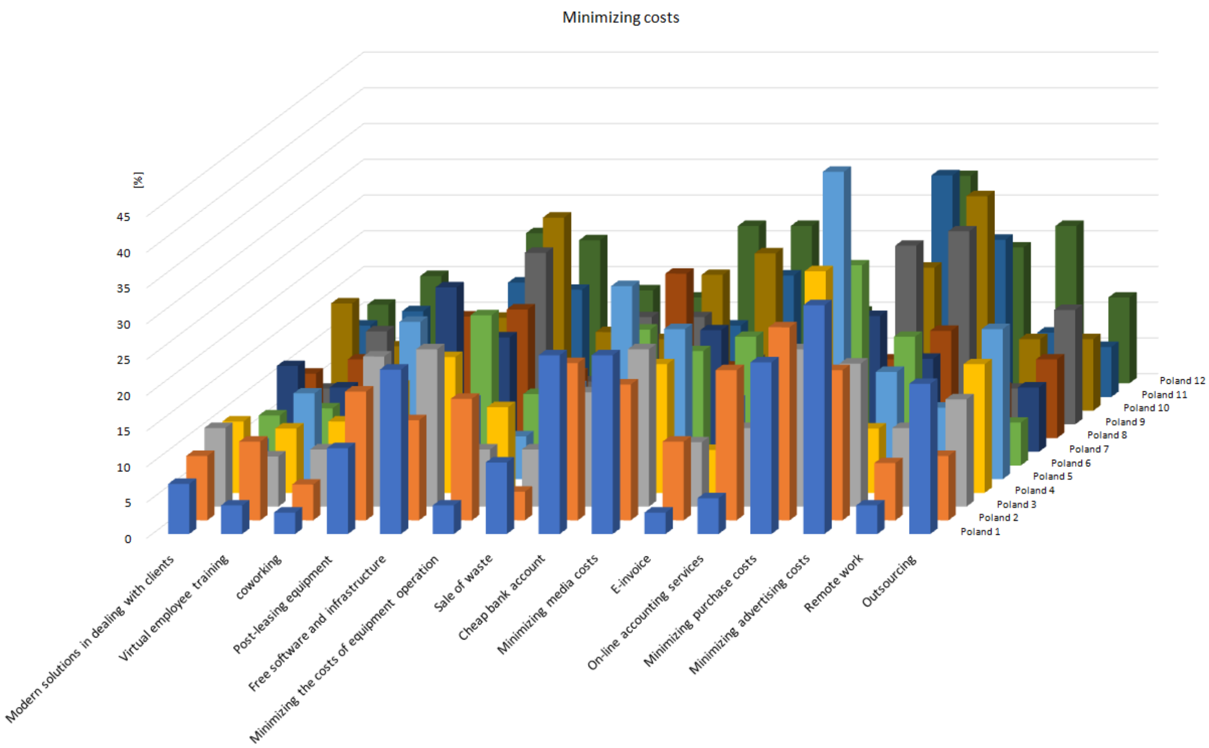
Source: own study

Fig. 9. Elements of productivity in Polish enterprises



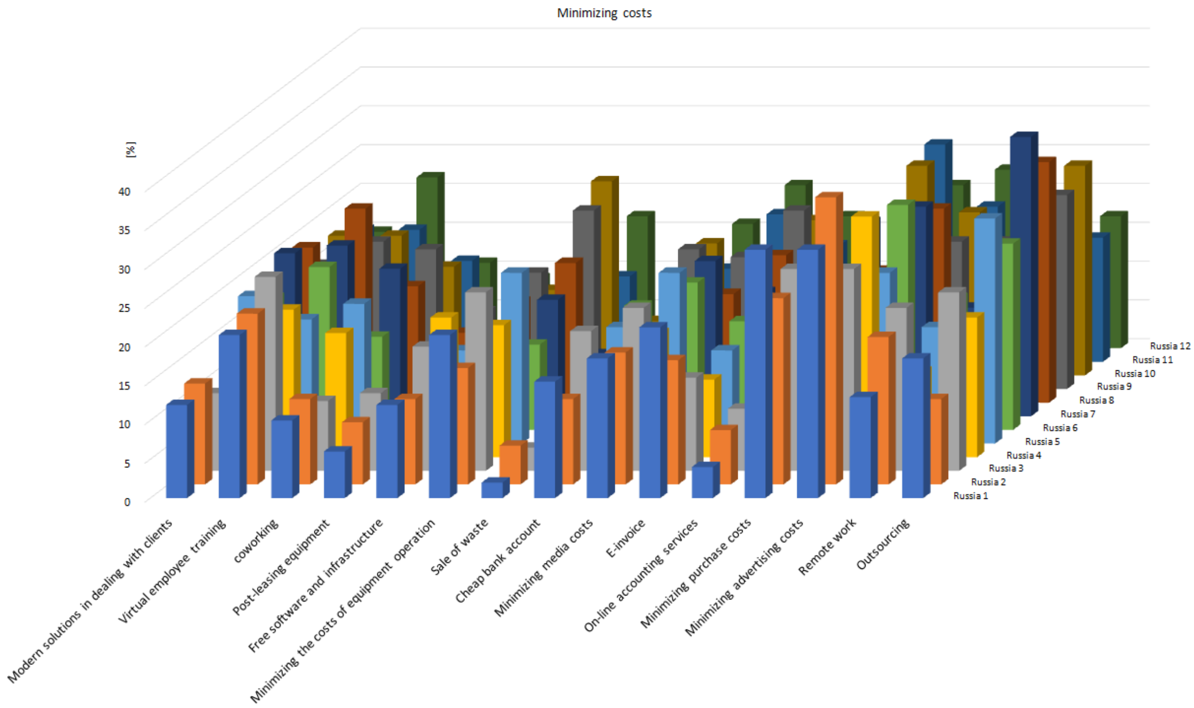
Source: own study

Fig. 10. Elements of productivity in Russian enterprises



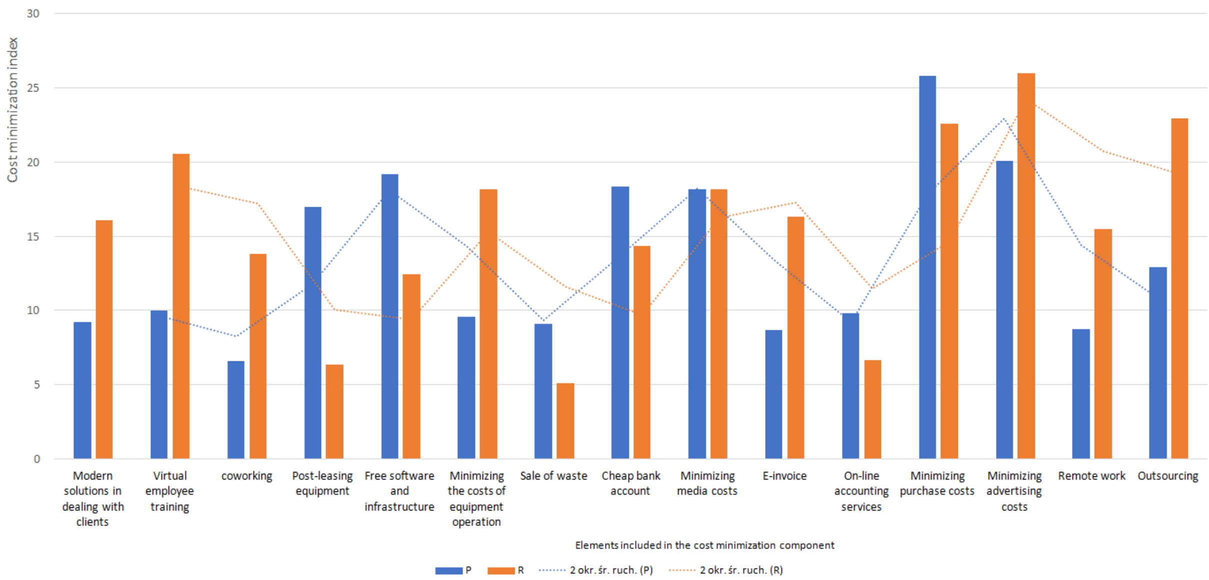
Source: own study

Fig. 11. Minimization of cost elements in Polish enterprises



Source: own study

Fig. 12. Minimization of cost elements in Russian enterprises



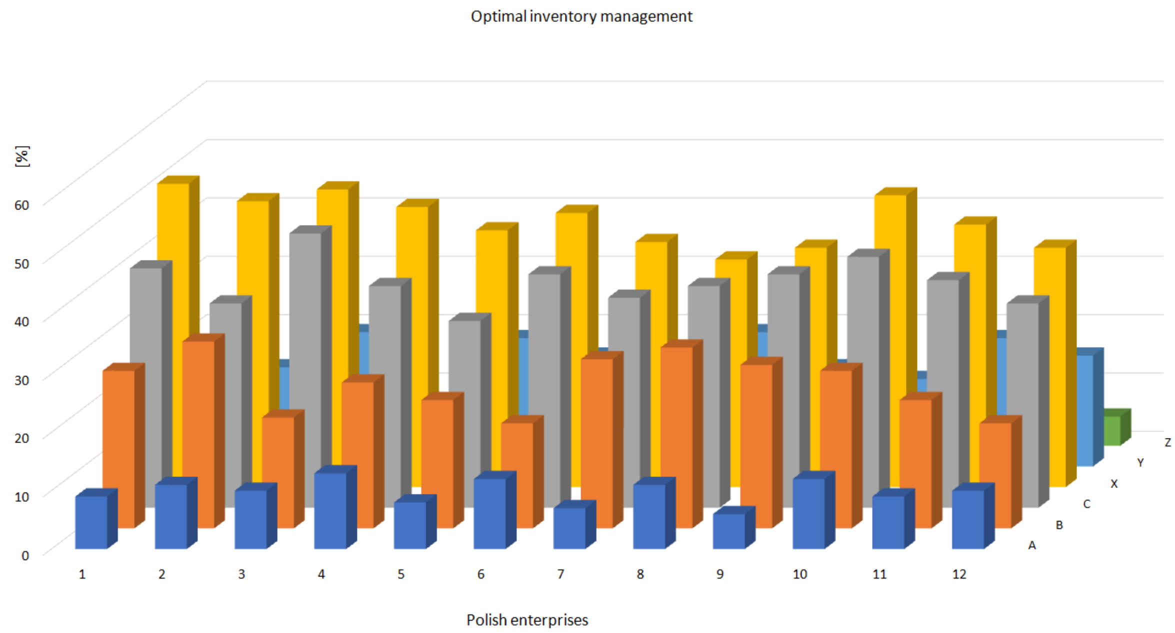
Source: own study

Fig. 13. Elements of cost minimization of Polish (P) and Russian (R) enterprises

In the use of EDI in enterprises, the use of inventory management methods is important. Therefore, in Fig. 14 and 15, the results of research on individual elements of the applied methods for Polish and Russian enterprises are presented. The individual elements of the studied methods are used with varying intensity in the surveyed enterprises. The results of the research presented in Fig. 16 show that the individual elements of both methods are applied to a different degree, with the C method and the X method being the most common method. Of course, other methods are also used, but with different frequency.

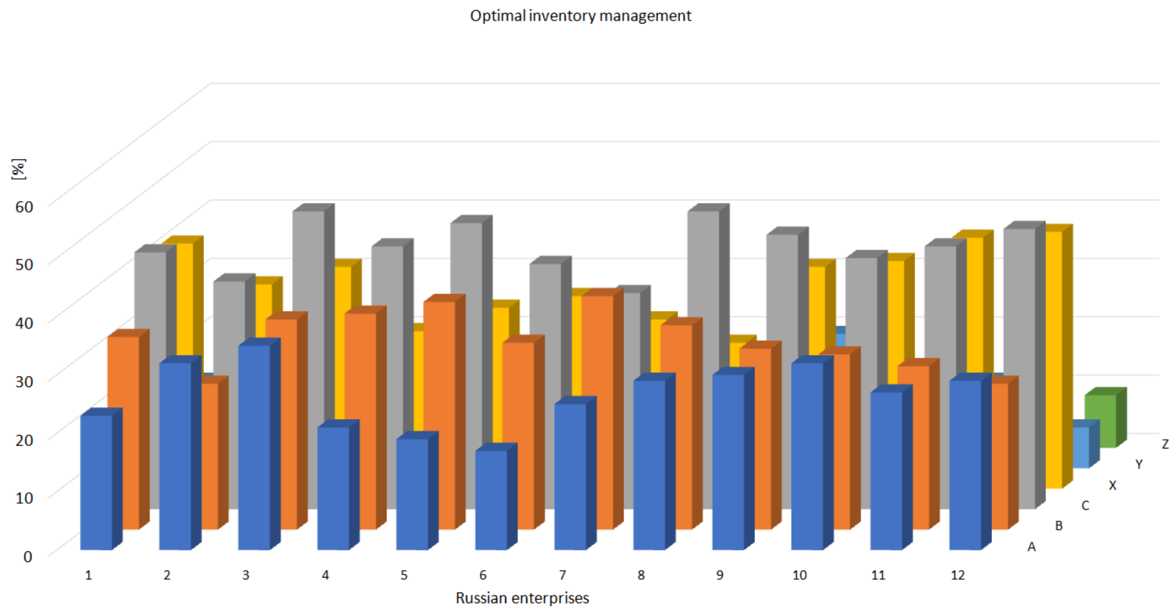
In the EDI system, the quality of the company's operations is of considerable importance. Obtaining the results of tests of elements falling within the scope of the company's operational quality is, therefore, of significant importance (Figure 17, Figure 18).

The analysis of Figs. 17-18 shows that Polish enterprises attach more importance to marketing, and Russian enterprises to the product.



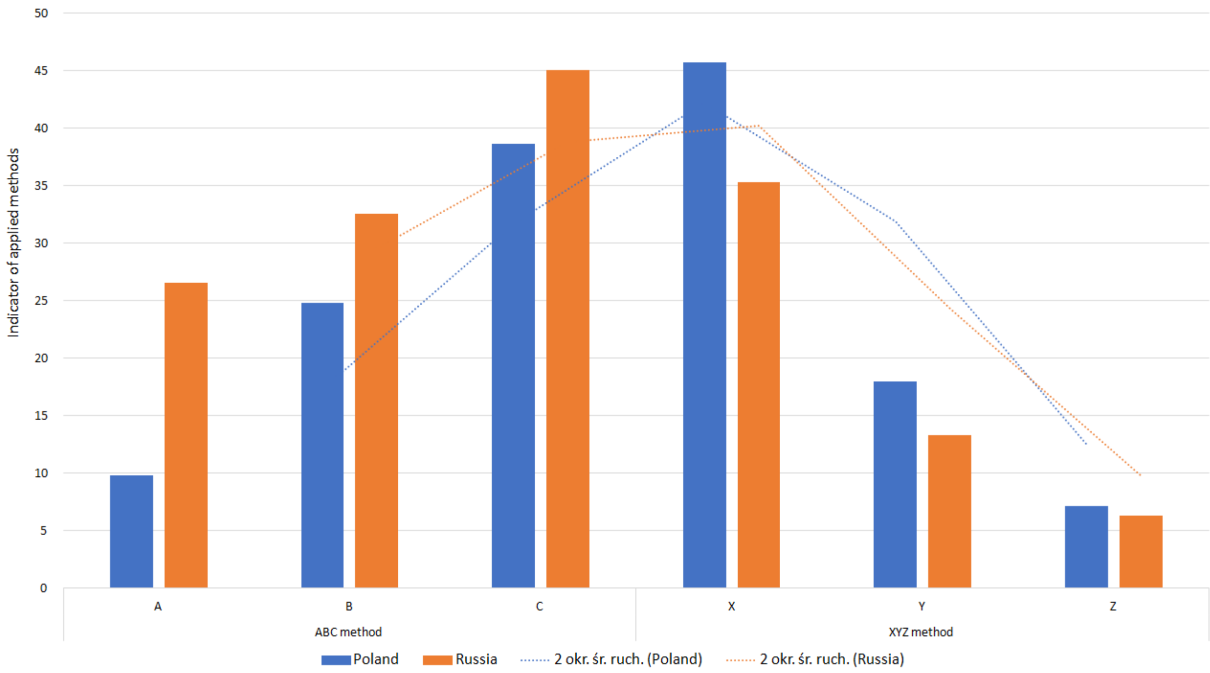
Source: own study

Fig. 14. Elements of optimal methods of inventory management in Polish enterprises



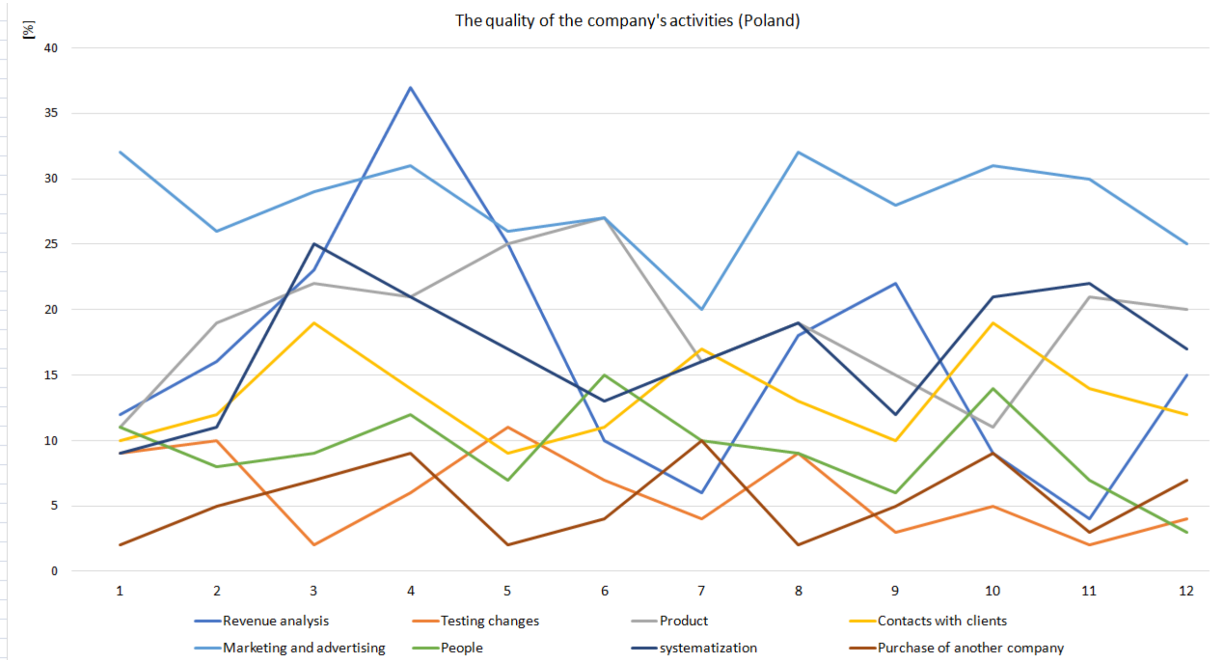
Source: own study

Fig. 15. Elements of optimal methods of inventory management in Russian enterprises



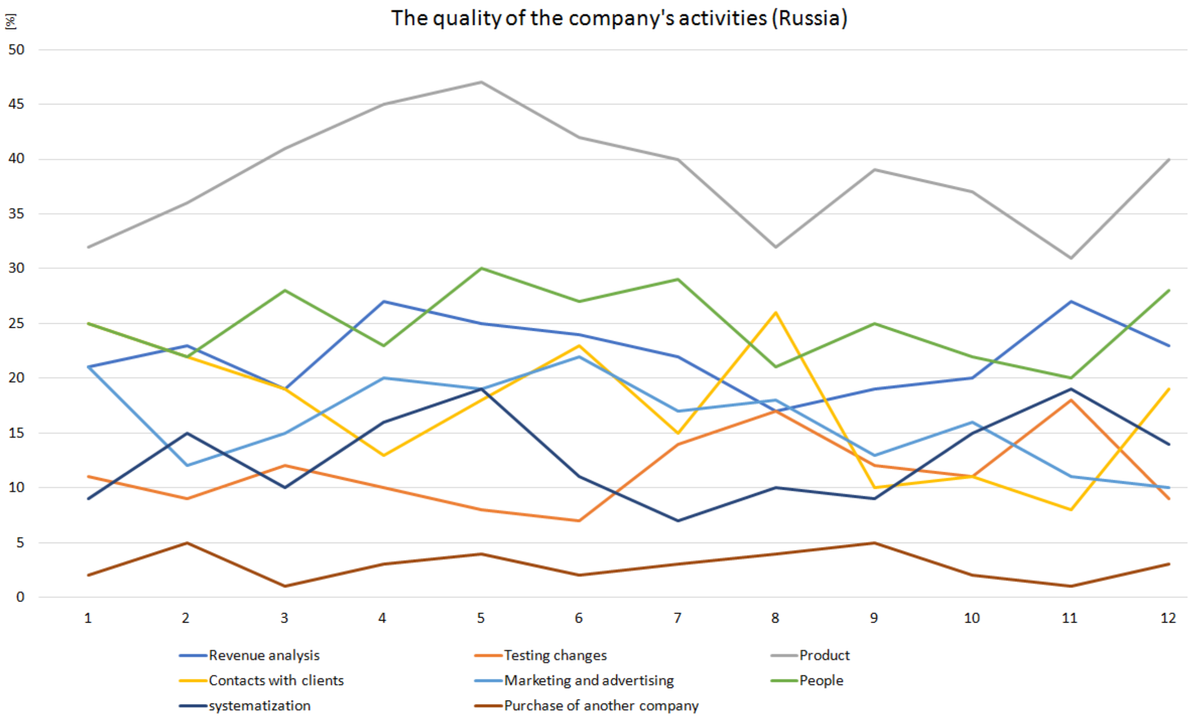
Source: own study

Fig. 16. Comparison of component components used in inventory management in Polish (P) and Russian (R) enterprises



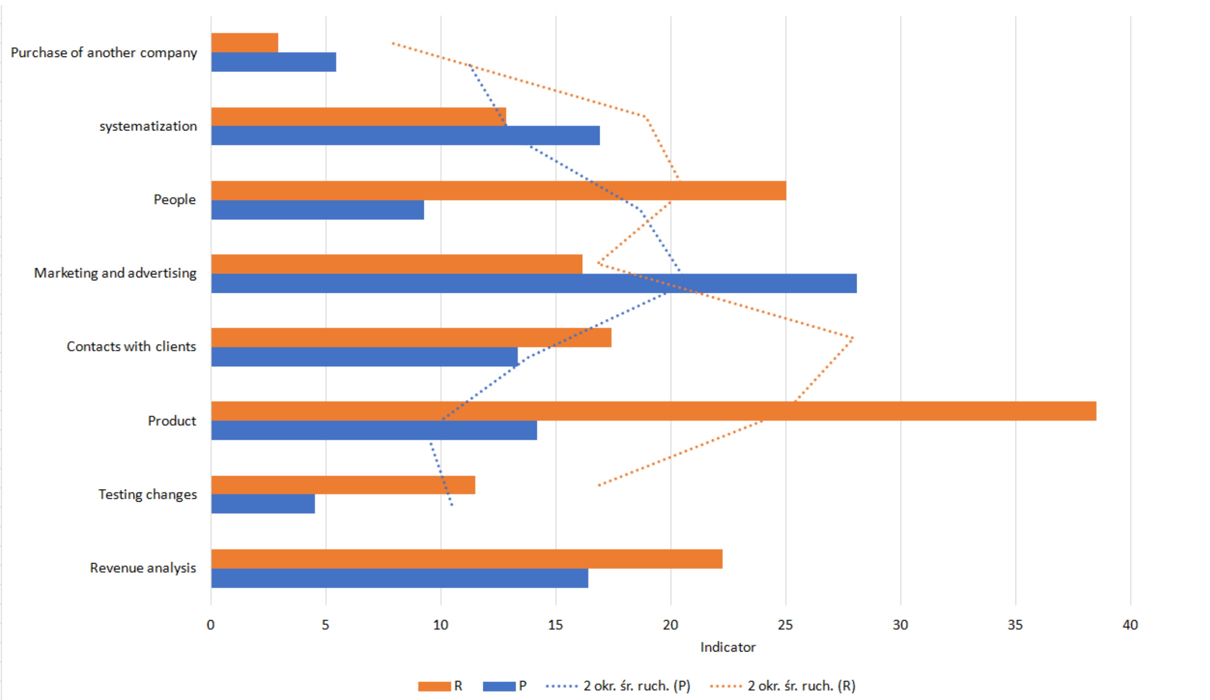
Source: own study

Fig. 17. Elements of the quality of management in Polish enterprises



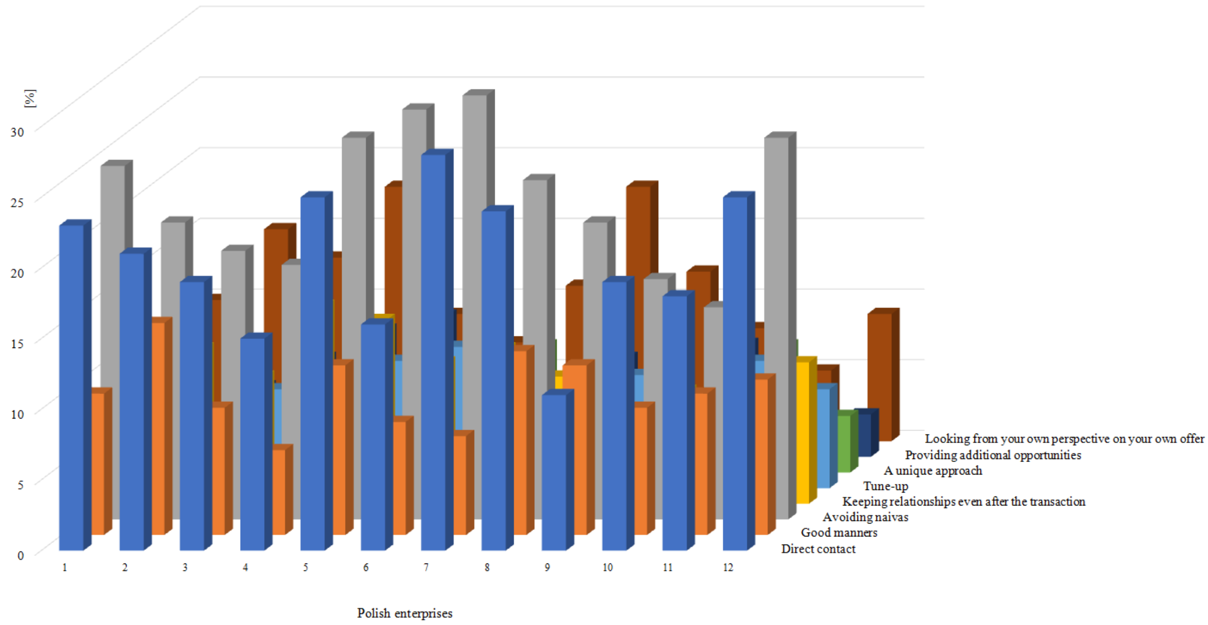
Source: own study

Fig. 18. Components of management quality in Russian enterprises



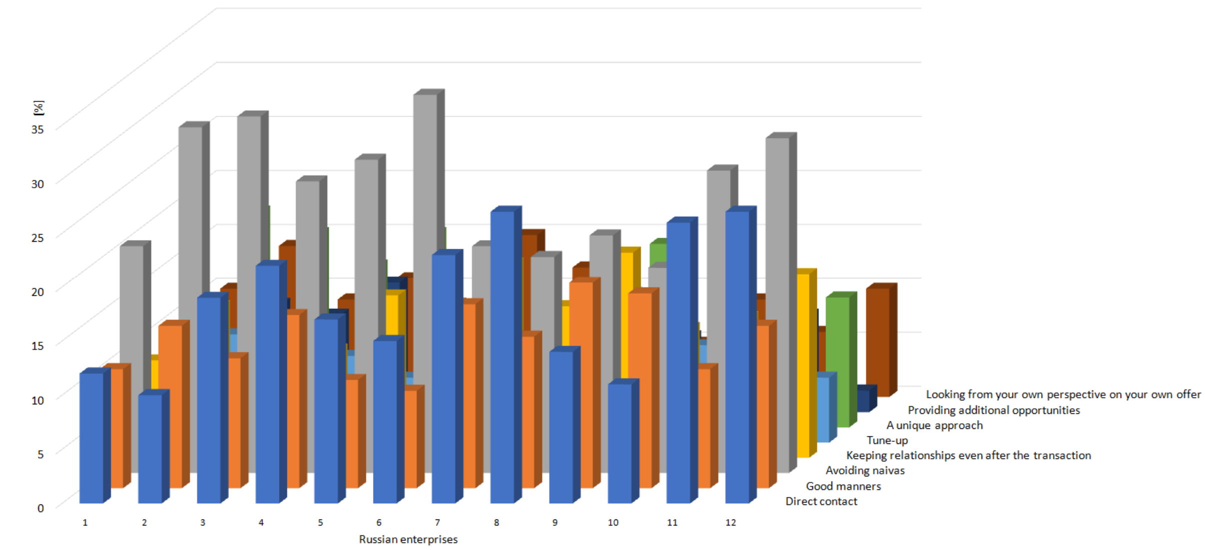
Source: own study

Fig. 19. Comparison of research results in the field of quality of activities for the surveyed enterprises along with trend lines



Source: own study

Fig. 20. Research results of elements occurring as part of improving relations with partners in Polish enterprises



Source: own study

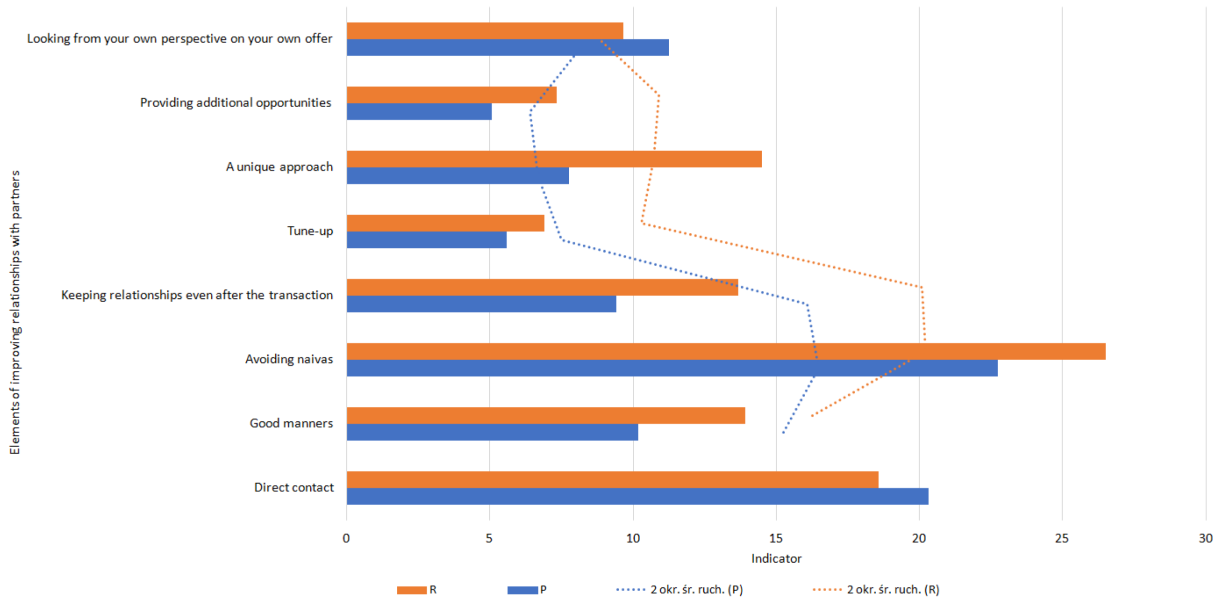
Fig. 21. Research results of elements occurring as part of improving relations with partners in Russian enterprises

The comparison of these research results illustrates different approaches in Polish enterprises and Russian enterprises in terms of quality of activities (Fig. 19).

In Polish enterprises, marketing and advertising, systematization, revenue analysis and product were recognized as the most important elements of the activities (Figure 19), while the Russian companies considered the product, people, revenue analysis and contacts with customers to be the most important elements of the quality of activities (Figure 19). Thus, there are differences in the approach and understanding of the quality of activities.

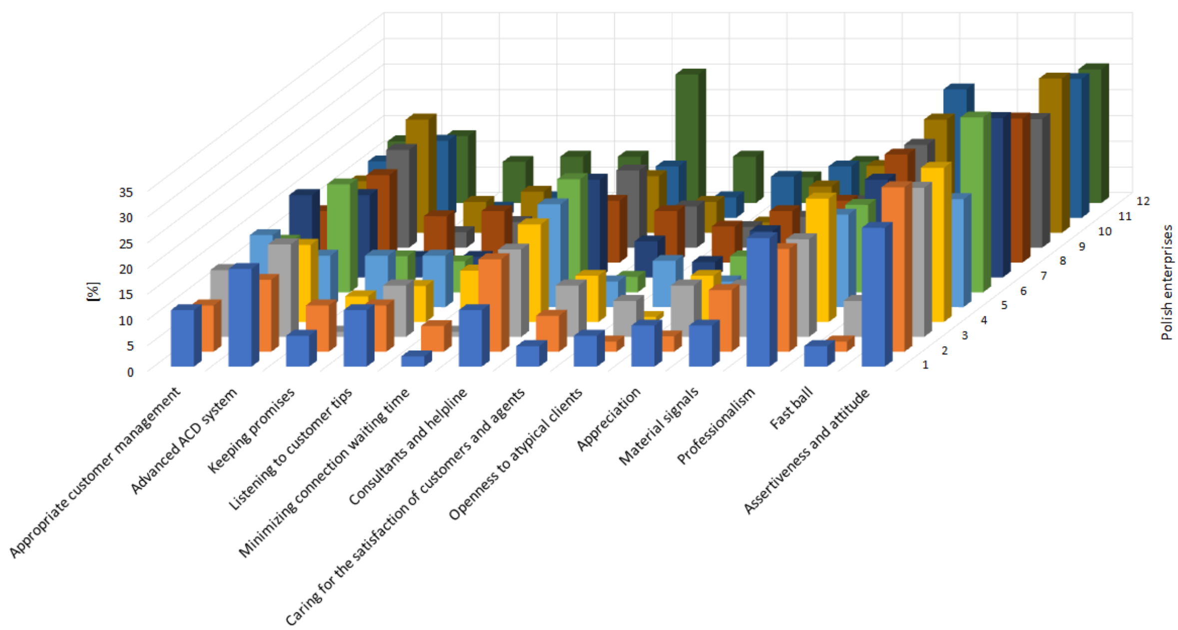
Research in improving relations with partners is presented in Fig. 20 and Fig. 21.

Fig. 22 presents the results of research on elements of improving relations with partners cumulatively for Polish (P) and Russian (R) enterprises. A comparison of the research results showed that Polish and Russian enterprises carry out almost parallel activities in the use of elements of improving relations with partners (Fig. 22).



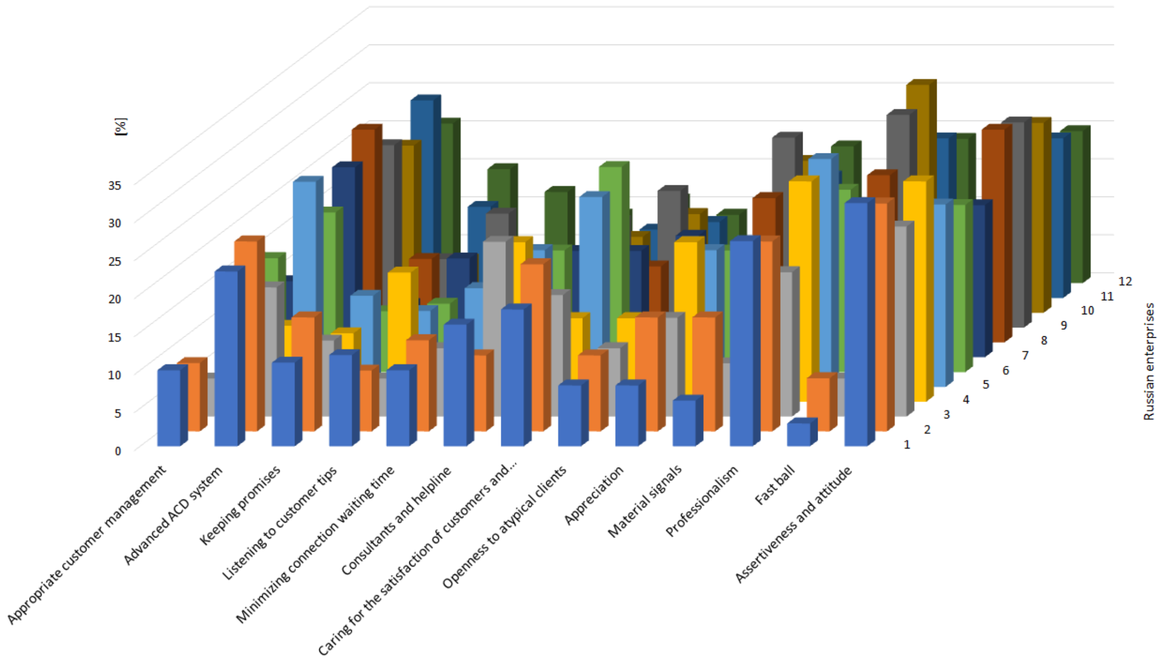
Source: own study

Fig. 22. Elements of improving relations with partners in Polish (P) and Russian (R) enterprises



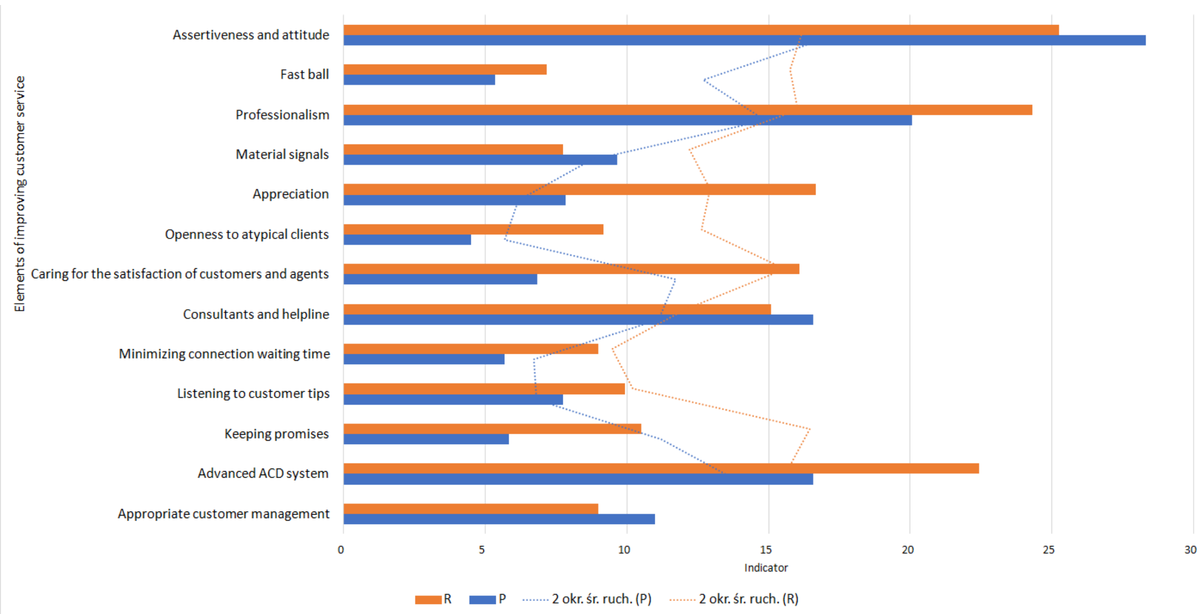
Source: own study

Fig. 23. Research results of elements of improving customer service for Polish enterprises



Source: own study

Fig. 24. Results of research on elements of improving customer service for Russian enterprises

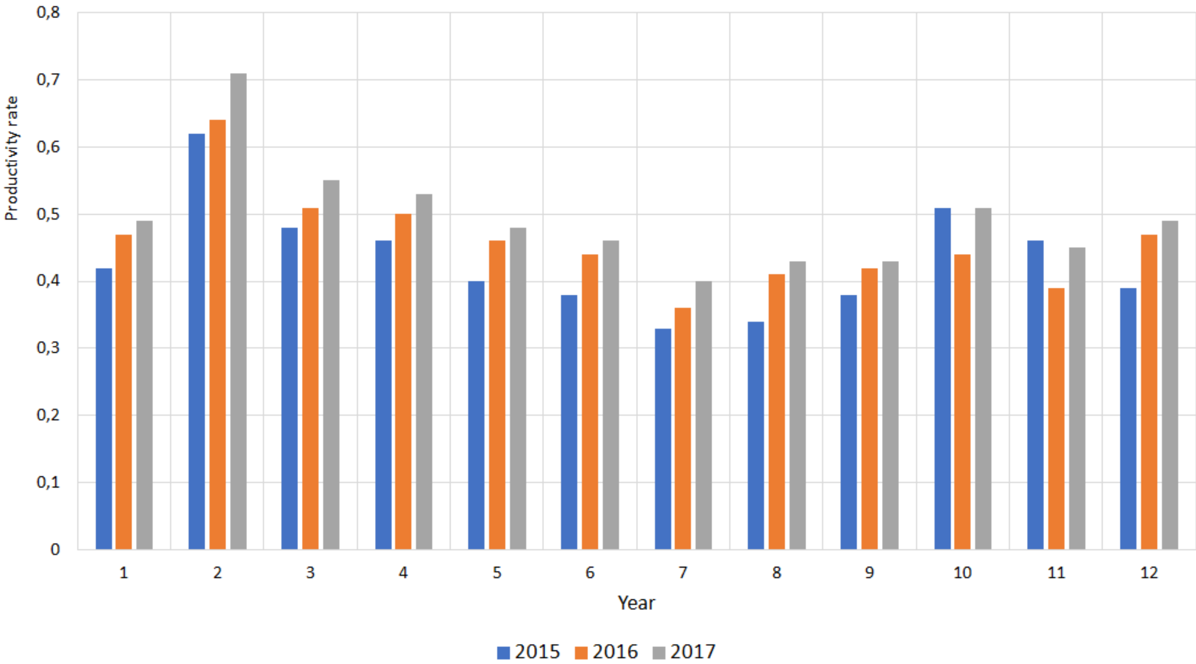


Source: own study

Fig. 25. Comparison of research results of elements of customer service improvement in Polish (P) and Russian (R) enterprises

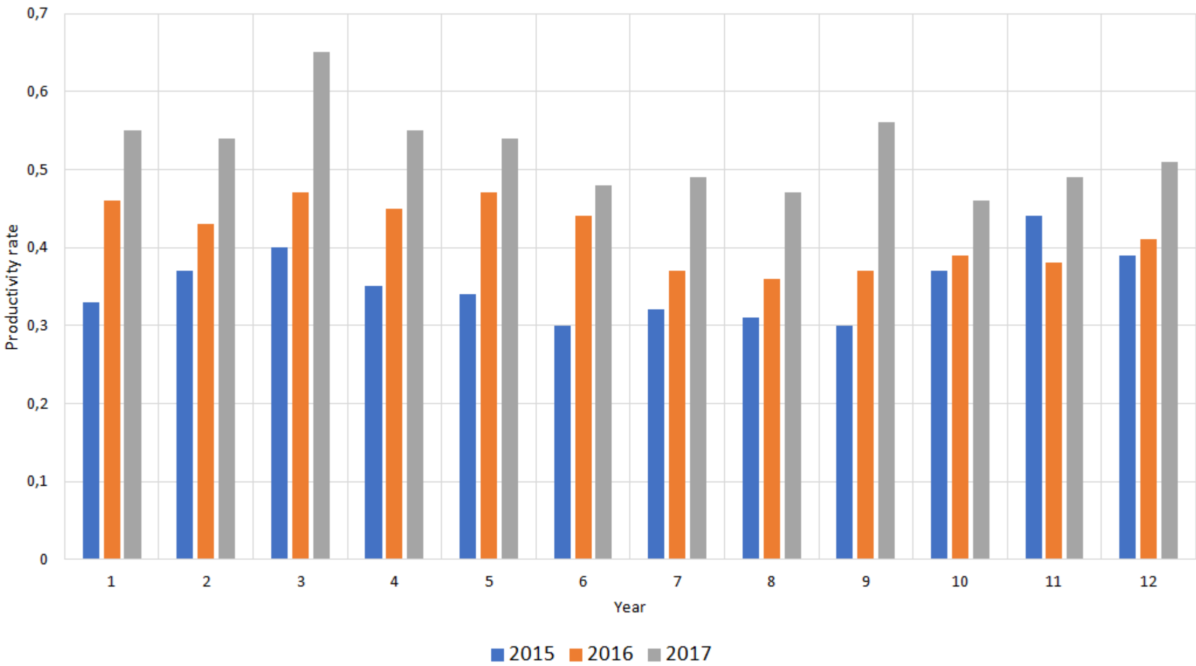
Russian companies use the elements of improving relations more than Polish enterprises to a greater extent. Polish companies dominate mainly avoiding intrusiveness, direct contact, looking from their own perspective on their own offer and good manners, while Russian companies should be distinguished by avoiding intrusiveness, direct contact, unique approach, maintaining relationships even after the transaction.

The results of testing elements in the field of customer service are presented in Fig. 23 for Polish enterprises and Fig. 24 for Russian enterprises.



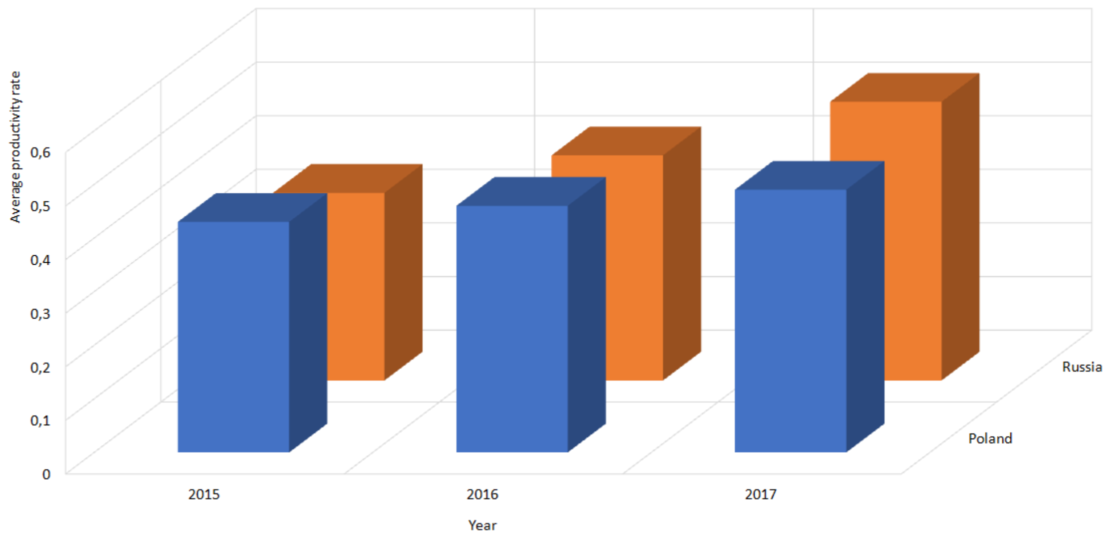
Source: own study

Fig. 26. Productivity index for Polish enterprises



Source: own study

Fig. 27. Productivity rate for Russian enterprises



Source: own study

Fig. 28. Comparison of the average productivity index for the surveyed enterprises

A comparison of research results in terms of elements of customer service improvement (Fig. 25) showed that there are four important activities in both Polish and Russian elements of improving customer service. In the case of Polish enterprises, you can include (appropriate) customer management, professionalism, consultants and helpline as well as an advanced ACD system (innovaphone Automatic Call Distribution), while in the case of Russian companies (Fig. 25) you can distinguish the appropriate customer management and professionalism, advanced ACD system and appreciating.

Regardless of the results of research obtained for individual factors, an important assessment of the efficient operation of the company is the assessment of productivity (Fig. 26- 27). The results of the productivity index survey for Polish enterprises are presented in Fig. 26, while for Russian enterprises Fig. 27.

When comparing Fig. 26 and Fig. 27, it is possible to notice how the productivity rate for the surveyed enterprises has been shaped over the years and which of the analyzed elements are of importance.

A comparison of the obtained research results (Fig. 28) accurately illustrates the average productivity index for the surveyed enterprises. It turns out that the indicator was more favorable for Polish enterprises in 2015 of around 19%, 2016 for around 9%, and for Russian enterprises the index was more favorable by about 6% in 2017.

CONCLUSIONS

The conducted research has shown that the EDI system is used in both Polish and Russian enterprises. The scope of application of this system varies and depends on the concept of its use by the management of enterprises.

Using the advantages of the EDI system by Polish enterprises is mainly focused on the optimization of inventory management, minimization of costs and productivity of the enterprise (Figure 8), while in the case of Russian enterprises, activities are aimed at improving relationships with partners, the quality of the company's operations and productivity (Fig. 8).

A comprehensive assessment of Polish and Russian enterprises requires further research including assessment of business management through integrated logistics systems.

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SYSTEM EDI W LOGISTYCZNYM ZARZĄDZANIU PRZEDSIĘBIORSTWEM

STRESZCZENIE. **Wstęp:** Obecnie wykorzystywanych jest wiele narzędzi informatycznych w każdej dziedzinie. Dlatego kierownictwa przedsiębiorstw chcą, aby nowoczesne rozwiązania informatyczne obejmowały także zastosowania logistyczne w różnych i zróżnicowanych profilach działalności. Związane jest to także z minimalizacją kosztów działalności. System EDI umożliwia realizację takich celów. Z tego względu przeprowadzono badania w wybranych przedsiębiorstwach polskich i rosyjskich oraz przedstawiono wyniki wraz z wnioskami w zakresie stosowania systemu EDI.
Metody: Przeprowadzono analizę porównawczą pomiędzy polskimi i rosyjskimi małymi przedsiębiorstwami. W celu wyselekcjonowano losowa próbę 100 przedsiębiorstw tj. 50 przedsiębiorstw polskich i 50 przedsiębiorstw rosyjskich. Dane do analizy zostały zebrane przy pomocy specjalnie przygotowanej ankiety.

Wyniki i wnioski: System EDI jest używany zarówno w polskich jak i rosyjskich przedsiębiorstwach aczkolwiek zakres i cel używania jest różny i zależy od koncepcji zarządzania w firmie. Polskie przedsiębiorstwa skupiają się głównie na optymalizacji zarządzania zapasem, minimalizacją kosztów oraz produktywnością natomiast rosyjskie przedsiębiorstwa skupiają się głównie na poprawie relacji z partnerami oraz jakością operacji biznesowych i produktywnością.

Słowa kluczowe: EDI, IT, narzędzia IT, rozwiązania IT, aplikacje logistyczne

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ORIGINAL PAPER

PROJECT MANAGEMENT MATURITY IN COMPANIES OPERATING ON POLISH LOGISTICS MARKET

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ABSTRACT. **Background:** The complexity and uncertainty of the modern world encourage companies to use nowadays project management practices. Research of project management maturity allows assessing how well companies are prepared to run projects. The main motivation behind the article was lack of project management maturity assessment on the Polish logistic market. In the article, the authors describe research that gives an overview of the subject which was conducted in logistics companies operating on the Polish market.

Methods: Quantitative approach delivered by an online survey was chosen as a method of research. Purposive sampling research strategy was used. Researchers surveyed 60 biggest logistics companies operating on the Polish market (according to revenue) receiving 13 responses from which 12 were used.

Results and Conclusion: In the perception of responding managers from the biggest logistics companies operating on the Polish market, they are functioning in a volatile and uncertain environment with a strong need for successful changes and project implementation.

Even though one could think that therefore researched companies are mature in the project management or the innovation management area, our research showed otherwise. Project management maturity is still in development phase and innovation management is nearly non-existing, which shows that logistic companies operating on the Polish market are in painful process "learning of project management by experience".

Key words: project management, project management maturity, dynamics of the industry, management system, project management readiness.

INTRODUCTION

How advanced in project management maturity are logistics companies operating on the Polish market? That was the initial research question. Project management maturity, even though it is not a new concept [Ibbs, Kwak 2000; Cooke-Davies, Arzymanow 2003], seems to be an important area for researchers and practitioners – both on general level [Görög, 2016, Brookes, et al. 2014] as on specific industry one [Backlund, Chronéer, Sundqvist, 2014, Spałek, 2015]. In the Polish market, this topic was also researched [Górecki, 2015, Jelonek, Nowakowska-Grunt, Ziora, 2014]. However, in the logistics industry except for some general conclusions in [Witkowski, Rodawski, 2007; Kisperska-Moroń, 2008] authors were not able to find empirical studies trying to measure the level of project management maturity in logistics companies.

A detailed search of most popular databases using EBSCO multiple database search and Google Scholar tool showed that on the one hand, there is much research around project management in logistics (also around Polish market) [Biernat-Jarka, 2014; Goździewska-Nowicka, Antoszak, 2017, Hadas, Stachowiak, Cyplik, 2011] but on the other there is a lack of knowledge about how mature in project management logistics companies operating on the Polish market are now. That is the knowledge niche that authors decided to

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analyse concentrating on the biggest logistics companies operating in the Polish market. The main purpose of this article is to answer the question: "Whether the biggest logistics companies operating on Polish market see the need for project management, how mature are they in this area, and finally are they organizationally ready to run them?"

THEORETICAL BACKGROUND

Logistic companies are perceived as process-oriented, and their maturity is mainly perceived by supply chain process maturity [Oliveira et al. 2012; Lahti, Shamsuzzoha, Helo, 2009]. However, in the turbulent environment "ability to change" or "ability to adapt to changes" also becomes an important factor [Cyfert, Bełz, Wawrzynek, 2014] that should be taken into account when assessing the company's maturity. It is also known that there are many challenges ahead of the logistics industry [Abdullah, et al. 2018; Lineth, Da Cunha, 2018] that will require implementation through projects.

There are many maturity models to assess maturity in change management or project management [Cooke Davies, 2004; Lam, 2011]. All of them propose long lists of factors that are needed to obtain a detailed picture of project/change management maturity measure. Since detailed maturity measure is not the purpose of this study, authors decided to simplify these models to some crucial factors that would give overview of the maturity level of logistic companies, opening a way for further, more detailed researches.

Project management maturity importance for supply chain integration

According to [Fawcett, et al., 2006] "Supply chain management is defined as involving process management and project management to meet customers' needs collaboratively" – this shows, that project management plays an important role for a supply chain.

To understand project management maturity influence on supply chain integration consequences of following definition: "supply chain integration (…) is the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organizational processes, in order to achieve effective and efficient flows of products and services, information, money and decisions, to provide maximum value to the customer" [Foster, Wallin, Ogden, 2011] will be discussed by authors in this article. If one considers a market without integrated supply chain, then, to increase integration, logistic companies have to implement changes to its internal logistic processes to align their processes with their business partners. It is known that it is happening on the level of material and information flow [Prajogo, Olhager, 2012]. This drives to two conclusions:

- Logistic companies increase supply chain integration by the implementation of changes according to its business surrounding expectations;
- Changes on the market (changes in processes of some supply chain participants) within the integrated supply chain will require changes from the rest of supply chain participants to keep supply chain integrated.

Project management is the method to implement big, time-consuming changes [Hornstein, 2015] therefore project management maturity plays an important role in the supply chain integration process.

The second factor that will also be discussed further is the perception of market changes. If the company can recognise market changes and its influence on its logistic processes, then from companies operating on fast-changing market one probably could expect higher project management maturity.

Project management maturity description

Trying to answer the question "Whether the biggest logistics companies operating on Polish market are organizationally ready to run projects?" authors will focus on the world "organizationally" since it shows whether the organisation is prepared to run projects. To be able to verify that statement one of the most popular definitions of the organisation by H. J. Leavitt [Firlej, 2007] will be used.

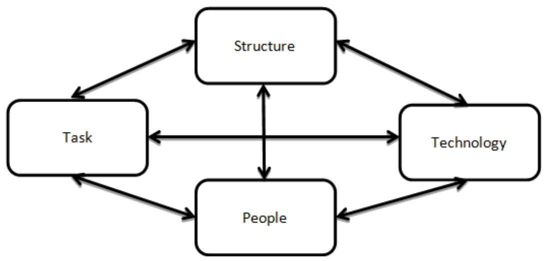

Fig. 1. Leavitt's Diamond organisational model

Above Leavitt's Diamond is not only used to define phenomena of the organisation but also – as originally mentioned by Leavitt – it defines critical success factors in change management.

Taking Leavitt's perspective, authors propose at least four elements that existence needs to be checked, to ensure there is an organisational readiness to implement projects:
- procedures or other work rules source that define requested tasks in project management;
- people dedicated to project management;
- some organisational structure element dedicated to project management;
- technology that supports project management.

Authors decided to refine above statements as follows:
- According to [Parker, et al., 2013] in the first statement, one may ask about procedures or project methodologies;
- According to [Larson, Gray, 2015] people dedicated to project management are Project Managers;
- According to mentioned maturity models [Cooke Davies, 2004] and [Dai, Wells, 2004], conclusion can be drawn, that in the literature of the subject, the organisational structure element dedicated to project management is called Project Management Office (PMO);
- According to [Anbari, Money, 2008] authors propose to reduce "technology that supports project management" to check if there is project management software.

Authors would also like to extend above list with one more, cultural factor and check if:
- there is a common awareness of what a project is.

Since if there is no such awareness, then the organisation is not able to recognise if there is a project that should be managed.

Need for project management

According to [Mavondo, Chimhanzi, Stewart, 2005; Augier, Teece, 2009; Kontoghiorghes, Awbre, Feurig, 2005] authors drawn the conclusion that the need for project or change may come from three different approaches:
- active - as the effect of the internal innovation process that has no source on the market event;
- adaptive - as the effect of adaptation to market events;
- predictive - as the effect of prediction of market events.

This will be used in research to answer the question: "Whether the biggest logistics companies operating on the Polish market see the need for project management?"

Innovation process

To consider if the organisation can "hear the need" for project management (or change management), Leavitt's diamond model will be used again. However, this time authors will consider it for innovations or change requests to check, if the company organizationally is able to produce, catch and evaluate ideas/proposals for changes what, after [Galanakis, 2006] will be called "innovation process".

According to the previous section, elements that are needed to be checked seem to be as follows:
- procedures that define requested tasks in the innovation process;
- some organisational structure element dedicated to the innovation process;

- technology that supports the innovation process;
- people dedicated to the innovation process.

Authors propose the following interpretation:

- According to [Prajogo, Pervaiz, 2006] organisational structure element dedicated to the innovation process is just Research and Development Department.
- Since the innovation process may request many different technologies, otherwise than in the previous section, authors decided not to narrow technology to information technologies this time.

Proposing operationalisation of the element "people dedicated to innovation process" it has to be considered that according to [Kontoghiorghes, Awbre, Feurig, 2005; Prajogo, Pervaiz, 2006] (and many other sources), all employees should be engaged in the innovation process. Therefore, to check if employees are able to participate in this process, authors propose a commonly known and simple approach "skill-will matrix" [Obolensky, 2017] checking ability and motivation for expected behaviour.

Therefore, instead of asking about dedicated people authors will check if:

- there is a common awareness of how to propose innovation or change;
- innovation and ingenuity of employees is appreciated

as the main success factors for engaging employees in the innovation process.

Market changes perception

To check an organisation's perception of market dynamics and need for adaptation authors will refer to commonly known [Dobbs, 2014] Porter's five forces framework. According to this framework, it will be checked how the organisation perceives changes in its industry:

- level of competitiveness (level of competitors' actions that request adaptation);
- the frequency of changes in customer expectations;
- the frequency of changes in offers of suppliers.

According to findings from the previous section, authors will also treat the market in the industry as some system without stable structures and check perception of:

- the frequency of regulatory and legal changes (as the source of task rules for organisation acting on the market);
- the frequency of technological changes (changes coming from element "technology");
- employee turnover in the industry (changes coming from element "people").

Authors will also ask if in management perception:

- market changes will be more frequent;
- there will be a need to implement organisational changes faster and more effectively than nowadays

what corresponds to the situation in which the organisation wants to increase its project management maturity not as a result of market changes but predicatively, in advance of market changes.

SURVEY METHODOLOGY

Quantitative approach delivered by an online survey was chosen as a method of research.

Purposive sampling was used. Researchers planned to conduct the survey in 65 biggest logistics companies operating on polish market (or subsidiaries of international companies operating on the Polish market) ordered by revenue according to polish journal Dziennik Gazeta Prawna [Brdulak, 2018]. Authors were driven by the approach that in general, the companies in the ranking represent the vast majority of logistics companies operating on polish market regarding overall revenue [Brdulak, 2018].

The mentioned ranking was the 23rd edition and it is being yearly delivered by prof Halina Brdulak from Warsaw School of Economics in cooperation with Dziennik Gazeta Prawna newspaper. The main ranking criterion is the revenue of the company. Companies that are invited into the ranking have to have revenue of more than two million Polish Zloty from logistics and it has to be no less than 51% of their overall revenues [Brdulak, 2018]. The companies in the 2018 edition have the revenue from 4 million up to over two billion of Polish Zloty, however, the vast majority of them (over 70%) exceeded 100 million of Polish Zloty [Brdulak, 2018].

Google Forms on-line survey was used as a tool to conduct this research. The survey was conducted in Polish. All questions were then translated to English for the purpose of this paper. The survey was sent directly to a targeted company representative on so-called "c-level" or managerial level, having in mind that for managers it is easier to have comprehensive overall knowledge about the company and company's market perception. Surveys were sent to only one representative from each company, who were carefully selected firstly through LinkedIn.com portal (name of the company and position) and then sent by either LinkedIn integrated messenger or through company e-mail. In the survey there was an explicit request not to resend the survey and to fill it only by one employee of the company – researchers wanted to have one answer from each company. The survey was anonymous.

Finally, due to problems with finding appropriate representatives contact data in a very small number of companies (3) and technical problems (like not-working e-mails - 2) survey was finally sent to 60 companies' representatives in Poland – more or less half by LinkedIn messenger and e-mail. The survey response rate was around 22% - 13 from 60 surveys were correctly filled in. The survey was conducted in November 2018 over a week. One entry was rejected in the final analysis, because, according to the metrics, one person who sent it was not on the managerial or c-level position.

The survey contained 25 questions divided into three sections. First one was linked to the surveyed organisation, the second one to market dynamics perception of the person who filled the survey and the third section was metrics. Apart from metrics, all questions were using a Likert-type scale from one to five, where one was: "strongly disagree", and five was: "strongly agree".

Final survey questions were as follows:

Section I: In my company…

1. …there is a project management procedure specifying project management rules;
2. …there is a project management office or other office that is performing the same function as PMO;
3. …there is common knowledge about what project is;
4. …projects are led by certified project managers;
5. …IT tools supporting project management are used;
6. …there is a procedure specifying innovation management or ideas management;
7. …there is a unit responsible for R&D in the company;
8. …there is common knowledge about how one may report a new innovation or a new idea;
9. …employees' innovations and ideas generation are appreciated;
10. …there are necessary technologies and tools needed to generate and assess new ideas for innovations or changes.

Section II: I believe that in my industry…

11. …there is strong, intensive competition;
12. …law regulations linked to our business are stable;
13. …as a company we must constantly invest in new technology to be competitive in the market;
14. …customer expectations are changing fast;
15. …suppliers and subcontractors dynamically change their product offer;
16. …the bargaining power of subcontractors and suppliers is growing;
17. …there is a high staff rotation;
18. …the dynamics of changes in company environment will increase;

19. …to achieve company goals there will be a need to implement organisational changes faster than nowadays;
20. …to achieve company goals there will be a need to implement organisational changes more effectively than nowadays;

Section III: Metrics:

21. I work in a logistics company (yes/no);
22. Number of company employees (below 10, from 10 to 49, from 50 to 249, from 250 to 2000, above 2000);
23. Position (c-level – board member, managerial position, without a managerial position);
24. Age (in years);
25. Gender (female / male);
26. If you want to receive a link to the article, that will be prepared based on this research, please leave here your e-mail address.

EMPIRICAL DATA

First five questions in the Section I were directly linked to the topic of project management maturity within the researched organisation. On the Figure 1, there is a summary of answers. The number above the bar shows the number of answers, and the colour of the bar corresponds to the Likert scale.

In general, over 67% of respondents agreed (strongly agree + agree) that there is a project management procedure specifying project management rules in their companies. The mean answer was 3,75 with median and mode 4. Project Management Office is working exactly in half of the researched companies. One respondent was not sure, and 42% of them disagreed (strongly disagree + disagree). Respondents were not sure about the fact whether there is common knowledge about what project is – answers were distributed nearly evenly with average 2,5 and two as a median. What is interesting here is that the correlation coefficient between those two last data sets (question 2 & 3) is only 0,24 (with p-value 0,448), which means that there is no correlation between having a Project Management Office and having a common knowledge about projects within the researched logistics companies.

In most of the researched companies project were either not led by certified project managers (58% - strongly disagree + disagree) or respondents were not sure about this. Only 25% of respondents agreed or strongly agreed with this statement.

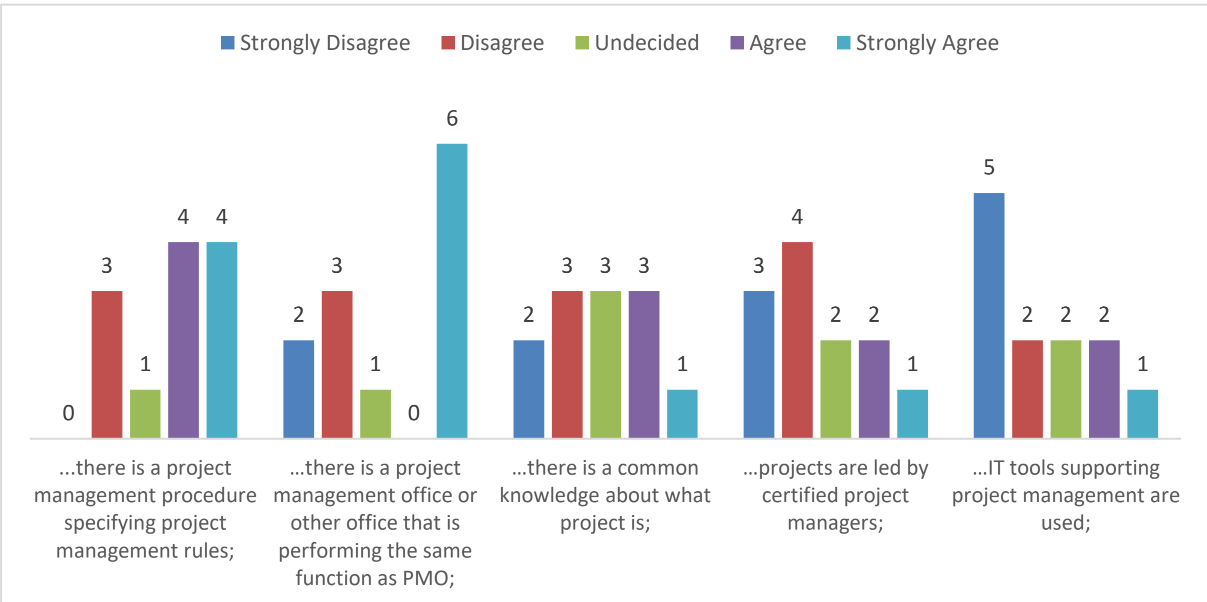

Fig. 2. Project management maturity in researched organisations

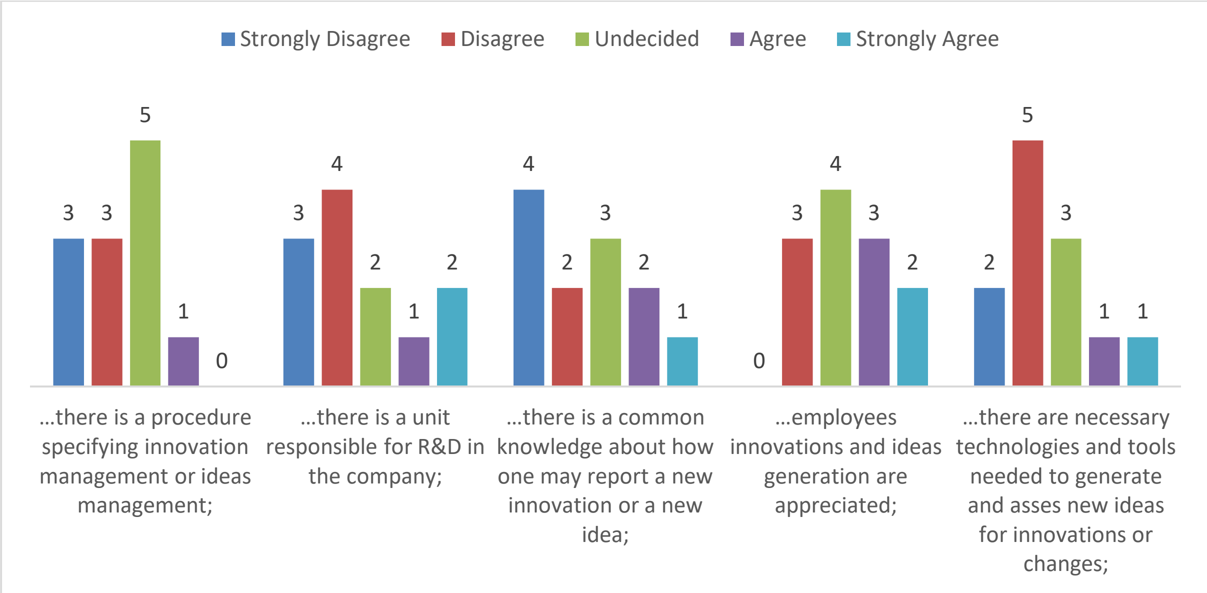

Fig. 3. Innovation management in researched companies

What was interesting for researchers is that less than a quarter of our respondents agreed that IT tools supporting project management are used within companies with nearly 42% strongly disagreeing with this statement – that was the strongest disagreement in the whole survey.

The next five questions in the conducted research were about innovation management and new ideas generation in logistics companies (Fig 3). Innovation management was much harder to asses from the point of view of respondents.

In general, in the question related to innovation and ideas management procedure people were less sure with answers (42% undecided) than in this related directly to project management procedure (8% undecided). There was only one respondent agreeing that there is a formal procedure in the researched area, and 50% disagreed or strongly disagreed.

Most of the respondents stated there are no units responsible for R&D in their organisations (58% disagreed or strongly disagreed), and only in the quarter of them, there is a unit like that. The knowledge about how to report innovation or new idea is not common within researched companies with the mode being 1, 50% respondents disagreeing or strongly disagreeing with this statement and only around a quarter agreeing or strongly agreeing.

Respondents were divided about whether innovations and ideas generation by employees is appreciated – even though there wasn't any strongly disagree answer the average was around 3,3 with median and mode being 3. Finally, technology again looks like Achilles' heel of logistics companies with only 17% of respondents agreeing or strongly agreeing that there "are necessary technologies and tools […]".

In the second section of our survey, authors researched the logistics companies' managers' perception of market dynamics (graph – next page). All our respondents agree or strongly agree that from their perspective ("I believe that in my industry…") there is strong, intensive competition in the industry of logistics companies operating on the Polish market. Most of the respondents also disagree that the law regulations are stable (58%, average 2,58, mean and mode – 2). Nearly 70% of our respondents believe (agree or strongly agree) that that as a company they should invest in new technologies to be competitive in the market.

Respondents were not clear about the fact that customer expectations are changing fast. Even though 50% agreed with this statement, still the average was only 3,58 with median 3,5 and mode 3 suggesting that is not a common belief in the industry. In general, the same uncertainty was expressed in case of suppliers and subcontractors dynamically changing their product offer with average 3,41 and median and mode being 3.

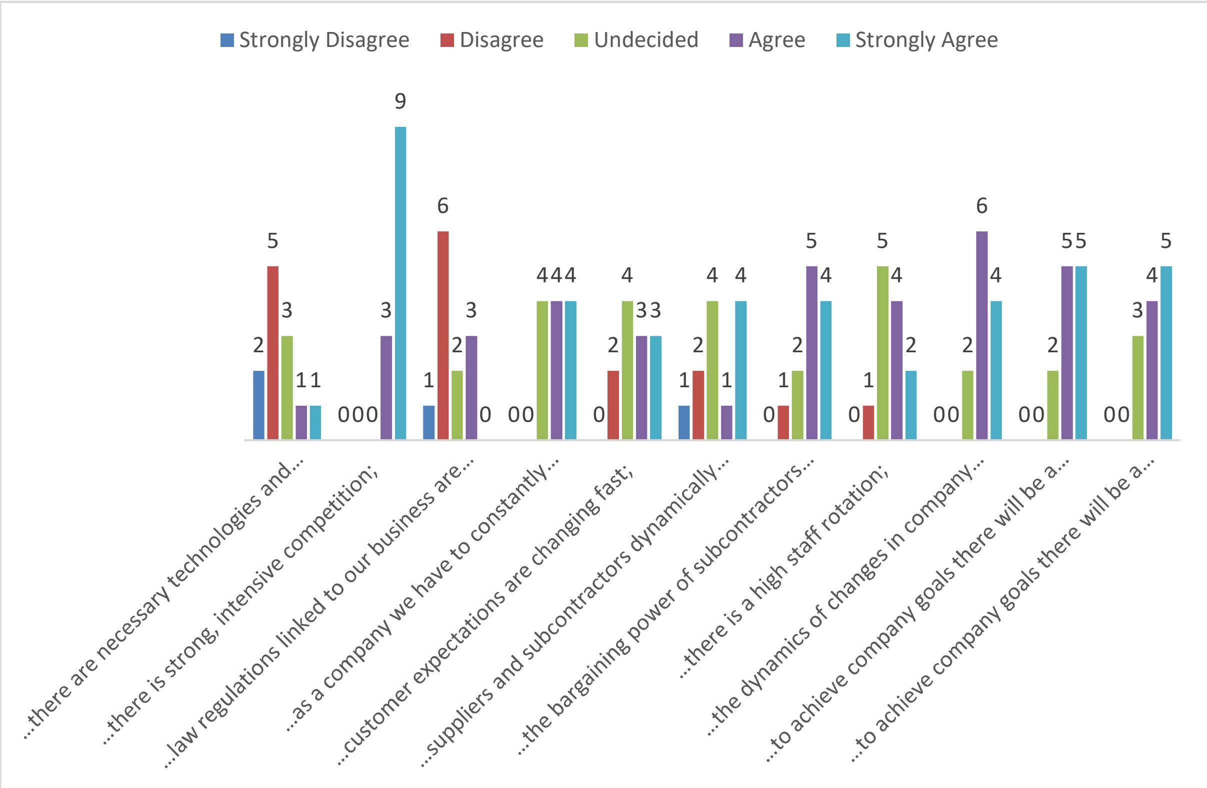

Fig. 4. Perception of market dynamics by managers of logistics companies

However, in case of the growing power of subcontractors and suppliers – respondents were very clear – 75% agrees or strongly agrees that this is happening with only 8% disagreeing.

It shows that in logistics industry right now the power of partners is growing. Also, it looks like that the employees' rotation might be a problem with 50% of respondents agreeing and only 8% disagreeing with the statement. However, it is important to note the high level of undecided answers (42%).

Last three questions strongly support authors' hypothesis about increasing dynamics and uncertainty in the logistics industry in Poland. Over 83% of respondents agreed or strongly agreed that the dynamics of changes in company environment will increase. Also, 83% agrees that to achieve company goals companies will have to implement organisational changes faster than nowadays. Finally, 75% of respondents agreed that there also will be a need to implement changes more effectively than nowadays. No respondents disagreed or strongly disagreed with any of last three questions.

The last section of the research was metrics. All answers were delivered by people from logistics companies. As it was stated before one of them was removed from further analysis due to the fact that the respondent was not on a managerial position (therefore all data are presented without this record). The most of respondents were from big companies with 250 employees+. The age of respondents was between 32 and 60 years with the majority of men (only three female respondents). Two respondents did not want to provide, age or gender. Seven people left an e-mail address to receive the results of research.

Before the final interpretation of presented data, the research team decided to build one more data analysis model which base on the aggregation of data according to the logic presented at the beginning of this paper. Therefore, authors aggregated the questions into three groups:

- The first one – project management maturity within researched companies that base on questions 1 to 5 from Section 1;
- The second one – innovation management within researched companies that base on questions 6 to 10 from Section 1;
- Perception of market dynamics that base on questions 11 to 20 from Section 2, where responses in Q12 have been reversed, to obtain market dynamics perception on the same scale as for the other questions in the section.

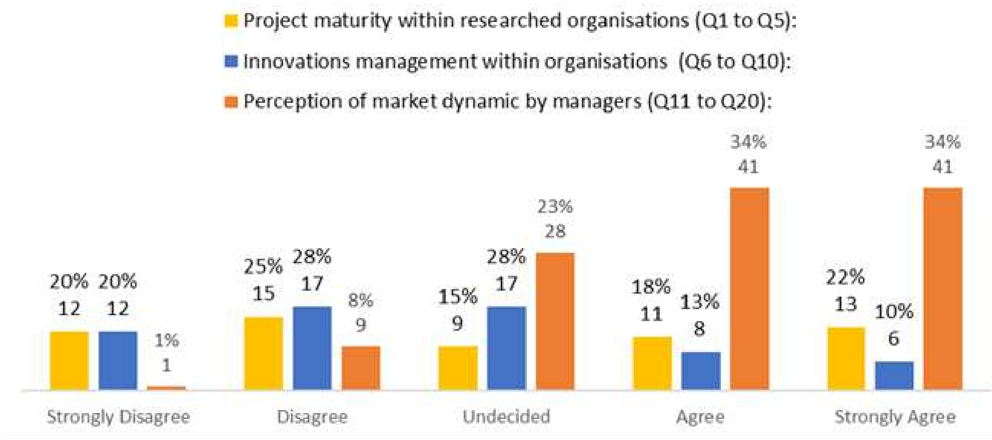

Fig. 5. Aggregated data from our research

Aggregated data confirm the general picture that was emerging from overall analysis. Most of the researched managers (68% strongly agree and agree) perceive market as dynamic in comparison to only 9% disagreeing with it. However, this is not corresponding with project management maturity, and innovation management in aggregated data. Overall only 40% of responses were for "agreed" or "strongly agreed" options linked to project management maturity in comparison to 45% against them (with 15% undecided). With innovation management is even worse – 23% for "agreed" or "strongly agreed" options linked this area of interest in comparison to 48% against them (with 28% undecided which is also an interesting observation).

Table 1. Average response in survey sections and company scale

Respondent	PROJECT MANAGEMENT (A)	INNOVATION MANAGEMENT (B)	MARKET DYNAMICS PERCEPTION (C)	COMPANY SCALE
1	3,6	1,6	3,5	5
2	4,4	2,6	4,3	4
3	3	3	4	4
4	4	2,2	3,3	4
5	1,4	1,4	3,6	2
6	1,6	1,8	3,5	4
7	3	4,6	4,1	4
8	3,8	3	3,8	4
9	3,4	3,8	4	4
10	2,4	2,2	4,6	5
11	2,8	2,6	4	4
12	2,2	3	4,5	4

Table 2. Correlations and p-values for data in Table 1

	correlation:	p-value:
A-B	0,29	0,354
A-C	-0,04	0,891
B-C	0,43	0,163

In the table 1, average response in sections of questions mentioning Project Management, Innovation Management, Market dynamics perception and the scale of a company based on numbers of employees of responding organisation have also been placed:

1. below 10,
2. from 10 to 49,
3. 50 to 249,
4. from 250 to 2000,
5. above 2000.

There are no strong correlations in the above dataset, which shows, there is no correlation between perceiving logistic market as turbulent by managers and preparing the company for changes by increasing project management maturity.

CONCLUSIONS

The data analysis shown that the answer to the question "Whether the biggest logistics companies operating on Polish market companies see the need for project management, how mature they are in this area, and finally are they organizationally ready to run them?" is "They see the need for project management according to perceived market dynamics and need for implementation of changes but are only partially ready to run projects".

Our research has shown that from the perspective of their managers, logistics companies operating on the Polish market are functioning in a volatile and uncertain environment with a strong need for successful changes and project implementation. Even though one could think that therefore researched companies are mature in project management or in innovation management our research showed otherwise.

Project management maturity in researched companies is still in the development phase, and innovation management is nearly non-existing. Authors believe that the biggest problem is lying not in the formal procedures (that many companies have according to research, at least partially for projects) but in their promotion within employees, increased pressure on employee training and project management certification and last but not least usage of supportive technology both for project and innovation management.

This result suggests that one may expect on the market some number of failed logistic projects until companies increase their level of maturity. It is also interesting why - having so many experiences from other industries and worldwide – polish logistic industry seems to be during painful and slow process of "learning of project management by experience". Authors think that above research due to a surprising conclusion and because of the relatively small size of research sample should be subject for some new, more detailed and comprehensive studies in this area.

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DOJRZAŁOŚĆ ZARZĄDZANIA PROJEKTAMI W FIRMACH LOGISTYCZNYCH DZIAŁAJĄCYCH W POLSCE

STRESZCZENIE. **Wstęp:** Złożoność i niepewność współczesnego świata zachęca firmy do używania współczesnych praktyk zarządzania projektami. Analiza dojrzałości zarządzania projektami pozwala ocenić jak dobrze firmy są przygotowane do prowadzenia projektów. Główną motywacją dla niniejszego artykułu była niedostępność badań nt. poziomu dojrzałości zarządzania projektami na polskim rynku logistycznym. W artykule autorzy opisują badanie, które dotyczy tego tematu i które zostało przeprowadzone w firmach logistycznych działających w Polsce.

Metody: Jako metoda badawcza wybrane zostało podejście ilościowe przeprowadzone za pomocą ankiety internetowej. Przeprowadzono badanie w 60 największych firmach logistycznych działających w Polsce (według przychodu), otrzymując 13 odpowiedzi, z których 12 zostało wykorzystanych.

Wyniki i wnioski: W postrzeganiu ankietowanych menedżerów, firmy logistyczne działające na polskim rynku funkcjonują w zmiennym i niepewnym otoczeniu, z wyraźną potrzebą wdrażania zmian i realizacji projektów. Wydawałoby się, że z tego powodu badane firmy będą dojrzałe w zarządzaniu projektami lub zarządzaniu innowacjami, jednak nasze badania wykazały, że jest inaczej. Dojrzałość zarządzania projektami jest nadal w fazie rozwoju, a zarządzanie innowacjami praktycznie nie istnieje, co pokazuje, że polskie firmy logistyczne są obecnie w bolesnym procesie "uczenia się zarządzania projektami przez doświadczenie".

Słowa kluczowe: zarządzanie projektami, dynamika branży, system zarządzania, dojrzałość w zarządzaniu projektami, gotowość do zarządzania projektami

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ORIGINAL PAPER

CONCEPT FOR MEASURING ORGANIZATIONAL MATURITY SUPPORTING SUSTAINABLE DEVELOPMENT GOALS

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ABSTRACT. **Background:** The following paper was developed to assess maturity levels in regards to sustainable development goals. Highly unstable business environment and opportunities occurring on the market require effective and quick decision making process. It is a challenge to follow such dynamic changes within and outside organization while maintaining sustainable goals. However authors state that this is possible thanks to modern concepts and available tools – Industry 4.0 concept or Business Intelligence to name only few. Those concept support making business decisions based on well gathered, analyzed data and setting sufficient strategy which promotes sustainable goals and allows organization to mature.

Methods: Authors based their own maturity model on identified in literature maturity models and international standard: PN-EN ISO 9004:2000.

Results: Authors have defined five maturity levels, each described with several features. On the basis of prepared tables one can define maturity level of organization. Additionally, further steps of development can be indicated and enforced in organizational strategy.

Conclusions: Application of sustainable development within organizational maturity can mitigate reaching sustainable targets. It is important to understand relations between maturity level of organization and sustainable development goals. By improving its maturity, organization should in parallel develop further sustainable measures.

Key words: Sustainable development, Business Intelligence, Industry 4.0., decision making, organizational maturity.

INTRODUCTION

Measuring organizational maturity has to be tailored to current situation observed in supply chains. Developing such system has to take into account current trends in development of technology and organization methods used in business. In the world full of information, highly unstable business environment and agile industry there is an urgent need to manage data correctly. Industry 4.0 seems to be a good solution for these challenges supporting industry and organizations in general. Industry 4.0 as a concept was presented in Germany in 2011 and was foreseen as a part of fourth industrial revolution [Kagermann et al.]. The concept was proposed as part of High-Tech Strategy 2020, Action Plan carried out by the German government. Within this term several models and ideas were developed, in particular Smart Factory, Internet of Things and Services, Cloud Computing or Cyber Physical Systems to name only the most common. Modern technologies, with high integration of supply chains with improved communication and wide customization opportunities are considered as base elements of Industry 4.0 concept which is also common outside Europe and known under different names e.g. Industrial Internet in USA [The Industrial Internet Consortium 2014] or Internet+ in China [Premier of the State Council of China 2015]. The main purpose of fourth industrial revolution is to improve quality of offered products and processes while meeting

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customers' requirements and adjusting to global markets at the same time. This is possible thanks to significant focus on communication and cooperation between people and machines in real time, production of small batches of highly customized products, flexible management of well automated processes and horizontal and vertical integration within company and supply chain [Prause and Weigand 2016]. It is expected that current industry will evolve towards the concept described within Industry 4.0 in following two years [Euromonitor International 2016] but it is also clear that, seeing advantages of implementation, some companies have already started using tools which make this evolution possible. Implementation of the Industry 4.0 concept requires not only usage of high-tech and artificial intelligence but also well designed network infrastructure, sufficient analytics software and smart controllers to use available data properly. Within Industry 4.0 cyber physical systems communicate efficiently not only within enterprise but also outside it integrating companies with customers and other users [Hermann et al. 2015]. The concept makes use of modern IT tools, being based on flexible, decentralized and intelligent structures of production inspection [Lee et al. 2017].

Authors understand sustainable development to be much broader term than Industry 4.0 concept. It is known since 1970s and has been defined differently due to intense development of socio-economic environment. Sustainable development focuses not only on area of industry but covers also construction, architecture, business, transport and consumption. Currently the idea of sustainable development functions as a way of satisfying the growing needs of the population while preserving the environment at the same time [Cash et al. 2003]. Despite relatively long functioning of the term 'sustainable development', the term is much more developed in theory than in practice which looks analogously to the Industry 4.0 term [Skowroński 2006]. Almost for the 20 years, the links between science, technology and sustainable development are noticed. The authors even argue that science and technology should play a central role in the implementation of the sustainable development concept [Cash et al. 2003].

To meet the needs related to the sustainable development concept goals, processes and sets of IT tools within industrial environment comes. These processes can be briefly described as those that transform stacks of raw data into clear information supporting decision making and analyzing activities within the enterprise. These processes are usually defined as the concept of Business Intelligence. Its main goal is a direct support in improving the results and increasing the efficiency of processes which take place in enterprises. Thanks to this it is possible to utilize resources within company more efficiently which directly supports the sustainable development concept for example in area of energy usage effectiveness. The full potential of Business Intelligence solutions requires a well-designed architecture of the entire data acquisition system, which consists of hardware and software. In the case of a production environment, it is a technical infrastructure that acquires data and consists of sensors controllers and computers connected directly to servers and databases. These data usually feed ERP or CRM systems. Thanks to a well-designed data warehouse, it is possible to aggregate and manage collected data in a way that proper analysis supports decision-making processes in business.

Decision making is a cognitive process of analyzing alternative solutions for a problem or particular situation with more than one explanation. Business decisions are being taken on the basis of well-gathered and analyzed data, understanding the whole scope of the problem, needs of organization, clients and also including all resources. Nevertheless it happens that business decision is taken without any research, on the basis of decider's feelings. Several researches have been made to proof that business analytics are supporting and improving decision making, however scientists still argue that business analytics leads to additional value in the process. [Sharma et al. 2014] Lack of available data, unknown relationships in analyzed systems, no clear goals and poorly understood risks lead to decision making based on intuition or experience only. Therefore, despite discussions, authors admit that decision making process currently is a crucial part of business management and still appears to be a challenging task. [Pourshahid 2011] Decision making process within enterprise should support completing targets set within business model. Business model describes what value company is creating, where process is being held, how value is brought to client and captures mechanisms it employs. Business models are defining the way of bringing profit to the enterprise by describing the process from early stage of value creation until the final stage of payment for this creation. Therefore role of business model itself is foreseen as significant and closely connected with business strategy and also tactic and operational management [Teece 2010] and should be supported by efficient decision making processes.

SUSTAINABLE DEVELOPMENT WITHIN BUSINESS

Sustainable Development concept is the result of changed approach within the industry that began to pay attention to the natural environment and its relationship in late 1960s. The term of Sustainable Development concerns not only the area of industry, but is a much broader concept that takes into account many aspects related to human existence e.g. Climate Action, Life on Land or Below the Water, Affordable and Clean Energy or Decent Work and Economic Growth which stands as just a few of a Sustainable Development goals. In total SD Agenda assumes delivering 17 various goals which are directly related to the environment, economy and society aspects [United Nations]. In this paper the term of Sustainable Development will be defined as a concept which includes all aspects of human life based on social, economic and environmental pillars. Authors focus mainly on economic and environment impact of business activity and its role within this global strategy.

Since the beginning of 21th century links between science, technology and sustainable development are significantly noticed. Currently the thesis that SD should play the key role in business strategies is more common than few years before. Unfortunately, in most cases, the development of technology is still executed without green trends that prevent the degradation of natural environment. It can be observed that industrial and economic development of the regions was highly connected with environment degradation. The objectives of SD concept assume the economic and technical growth without negative impact on earth. Goals that are the closest to business activity are directly related to:

- efficient use of natural resources,
- reduced waste generation through prevention, reduction, recycling and reuse,
- development of top quality, reliable, sustainable and resilient infrastructure.

What is more it is desired to adopt sustainable practices and integrate sustainability information with economic units like companies within their reporting cycles.

Before understanding relations between sustainable development and business it is important to clarify how companies are measuring their performance. Usually it should be measured by defining and following key performance indicators. These evaluate success of activities or organization in general. KPIs are being regularly tracked and reviewed by management team. They are strictly connected to the business model and targets for the company. KPIs can have a form of quantitative measurement which is a specific value or objective, usually numeric measured or qualitative values which are influenced or based by subjective assessment. Examples for key performance indicators differ from business types. Nevertheless as authors focus on industry business following KPIs are usually used in manufacturing, to name only a few:

- Safety measured usually as a number of accidents in taken time unit
- Efficiency of equipment, often described as OEE (overall equipment effectiveness)
- Quality measured differently, as an example as Share of finished goods that are inspected by a quality unit and are in compliance with the inspection plan without further need of clarification, retesting or reworking and obtain a positive usage decision

- Production frequency (or availability) measured as days in between production of particular finished good.
- Utilization rates measured as a capacity versus demand of particular equipment
- MTBF / MTTR known as basic indicators for maintenance teams. MTBF (Mean Time Between Failure) refers to the amount of time that elapses between one failure and the next and MTTR (Mean Time To Repair) which represents the average time required to repair a failed component or device
- Stock coverage understood as a total demand that is covered by the gross value of stock in warehouses and stock in transit
- Costs detailing expenses for conversion of materials into finished goods

Most effectively key performance indicators should support reaching all sustainable development goals. Nevertheless authors state that such relation will appear only within highly mature organization which includes fully sustainable development in its strategy. To understand and specify features of sustainable development on each level of organizational maturity authors prepared description of each in following chapter.

SUSTAINABLE DEVELOPMENT WITHIN ORGANIZATION

In tables designed in following chapters, authors proposed combined approach for achieving sustainable development goals within key performance indicators. The reason behind such approach is that organization's primary target usually is defined by KPIs while sustainable development stands besides or is developed in parallel. Using proposed solution, authors believe that both targets can be reached easily. PN-EN ISO 9004:2000 distinguishes following levels of organizational maturity:

1. Level 1. No formal approach. Organization is not using any systematic approach to management. It does not measure results or measures are irrelevant.
2. Level 2. Reactive organization. Minimum required to achieve ISO 9001. Organization is taking conscious decisions based on simple measures.
3. Level 3. Stable, formalized approach. System approach to management. Organization is tracking key performance indicators and understands trends.
4. Level 4. Continuous improvement approach. Organization gains stability in improving results. Continuous improvement process is implemented.
5. Level 5. World class manufacturing. Organization is leading in specific market. Organization has highly integrated improvement process and its key performance indicators are usually higher than relevant measures of their competitors. Level 5 is usually reached by global companies.

Organizational maturity levels are well described in the norm PN-EN ISO 9004:2000. Since 2000 it has developed, including sustainable development in recent years (e.g. PN-EN ISO 9004:2018). This proofs that topic chosen by authors is valid and requires further attention.

ORGANIZATIONS MATURITY – RESEARCH FREAMWORK

General description of a model

To describe the maturity level of the organization authors decided to use the terms for the next levels of organizational maturity as Ignoring, Defining, Adapting, Managing and Integrating [16]. Each maturity level characterizes selected feature's level of advancement. The levels are described in the tables presented below. The following tables consist of 5 columns. First column divides features described in ISO norm (column 2) into 3 different evaluation areas: human factor, technical/organizational and management. In third column characteristic of each feature on particular organizational maturity level is described in details. The description of each characteristic is based on ISO norm. According to those authors has chosen KPI proposals (column 4) for tracking and measuring each feature and sustainable targets which might be achieved within the feature. Sustainable development goals included in tables were addressed officially by United Nations as "blueprint to achieve a better and more sustainable future for all".

Goals are listed as follows: Goal 1: No Poverty, Goal 2: Zero Hunger, Goal 3: Good Health and Well-Being, Goal 4: Quality Education, Goal 5: Gender Equality, Goal 6: Clean Water and Sanitation, Goal 7: Affordable and Clean Energy, Goal 8: Decent Work and Economic Growth, Goal 9: Industry, Innovation and Infrastructure, Goal 10: Reduced Inequalities, Goal 11: Sustainable Cities and Communities, Goal 12: Responsible Production and Consumption, Goal 13: Climate Action, Goal 14: Life Below Water, Goal 15: Life On Land, Goal 16: Peace, Justice and Strong Institutions, Goal 17: Partnership for the Goals.

Maturity levels

Features and characteristics describing organizations on first level of maturity level are described in the Table 1 that shows also business KPIs and sustainable targets supported by improving particular feature. This level of maturity authors describe as "Ignoring Level" as in Oleskow-Szłapka and Stachowiak [2019]. The truth is that at this level organization is not using any business KPIs or measures are really basic according to the norm. (ISO-9004:2018(E)) Sustainable development as a concept does not exist either however some aspects are being developed or addressed in informal manner.

Table 1. Maturity level 1

Evaluation area	Feature	Characteristic	Business KPI	Sustainable targets
Human factor	9.5 Work environment	Work environment needs related to sustainable development are addressed in informal and ad hoc manner.	Physical factors like humidity noise or heat compliance	Goal 3
	9.2 People	Competent and engaged people are considered to be resource. There are some informal processes related to competence development.	N/A	Goal 8
	7.4 Communication	Communication about sustainable development strategy and objectives within organization is informal and had hoc.	N/A	Goal 8
	6.2 Mission, vision, values, culture	A process of determination vision and values related to sustainability is informal and ad hoc.	N/A	Goals: 3, 5, 8, 10, 13, 14, 15
Technical / organizational	9.7 Natural resources	Organization does not manage the use of natural resources and does not consider the impact of it. The only use of natural resources comes from current process needs.	N/A	Goals: 7, 9, 11, 12, 13, 14, 15
	9.5 Infrastructure	Infrastructure needs related to sustainable development are addressed in informal and ad hoc manner.	N/A	Goals: 7, 8, 9
	9.4 Technology	Advances in current technology used within organization are informal and irregular.	N/A	Goals: 7, 8, 9, 11, 12, 13, 14, 15
Management	9.1 Resource management	Improving and supporting the operation in organization are performed in an informal manner. Some objectives are determined.	N/A	Goal 7, 9, 11, 12
	9.3 Organizational knowledge	Current knowledge is captured in an informal or ad hoc manner. Processes to improve the situation are informal.	N/A	Goals: 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15
	10.3 Performance analysis	Performance analysis is made in ad hoc manner. The analysis are made in event type way rather than process.	N/A	Goals 8, 9
	10.5 Self-assessment	Internal audits are reactive in response to problems and issues.	Number of audits per year	Goals: 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15

Source: own work based on ISO 9004:2018(E)

Features and characteristics describing organizations on second level of maturity level are described in the Table 2 that shows also business KPIs and sustainable targets supported by improving particular feature. This level of maturity authors describe as "Defining Level". Sustainable development on this level of maturity appears to be an issue. It is starting to be defined and good practices are being implemented.

Table 2. Maturity level 2

Evaluation area	Feature	Characteristic	Business KPI	Sustainable target
Human factor	9.5 Work environment	Some processes for addressing work environment issues are in place.	Physical factors like humidity noise or heat compliance	Goal 3
	9.2 People	Processes to attract competent and engaged people are in place. There are some processes related to competence review and development plans.	N/A	Goal 8
	7.4 Communication	There is a procedure for communicating selected information about sustainable development. There is a process for determination the types and degrees of needed communication.	N/A	Goal 8
	6.2 Mission, vision, values, culture	A basic understanding of organization mission and vision related to sustainable development is in place. The understanding of the need of change is informal.	N/A	Goals: 3, 5, 8, 10, 13, 14, 15
Technical / Organiza-tional	9.7 Natural resources	Organization implements good practises in current procedures of usage of natural resources.	N/A	Goals: 7, 9, 11, 12, 13, 14, 15
	9.5 Infrastructure	Some processes for addressing infrastructure issues are in place.	% effectiveness of equipment usage; MTBF / MTTR	Goals: 7, 8, 9
	9.4 Technology	Some of the processes related to innovation and development are in place.	N/A	Goals: 7, 8, 9, 11, 12, 13, 14, 15
Manage-ment	9.1 Resource management	Some of the processes within organization on basic level focus on efficient usage of resources. Risk and opportunities assessment is set on a basic level. Process of determination and management of needed resources exists. Efficient use of resource is not defined.	% of processes covered with resource management approach.	Goals: 7, 9, 11, 12
	9.3 Organizational knowledge	Some processes for protecting and documenting organizational knowledge exist.	N/A	Goals: 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15
	10.3 Performance analysis	Limited analysis of the performance. Some basic tools are in use.	Cost per unit; % of machine effectiveness; Productivity hours/unit	Goals: 8, 9
	10.5 Self-assessment	Internal audits for key processes are managed systematically. Data are used in preventive way.	Number of non-conformities	Goals: 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15

Source: own work based on ISO 9004:2018(E)

Features and characteristics describing organizations on third level of maturity level are described in the Table 3 that shows also business KPIs and sustainable targets supported by improving particular feature. This level of maturity authors describe as “Adapting Level”. In this level of maturity mission, vision and values of organization are based on sustainable development concept. Processes are ensuring effective resources management. Performance is being tracked and analyzed with sustainability behind.

Table 3. Maturity level 3

Evaluation area	Feature	Characteristic	Business KPI	Sustainable targets
Human factor	9.5 Work environment	Processes that address risks and opportunities for the work environment are in place. There are activities that measure, monitor and protect infrastructure and work environment.	Physical factors like humidity noise or heat compliance	Goal 3
	9.2 People	Transparent, ethical and socially responsible approach is applied at all levels of the organization. Revision of the actions effectiveness is aligned with the mission vision and objectives.	Associates development plan - % of succession Level of satisfaction	Goal 8
	7.4 Communication	Communication processes are defined and in meaningful manner facilitate process that is tailored to different recipients in accordance to sustainable development concept. A feedback mechanism is present in place.	N/A	Goal 8
	6.2 Mission, vision, values, culture	Top management is involved in determining the mission vision and values based on sustainable development concept. The need of change of current situation is in place. Changes of the organization identity are communicated informally to interested recipients.	N/A	Goals: 3, 5, 8, 10, 13, 14, 15

Evaluation area	Feature	Characteristic	Business KPI	Sustainable targets
Technical / organizational	9.7 Natural resources	Management of natural resources is linked with organization management system. There is evidence in improving the actual use of natural resources measured by some indicators.	% use of natural resources.	Goals: 7, 9, 11, 12, 13, 14, 15
	9.5 Infrastructure	Processes that address risks and opportunities for the infrastructure is in place. There are activities that measure, monitor and protect infrastructure.	Total operating capacity value for key equipment; % effectiveness of equipment usage; MTBF / MTTR	Goals: 7, 8, 9
	9.4 Technology	There is a process of evaluating the benefits and risk related to implementation of suitable solutions linked with sustainable development concept. Cost, savings and other benefits assessment is in place.	% of effectiveness and cost improvement vs. previous year.	Goals: 7, 8, 9, 11, 12, 13, 14, 15
Management	9.1 Resource management	Some of the processes within organization focus on efficient usage of resources. Resource management approach is implemented systematically within organization.	% of processes covered with resource management approach.	Goals: 7, 9, 11, 12
	9.3 Organizational knowledge	Some of the processes are documented and described. There are activities that determine whether the knowledge is explicit or hidden. There is a process of identifying important information and distributing them through organization.	% improvement of processes described vs. previous year.	Goals: 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15
	10.3 Performance analysis	Performance is analysed to identify issues and opportunities. Statistical tools are used for support analysis.	Cost per unit; % of machine effectiveness; Productivity hours/unit; % of materials usage effectiveness; Joules/ Unit; Media usage/unit	Goals: 8, 9
	10.5 Self-assessment	Audits are made in a consistent way by the 3rd party personnel. Audits identify problems and nonconformities.	% of non-conformities; % of improvements vs. current state	Goals: 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15

Source: own work based on ISO 9004:2018(E)

Features and characteristics describing organizations on forth level of maturity level are described in the Table 4 that shows also business KPIs and sustainable targets supported by improving particular feature. This level of maturity authors describe as "Managing Level". In this level of maturity whole organization is starting to understand and follow sustainable goals. Organization's culture is aligned with mission, vision and values of sustainable development.

Table 4. Maturity level 4

Evaluation area	Feature	Characteristic	Business KPI	Sustainable targets
Human factor	9.5 Work environment	Processes implements advanced techniques to improve performance and resource usage efficiency. There is proactive manner into implementation process.	Physical factors like humidity noise or heat compliance	Goal 3
	9.2 People	People across the organizations are aware of their personal development. Career planning is well developed. Information and knowledge are accessible for employees and teamwork within organization is seen and present. Competence development is made for achieving new skills.	Associates development plan - % of succession Level of satisfaction	Goal 8
	7.4 Communication	The processes of communicating the strategy and objectives related to sustainable development are regular and show a direct relationship to the context of the organization.	% of changes within organization communicated	Goal 8
	6.2 Mission, vision, values, culture	Organization's culture is aligned with mission, vision and values of sustainable development. Understanding of the current culture and the need for a change is evident. Changes of any key factors are communicated.	N/A	Goals: 3, 5, 8, 10, 13, 14, 15
Technical / organizational	9.7 Natural resources	The organization knows its responsibility to society for managing natural resources. Some best practise solutions have been implemented within organization.	% use of natural resources. % efficiency of resource usage	Goals: 7, 9, 11, 12, 13, 14, 15
	9.5 Infrastructure	Processes implements advanced techniques to improve performance and resource usage efficiency. There is proactive manner into implementation process.	Total operating capacity value for key equipment; % effectiveness of equipment usage; MTBF / MTTR; 3 year roadmap with initiatives	Goals: 7, 8, 9
	9.4 Technology	Organization's knowledge and resource capability needed to implement innovation solutions and asses the risks and opportunities are in place.	% of spent funds for sustainability projects; % of spent funds for efficiency improve projects	Goals: 7, 8, 9, 11, 12, 13, 14, 15

Evaluation area	Feature	Characteristic	Business KPI	Sustainable targets
Management	9.1 Resource management	Controls to support the efficient usage of resources are in place. External providers are encouraged by organization to improve usage effectiveness of the resources. Strategic planning processes are aligned with organization's objectives in order to achieve efficient performance.	% of utilization of the resource.	Goals: 7, 9, 11, 12
	9.3 Organizational knowledge	There are processes of gathering and analysing data. The process of staff understanding evaluation is present. There are methods of communication the roles and owners of managed processes.	% of processes described within the system vs. previous year.	Goals: 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15
	10.3 Performance analysis	Performance is analysed to identify weaknesses within the processes: Insufficient resources, Insufficient competences, Defining "the role model" processes to share with other parties. The analysis and results are shown with interested parties.	Cost per unit; % of machine effectiveness; Productivity hours/unit; % of materials usage effectiveness; Joules/Unit; Media usage/unit; Leading and Lagging indicator system for key contributors.	Goals: 8,9
	10.5 Self-assessment	The organization is prepared to review all internal audit reports to prepare corrective actions.	% of non-conformities % of ; improvements vs. current state; % of improvement vs. previous year	Goals: 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15

Source: own work based on ISO 9004:2018(E)

Features and characteristics describing organizations on fifth level of maturity level are described in the Table 5 that shows also business KPIs and sustainable targets supported by improving particular feature. This level of maturity authors describe as "Integrating Level". This is highest level of sustainable development integration within organization. Sustainable targets are being reached in different areas, by different features.

Table 5. Maturity level 5

Evaluation area	Feature	Characteristic	Business KPI	Sustainable targets
Human factor	9.5 Work environment	The work environment is managed in a way that allows, support and not disturb in achieving desired results.	Physical factors like humidity noise or heat compliance and all related to ergonomics and comfort at work.	Goal 3
	9.2 People	People across the organizations take part within the development of the processes related to achieving sustainability. The results achieved for competent, engaged and empowered people are shared within the organization and compared with other organizations.	Associates development plan - % of succession Level of satisfaction	Goal 8
	7.4 Communication	The processes of communicating the strategy and objectives related to sustainable development are dynamic with the interrelationships of the strategy or objectives. They are clearly conveyed to all recipients and accounts their different needs related to changes.	% of changes within organization communicated	Goal 8
	6.2 Mission, vision, values, culture	A process of reviewing these elements by top management is regular and maintained. The analysis and consideration includes both internal and external factors related to sustainable development concept to ass alignment of between the business objectives and the concept.	% of review made on time.	Goals: 3, 5, 8, 10, 13, 14, 15
Technical / organizational	9.7 Natural resources	The organization knows its responsibility to society for managing natural resources and the lifecycle of their products. Management of natural resources is widely recognized as important in whole organization what is more the future role of the resource usage is very well known and practised. New technologies and trends are very important part of the strategy for maximizing the efficiency of resource usage.	% use of natural resources; % efficiency of resource usage; number of new initiatives related to natural sources	Goals: 7, 9, 11 ,12, 13, 14, 15
	9.5 Infrastructure	Infrastructure is managed in a way that becomes a key contributor in achievement of desired results.	Total operating capacity value for key equipment; % effectiveness of equipment usage; MTBF / MTTR; 5 year roadmap with initiatives	Goals: 7, 8, 9
	9.4 Technology	Organization takes measures to keep informed of new technologies and methods and evaluate their possible benefits and impact on organization and sustainable development goals.	% of spent funds for sustainability projects; % of spent funds for efficiency improve projects	Goals: 7, 8, 9, 11, 12, 13, 14, 15

Evaluation area	Feature	Characteristic	Business KPI	Sustainable targets
Management	9.1 Resource management	The cooperation with external providers of the resources depends on joint initiatives to implement improvements on the usage of the resources.	% of utilization of the resource.	Goals: 7, 9, 11, 12
	9.3 Organizational knowledge	There are processes of gathering and analysing data for every area and process that organization is interested in and helps to track impact on sustainable development targets and goals.	% of processes described within the system	Goals: 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15
	10.3 Performance analysis	Performance is analysed comprehensively within the organization by numbers of indicators to strengthen the leadership activities or identify weaknesses within the processes. The analysis can cover all areas that drive the main areas of interest within organization that shows the effectiveness of the system e.g. Profits and Losses, machines utilisation or customer service indicators.	Cost per unit; % of machine effectiveness; Productivity hours/unit; % of materials usage effectiveness; Joules/Unit; Media usage/unit; Leading and Lagging indicator system for key contributors.	Goals: 8, 9
	10.5 Self-assessment	The organization is prepared to control itself internally to identify weaknesses and address corrective actions for improvement to be back on its standards.	% of non-conformities % of improvements vs. current state % of improvement vs. previous year	Goals: 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15

Source: own work based on ISO 9004:2018(E)

CONCLUSIONS

Application of sustainable development within organizational maturity can mitigate reaching sustainable targets. Authors therefore described basic assumptions in the table 6 which is a summary of previous, detailed tables of each maturity level. It is important to understand relations between maturity level of organization and sustainable development goals. By improving its maturity, organization should in parallel develop further sustainable measures.

Table 6. Maturity levels summary

Organizational maturity level and name	Functional description within sustainable development
Level 1: Ignoring	Procedures of working according to sustainable development concept do not exist. There are no sustainable activities or informal and immature activities appear. Regarding sustainable development no measures are applied and no data is being gathered.
Level 2: Defining	Key processes and procedures related to sustainable development are being defined. First approach of including sustainable development into strategy. Goals area being measured. Data is being partially gathered and analyzed.
Level 3: Adapting	Key performance indicators are built on the basis of effective resource management and sustainable development. Organizational goals are highly related to usage of resources and are being spread across several departments.
Level 4: Managing	Some best practice solutions have been implemented within organization for managing natural resources. The performance of the processes are evaluated and improved systematically while using opportunities and managing risks. Sustainable development is being supported and plays significant role in managing organization.
Level 5: Integrating	Sustainable development goals are highly interlaying organizational strategy. The processes are designed in a way that allow to achieve demand performance effectively and efficiently within sustainable development concept and on the basis of performance which is analyzed comprehensively, on regular basis. New technologies and trends are playing important part of the strategy. Both external and internal resources are being used to ensure higher sustainability. Knowledge level within the crew is measured and developed constantly.

Source: own work

Authors state that more and more organizations are developing towards highest maturity levels including and implementing sophisticated measures and tools to make it feasible. Despite current maturity level, tables shown within paper should contribute in measuring current status of organizational development and help with describing further steps of development.

In the further research authors are going to precise via quantitative research business KPI values (targets) on each maturity levels. When all the values will be identified model will be ready to its validation across companies.

For sure one of key development features is usage of Business Intelligence within industry (use to identification values of business KPI's).

Business Intelligence should allow to gather and analyze complex data supporting operational processes on every organizational level. Data gathered continuously in various areas should be analyzed anytime. History of data should be stored safely for general summaries of longer periods. Analysis of different periods should be enabled automatically. User should have possibility to view situation of each resource in any moment, from the beginning of operation.

Analysis of maturity level in area of sustainable development have to take into consideration current trends in supply chain development. Implementation of the Industry 4.0 concept require not only usage of high-tech and artificial intelligence but also well designed network infrastructure, sufficient analytics software and smart controllers to use available data properly. All those features will support reaching of sustainable development goals.

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KONCEPCJA OCENY DOJRZAŁOŚCI ORGANIZACYJNEJ WSPIERAJĄCEJ CELE ZRÓWNOWAŻONEGO ROZWOJU

STRESZCZENIE. **Wstęp:** Celem artykułu jest zaprezentowanie modelu oceny poziomów dojrzałości organizacji w odniesieniu do celów zrównoważonego rozwoju. Bardzo niestabilne otoczenie biznesowe i możliwości pojawiające się na rynku wymagają efektywnego i szybkiego procesu decyzyjnego. Wyzwaniem jest śledzenie tak dynamicznych zmian wewnątrz i na zewnątrz organizacji przy zachowaniu trwałych celów. Autorzy zauważają, że jest to możliwe dzięki nowoczesnym koncepcjom i dostępnym narzędziom – takim jak przemysł 4.0 czy Business Intelligence. Te koncepcje wspierają podejmowanie decyzji biznesowych w oparciu o zebrane i przeanalizowane dane, określając odpowiednią strategię, która promuje cele zgodne ze zrównoważonym rozwojem.
Metody: Autorzy oparli swoją koncepcję modelu dojrzałości organizacji na opisanych w literaturze modelach raz na międzynarodowym standardzie (jego polskiej wersji): PN-EN ISO 9004:2000.
Wyniki: Autorzy zdefiniowali pięć poziomów dojrzałości, z których każdy opisany został kilkoma cechami. Na podstawie przygotowanych wytycznych można zdefiniować poziom dojrzałości organizacji.
Wnioski: Istotnym aspektem jest zrozumienie relacji między poziomem dojrzałości organizacji a celami zrównoważonego rozwoju. Opracowany model pozwala na włączenie elementów zrównoważonego rozwoju do oceny poziomu dojrzałości organizacji.

Słowa kluczowe: zrównoważony rozwój, Business Intelligence, przemysł 4.0., proces podejmowania decyzji, dojrzałość organizacji

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ORIGINAL PAPER

ATTEMPT OF WAREHOUSES CLASSIFICATION FROM THE POINT OF VIEW OF FUTURE USERS

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ABSTRACT. **Background**: Businessmen intending to rent or purchase a warehouse facility find it difficult to compare them. Surface area, cubic capacity or the number of reloading docks are not sufficient factors to make a decision.

The aim of this paper is to provide a basis for the creation of international system of evaluation of warehouses from the point of view of future investors.

Methods: A literature review was carried out in terms of magazine division. Then, using comparative analysis, the identified divisions were collated.

Results: The set of parameter and their values for three different warehouse classes are suggested in the final table. The presented parameters of the division are a preliminary proposal of the possible classification system of warehouses.

Conclusions: The assumption of this publication is to start a discussion on the division of warehouse facilities into classes, which will ultimately lead to crystallization of the division, useable for businessmen during the investment process.

Key words: warehouses classes, storage classes, warehouse classification.

INTRODUCTION

Businessmen intending to rent or purchase a warehouse facility find it difficult to compare them. Surface area, cubic capacity or the number of reloading docks are not sufficient factors to make a decision. Some real estate agencies, therefore, use warehouse classes, in fact, class A, to identify potential best locations. However, there is no consistency in defining warehouse classes, which requires ordering. As far as the parameters of the class A warehouse are available on the Internet (although to their consistency one may have doubts), the existence of definitions of the alleged classes B or C is unclear. It is necessary to create an international system of evaluation of logistic properties in order to make it easier to compare and offer them to potential buyers or tenants.

DIVISIONS OF WAREHOUSES

The division of warehouses can be carried out according to various criteria. An example of the diversity of classifications is presented in Table 1.

Apart from the first one, the divisions are in principle not strict with a significant possibility of interpretation of the criteria applied. Functionally, a contract warehouse can be both a distribution and, in some cases, a production one. In the constantly growing trend of direct Internet sales (e-commerce), production warehouses become distribution warehouses [Hrach, Alt, 2018].

It is rare for warehouses to be operated manually, mechanically or automatically - in

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practice, in most cases in a single facility, a variety of technological solutions are applied at different scales [Prakash, Prakash, 2018; Bieringer, Müller, 2018].

Table 1. Examples of warehouses divisions

Divided by	Groups of division	Source
Construction	open half-open closed	[Wojciechowski, Wojciechowski, Kosmatka 2009]
Function	distribution production contract	[Van Den Berg, Zijm 1999]
Technology applied	manual mechanized automatized	-
Usable height	low height medium height high-bay	-

Neither is the last division unequivocally interpreted. It should be assumed that low storage warehouses are operated manually (assuming the use of ladders) or with the use of walk-behind forklift trucks. Medium storage warehouses are limited by the lift height of counterbalance trucks (although modern walk-behind forklifts have slightly lower lift heights). High bay warehouses, on the other hand, are served by reach trucks or other devices, with similar or higher lifting heights [Culler, Long, 2016].

COMMERCIAL PROPERTY CLASSES

The above divisions of warehouses, which are important during their operation, do not offer support in making decisions about the desired facility. This offers a division of buildings transferred from the office space classification into classes A, B, and C, but not defined in the scientific literature. Hence, most of the sources, on the basis of which the division of warehouse space is created, are marketing sources. Therefore, it requires a scientific approach.

Table 2. Example criteria for the classification of office buildings

Building class	Class description
A	"A classification used to describe an office building with rents in the top 30 to 40 percent of the marketplace. Class A buildings are well-located in major employment centres and typically have good transit, vehicular and pedestrian access. Additionally, they are located adjacent to or in proximity to a high number of retail establishments and business-oriented or fast casual restaurants. Building services are characterized by above-average upkeep and management."
B	"A classification used to describe an office building with rents that are based between those of Class A and Class C buildings. Class B buildings are in good to fair locations in major employment centres and have good to fair transit, vehicular and pedestrian access. They are located adjacent to or in proximity to a moderate number of retail establishments and business-oriented or fast casual restaurants. Building services are characterized by average upkeep and management."
C	"A classification used to describe an office building with rents in the bottom 10 to 20 percent of the marketplace. Class C buildings are in less-desirable locations relative to the needs of major tenant sectors in the marketplace. They can be older, neglected buildings in good locations or moderate-level buildings in poor locations, so transit, vehicular and pedestrian access may vary. Typically, fewer amenities and restaurants are found in or near these buildings, and they are usually of moderate to low quality. Building services are characterized by below-average upkeep and management."

Source: Commercial Real Estate Development Association, https://www.naiop.org/en/Research/Terms-and-Definitions?letter=C access 12.12.2018

The definitions offered by the developers and real estate agencies are not in any way agreed, and their consistency is a matter of chance - it is not possible to directly compare class A objects of two different associations of real estate agencies. At most, you can expect regional, informal arrangements in limited markets. Not only the lack of consistency, but also the lack of clear criteria raises doubts when allocating to particular groups.

Examples of criteria described on the websites, classifying particular classes of warehouses, are listed in Table 2.

CLASSIFICATIONS OF WAREHOUSE FACILITIES

Classifications of warehouse facilities published on the websites are similarly inconsistent, not only in terms of the value of indicators, but also in terms of evaluation criteria. While class A definitions are relatively easy to access, other classes are much more difficult to find. This indicates the current, only marketing function of this unclear classification.

One of the most comprehensive and detailed classifications is presented on the Impact Real Estate Agency website. In the classification (without a given source) there are 6 classes (A+, A, B+, B, C, D), and the last class includes, among others, cellars. This is a classic approach of a real estate agency, without taking into account the communication of the plot with the road network. In this aspect the CBRE classification is more exhaustive, but in principle it focuses on class A facilities. On the other hand, the Realty Module classification will focus on the quality of warehouse facilities. Apart from real estate agencies, one can find the definition of warehouse class among companies dealing with trainings - an example is Trans.eu Group S.A. and the definition of A-class warehouses available on the website.

The list of parameters in each identified classification is presented in Table 3.

Table 3. Example criteria for classifying warehouses (class A)

Classification parameter	CBRE	edu.trans.eu	Knight Frank
Location of the facility			
access	unlimited	-	-
communication with the road network (distance to the main traffic junction)	to 10 km	-	necessary
outside residential areas	required	-	-
Area of the facility			
yard	full-size	-	yes
parking of passenger cars	yes	-	yes
truck parking	yes	-	yes
fenced area	yes	yes	yes
lighted area	yes	-	yes
protected / guarded area	yes	-	yes
monitoring of the warehouse complex	yes	yes (class A++)	yes
Object parameters			
minimum usable height [m]	10	8-10	10
minimum length [m]	75	-	-
minimum load capacity of the floor [t/m2]	5	5	5
floor dust cover	-	-	yes
columns / pillars grid [m]	12x24 12x22,5	12x24	9x24
share of office space	5-10%	-	(required)
Facility equipment			
minimum number of loading and unloading dock per m^2	1/1000	1/1000	1/1500
minimum number of 0 level gates per m^2	1/5000	1/5000	-
smoke detectors	-	yes	yes
sprinklers system	preferred	-	yes
Installations			
minimum illumination intensity [lux]	150	-	-
energy efficiency	preferred	-	-
LED lighting	preferred	-	-
skylights	-	yes	-
heating system	-	yes	yes
ventilation system	-	yes	yes
optical fibres	-	yes	yes
autonomy-voltage and thermal unit	-	-	yes
Others			
minimum lease term	3 years	-	-
illuminated landscaped area	yes	-	yes
professional management system	-	-	yes
experienced developer	-	-	yes
the system of accounting and control employee access	-	-	yes
CCTV	-	-	yes
proper proportions of length and width of the warehouse	-	-	yes
modern building	-	-	yes

Source: http://bachfest-leipzig.com/classification-warehouse/#more-51 access 15.12.2018, www.industrialgo.pl/czy-wiesz-ze/1 access 15.12.2018, https://edu.trans.eu/kursy/magazyn/magazyny-w-pigulce/3 access 15.12.2018

Part of the parameters, if present in at least two classifications, is in agreement. Differences exist in the definition of:

- the distance to the nearest communication node, which is crucial from the point of view of the future user,
- the usable height of warehouses and the preferred column grid,
- the number of reloading docks per square metre of the warehouse,
- level 0 gates availability.

Some of the parameters of warehouse equipment, indicated in the available data, are necessary, for example, for reasons of occupational health and safety – for example the indicated value of lighting intensity (150 lux) is sufficient in the temporary work zone. In areas where workers are permanently present, such as control areas, a value twice as high is required.

Some of the criteria used, for example, "modern building" or "experienced developer", are not measurable and their application would require the establishment of valuable indicators, e.g. a building that has been in use for no longer than 10 years. What does not include modernized facilities, and even considering a modernized facility as modern, there is a question of scale/scope of modernization.

Also, criteria that are not strict, such as parking lots for cars and trucks, the manoeuvring area in general, or the availability of office space without specifying the space, are not sufficient for a detailed assessment of potential warehouse facilities.

Among the indicators not identified in the available data, attention should be paid to the size of the social facilities (expressed in terms of the number of employees who can use it during one shift).

The parameters of the remaining classes (assuming two classes, B and C) of warehouses are not available in such a wide interpretation. In general, it can be assumed that:

- the usable height of warehouse halls drops, even down to 6 meters in the case of class C facilities,
- the column grid is 'thickened',
- the number of modern installations, including heating and teletechnical installations, is decreasing,
- it is more difficult to access the warehouse, manoeuvring on the yard is complicated,
- number and quality of docks is decreasing,
- the quality of the warehouse itself, as well as social and office facilities also decreases, although this is a subjective parameter.

Many of the required parameters of the warehouse facilities are values resulting not from the infrastructure, but from the planned flows. These include, among others, the number of docks or the number of parking spaces. Also, the size of social and office facilities is not a universal parameter but results from the user's needs - the volume of planned flows, the level of employment, etc. Therefore, these parameters should not be treated as universal, but resulting from real demand. Of course, theoretically "the more, the better", but practically many users do not use the whole potential of class A warehouses. It is enough to look at the long strings of closed gates of logistic centre loading bays, already at first glance used in fractions of percent.

However, some parameters can be correlated. For example, if the expected minimum number of loading bays for class A is 1/1000 m^2, it can be assumed that one parking place for trucks is required per loading bays.

Many commercial areas for storage of goods are referred to as class A warehouses. However, it is difficult to find rental offers for B and C class warehouses. An attempt to define basic parameters of both A-class warehouses, as well as B and C-class warehouses, by analogy to the available A-class definitions, can be found in table 4.

Table 4. Attempt to define basic parameters of warehouse classes

Classification parameter	Class of the warehouse		
	A	B	C
Location of the facility			
access	unlimited	unlimited	limited
communication with the road network (distance to the main traffic junction) [km]	up to 10	up to 50	above 50
outside residential areas	yes	yes	option
Area of the facility			
truck manoeuvring on the yard	unlimited	unlimited	limited
number of truck parking slots per sqm	1/2000	1/10000	any
number of car parking slots	as required	below requirements	any
fenced area	yes	yes	option
lighted area	yes	option	option
protected / guarded area	yes	yes	yes
monitoring of the warehouse complex	yes	option	option
Object parameters			
minimum usable height [m]	10	8	6
length/width ratio	2/1	any	any
minimum load capacity of the floor [t/m^2]	5	below 5	below 5
floor dust cover	yes	yes	option
columns / pillars grid [m]	12x24/22,5	9x24/22,5	any
share of office space	5-10%	any	any
Facility equipment			
minimum number of loading and unloading dock per sqm	1/1000	1/5000	any
minimum number of 0 level gates per sqm	1/5000	1/10000	any
smoke detectors	yes	yes	option
sprinklers system	yes	option	option
Installations			
energy efficiency	preferred	option	option
skylights	preferred	option	option
heating system	yes	option	option
ventilation system	yes	yes	yes
optical fibres	yes	option	option
autonomy-voltage and thermal unit	option	option	option
Others			
minimum lease term	3 years	2 years	1 year
illuminated landscaped area	option	option	option
the system of accounting and control employee access	option	option	option
CCTV	option	option	option
Modern building	option	option	option

Source: own work based on sources from table 3

CONCLUSIVE REMARKS

The presented parameters of the division are a preliminary proposal. The assumption of this publication is to start a discussion on the division of warehouse facilities into classes, which will ultimately lead to crystallization of the division, useable for businessmen during the investment process.

The interpretation of parameters from the point of view of science should be combined with the point of view of practitioners. Therefore, it is important to look at the division in terms of the significance of individual parameters - the lack of some parameters excludes investments, others qualify it only for less attractive ones.

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Słowa kluczowe: klasy magazynów, magazynowanie, podział magazynów, magazyn

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ORIGINAL PAPER

RISK FACTORS AFFECTING RELATIONS WITH SUPPLIERS

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ABSTRACT. **Background:** In the recent period, one could notice that more and more international companies implementing their strategies based on the concept of risk management. These companies when they evaluate and qualify their suppliers use the requirements of quality management standards, quality assurance standards (in particular sectors), safety and security management standards for supply chain, as well as business continuity management standards. This article aims to determine the importance of the risk factors affecting relations with suppliers.

Methods: The research was carried out between October and November 2017 using the Computer Assisted Telephone Interview (CATI) technique. The study covered 300 producers from the automotive, metal and chemical sectors operating in the Polish B2B market.

Results: The surveyed enterprises indicated as the most critical sources of threats in relations with suppliers: the possibility of untimely deliveries, quality defects of products, the financial situation of suppliers, communication problems (related to the understanding of the requirements by the supplier), low level of supply flexibility, product assortment errors, limited production capacity.

Conclusions: Recapitulating the theoretical considerations and the results of empirical study, it can be stated that the role of the risk management concept in relations with suppliers is significant. Risk management is still essential to ensure the safety of purchased products as well as to ensure the continuity of processes and to avoid disruptions in supply chains.

Key words: relationships with suppliers, risk management, safety management standards in the supply chain.

INTRODUCTION

Many enterprises establishing relationships with new suppliers focus their requirements on the guidelines contained in international quality management and safety management standards [Rebelo et al. 2016]. The latest edition of these standards in its assumptions takes into account the concept of risk management. For this reason, the attention of business customers is increasingly focused on assessing the ability of suppliers to ensure the safety of products and processes in the supply chains. For these reasons, B2B companies are expecting evidence that suppliers can guarantee the technical quality of product solutions to the highest possible degree, ensure timely deliveries, and achieve the ability to reduce operating costs [Alikhan et al. 2019].

Often, B2B clients (and especially multinationals) carry out a comprehensive preliminary assessment of suppliers by analysing the data contained in the self-assessment cards provided by suppliers concerning specific requirements relating to the above-mentioned criteria. The credibility of these data is verified by audits. The assessment of the technical quality of products is of particular importance. B2b customers carry out an assessment of the technical quality of products, including through a comparative laboratory analysis of samples from potential suppliers and assessment of their compliance with the required technical specification, trial purchase, free temporary use (in relation to machines and devices), collecting opinions from current users (during the so-called reference visits). Due to the perspective of shaping long-term partnerships between

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economic entities, the legal and financial situation is also important for the initial assessment of suppliers. This assessment includes the performance of obligations (financial / material / intangible assets, indebtedness, profitability, financial liquidity, shares in other enterprises, type and range of insurance and financial guarantees) that may determine the stability and sustainability of these relationships in the future.

The criteria above mentioned are not taken into account only in the initial assessment and qualification of suppliers. They are also the basis for their periodic assessment, which is largely based on past experience resulting from cooperation. Of particular importance in this respect are elements such as timeliness of deliveries as well as their flexibility, effective communication, production and technological (technical or organizational) capacity to reduce costs, shorten cycles of operational processes, improve the impact on the natural environment, improve safety conditions and ensure continuity of inflow products and information in the supply chain. Periodic qualification is often based on a comprehensive analysis of suppliers' assessment sheets, self-assessment questionnaires (containing data indicating effectiveness in achieving expected process improvement indicators), and also through audit results [Singh 2014, Govindan et al. per 2015, Torres-Ruiz, Ravindran 2018].

REQUIREMENTS FOR SUPPLIERS IN THE FIELD OF RISK MANAGEMENT

As already mentioned, a particularly important element of the suppliers' assessment is to guarantee the technical quality of the products. Ensuring the quality of the product requires strict compliance with the legal requirements relating to providing the safety (included in the European Union directives and technical standards) of the specific supervision of operational processes associated with the realization of the product (like customer service, research and development, purchasing, production, packaging, delivery to the customer) as well as the resources (employees, infrastructure and environment). An essential role in ensuring the safety of products is the effectiveness of monitoring and measurements of operating processes and their parameters. The unified requirements for companies that are suppliers in the above issues are contained in the international organizational standard ISO 9001 [Su et al. 2015]. The latest edition of the ISO 9001 standard based on the risk management concept (described in the ISO 31000 standard) should make the suppliers more obliged to ensure the safety of products and operational processes[Oliveira et al. 2017].

Particular attention is paid to operational risk, which is connected with the possibility of incurring losses due to insufficient or faulty infrastructure, incorrect operating procedures, mistakes made by people, problems with suppliers and / or customers, and external events. Examples of operational risk include:
- delivery of defective materials or infrastructure by suppliers,
- untimely delivery of materials / infrastructure;
- shortage of employees with the required qualifications;
- failure to achieve the required process objectives (efficiency, effectiveness, timeliness, technical parameters);
- accidents, breakdowns caused by difficult working conditions or non-compliance with OSH rules, or extreme natural events, such as flood, hurricane, earthquake.

One of the most frequently used tools that enables the company to identify the risk of threats in processes and products (as well as to determine their detection and potential impacts and significance for companies as well as for clients), and to design preventive and corrective methodologies is FMEA [Dudek-Burlikowska 2011, Bhattacharya 2015, Sutrisno et al. 2015, Hrbackova 2016]

It can be observed that, in addition to the often-used FMEA (FEMCA-FMECA - Failure Mode, Effects, and Criticality Analysis), enterprises use other risk assessment tools such as check lists, Preliminary hazard analysis, Structured interview brainstorming, Delphi technique, Root Cause Analysis/ Single Loss Analysis (RCA/ SLA), Business Impact Analysis (BIA), Fault Tree Analysis (FTA), Event Tree Analysis (EFA), Cause-

Consequence Analysis (CCA), Hazard and Operability Study (HAZOP). These tools are described in the standard complementary to ISO 31000, which is IEC/ISO 31010 Risk management - Risk assessment techniques.

It should be noted that in some sectors the requirements placed on suppliers in the field of quality management is not only concern compliance with the guidelines contained in the ISO 9001 standard. They are also extended by additional requirements listed in relevant documents (specifications, standards) such as the automotive sector (ISO/TS, IATF 16949, VDA series 6), the aviation sector (AS/EN /JISQ 9100), the rail industry sector (ISO/TS 22163), the medical devices sector (ISO 13485),–petroleum, petrochemical and natural gas industries (ISO/TS 29001), the direct packaging materials sector of medicinal products (ISO 15378), the cosmetics production sector (ISO 22716), the packaging industry for food products (EN 15593) and the sector of fusion welding of metallic materials (ISO 3834).

Risk management in supply chains refers to emergencies (such as fire, explosion, chemical leakage) that can cause adverse effects on employees, infrastructure and the environment. These situations can have a significant impact on the disruption of the flow of products in the supply chains. For this reason, enterprises require their suppliers to prevent effectively and adequately emergency preparedness. Particular supervision should cover sources of potential hazards such as the use of flammable liquids, compressed gases or storage and transport processes of products.

THE ROLE OF SAFETY MANAGEMENT AND BUSINESS CONTINUITY MANAGEMENT STANDARDS IN THE SUPPLY CHAIN

Enterprises recognize the significance of risk of threats in processes implemented in the supply chain, which are the result of internal and external conditions [Papa 2013, Cedillo-Campos 2014]. The main threats to enterprises can be errors made by employees or the lack of adequate supervision over the efficiency and security of the infrastructure. On the other hand, external threats include fires, energy failures, floods, hurricanes, transport accidents, catastrophes, sabotage, theft [of goods, means of transport, documents], terrorism, failure to meet the terms of the contract by suppliers or customers, loss of commercial credibility, or financial. It can be noticed that more and more often companies also carry out Vendor Due Diligence, which analyses and assesses the level of implementation of broadly understood security procedures of partners [Bueno-Solano 2014]. For these reasons, more and more economic entities offering logistics services are beginning to be interested in implementing the guidelines contained in international standards of supply chain security management included in the ISO series 28000 standards. The main ISO 28000 standard (which is the basis for certification) provides guidelines for the planning, implementation, and monitoring of the flow of products and services to the final customer. Application of the safety management system in the supply chain is based on the analysis and assessment of the risk of threats in individual processes carried out by partners participating in the supply chain and verification of the standardization of procedural rules ensuring continuity of their implementation, as well as emergency procedures. The effectiveness of the implementation of this system is strictly dependent on the principles of communication with the partners who are participants of the supply chain (mutual information on possible threats) and the awareness of employees involved in the implementation of processes. Supervising this system requires monitoring and measuring the effectiveness of measures to ensure security in the supply chain [Park et al. 2016]. Implementation of a system compliant with the requirements of ISO 28000 is a tool approach to risk management in processes related to purchases, production, packaging, storage and transport (maritime, car, rail) of goods, as well as supporting activities such as: transaction financing, customs agency activities, delivery IT services [Manuj and Mentzer 2008]. To limit the risk of threats, more and more enterprises focus their attention on implementing the concept of business continuity management by suppliers. Supervision of the business continuity ensures achieving the set goals and affects the positive image, and thus the value of the organization. The requirements in this respect are set out in the ISO 22301 standard. Societal security - Business continuity management systems - Requirements. More detailed solutions regarding the implementation of the concept of continuity management are set out in the ISO 22313 standard. Societal security - Business Continuity Management Systems - Guidance [Torabi et al. 2016]. The concept is based on the identification of threats to the functioning of organizations cooperating within the supply chain and the development of Disaster Recovery Planning DRP, which are necessary in case of incidents and crisis situations that could disrupt its proper functioning, such as floods, fires, technological failures, disasters, sabotage, terrorism, loss of commercial or financial credibility [Baba et al. 2014, Rennemo et al. 2014, Blos et al.2015]. The ISO 22301 standard assumes that for events with unacceptable risk (e.g. failure, disaster) activities are planned and implemented, taking both the form of technical and organizational solutions (such as DPR) to ensure removal of the consequences (and their causes) on the basis of defined operational procedures (emergency procedures) and restoration of the process under normal conditions. The parameters of operations that are managed within BCM are availability (services, resources, etc.) and timeliness (performance of tasks, processes, etc.). Defining the required minimum parameters in the scope of processes allows for the selection of appropriate operating procedures and resources, which are included in Business Continuity Plans, BCP [Faertes 2015].

The implementation of the concept of business continuity management is based on Business Impact Analysis (BIA). The guidelines for its application were defined in the technical specification ISO / TS 22317 Societal security - Business continuity management systems issued in 2015 (BIA). This analysis allows to identify critical elements for the implementation of processes and specify the necessary procedures and resources to ensure the organization functioning in the event of unforeseen events / incidents / crisis situations that could disrupt its proper operation. Effective implementation of this concept requires:

– -identification of threats and determining the acceptable level of risk associated with them;
- identification of critical processes and resources (supervised infrastructure, qualified personnel, current and reserve suppliers) and their impact on maintaining the continuity of the implementation of products offered by the organization;
- determination of the assumed parameters MBCO (Minimum Business Continuity Objective), RTO (Recovery Time Objective), RPO (Recovery Point Objective), MTPD (Maximum Tolerable Period of Disruption);
- determination of emergency procedures and necessary technical measures in the event of incidents interfering with the functioning of processes;
- shaping the organizational culture by supervising the observance of procedures defining the rules of conduct in emergencies, training employees (raising employees' awareness) and
- conducting audits and reviews of the business continuity management system, assessing the effectiveness of its implementation.

The principles of cooperation between partners in supply chains are defined by ISO / TS 22318 Societal security - Guidelines for supply chain continuity. The guidelines in this document indicate that activities carried out by partners in the supply chain by focusing on ensuring business continuity should provide resilience that reflects immunity to the disruption that may arise [Torabi et al. 2015, Parkouhi et al. 2019].

ISO / TS 22318 defines the methodology of cooperation with partners who are sources of purchases within the chain. Its first stage is to subject mapping the supply chain and to conduct a business impact analysis of the risk of each partner.

The most important group are strategic suppliers whose replacement is associated with a high level of risk, as they often provide goods with unique technology that are difficult to substitute. Another group is core suppliers that ensure products and services that are important for the chain's operation. The last group, however, are transactional suppliers, also referred to as non-critical or routine, offering material products or widely available services. For each of the separate groups of suppliers, the goals defining Recovery Time Objectives (RTOs) are defined. The critical element of this methodology is the adoption of a specific strategy for building relationships and ensuring the continuity of the chain. In the case of critical suppliers, this cooperation should aim at building strong relationships based on mutual trust, defining common goals determined of improving performance and efficiency (and in particular reducing the time of reaction to disruptions).

THE METHODOLOGY OF RESEARCH AND RESULTS

The subject of the empirical study conducted identification of threat sources in relations with suppliers and determination of methods for assessing these threats. The research was carried out between October and November 2017 using the Computer Assisted Telephone Interview (CATI) technique. The study covered 300 producers from the automotive, metal and chemical sectors operating in the Polish B2B market. The study was commissioned to a specialized research agency that conducted a targeted selection of companies registered in the database, which is a search platform of a business directory. The surveyed enterprises indicated as the most critical sources of threats in relations with suppliers: the possibility of untimely deliveries and quality defects of products. These threats were particularly indicated by large enterprises (employing over 250 employees) operating in the automotive and chemical sectors.

The results of the research show that the product quality worms are very important for enterprises with foreign capital. Significant sources of threats covered the financial situation of suppliers, communication problems (related to the understanding of the requirements by the supplier), low level of supply flexibility, product assortment errors, limited production capacity. Detailed results of the research are presented in the tables 1 and 2.

Table 1. The importance of risks in relationship with suppliers (general results and a comparison between the segments depending on the capital, ranking using the Likert scale, correlations)

Risks in relationships with suppliers	General N=300	Capital	
		Polish N=120	Foreign N=180
Timely deliveries	3.536667	3.558333	3.522222
Quality defects of products	3.316667	3.150000	3.427778
The financial situation of suppliers	3.120000	3.025000	3.183333
Communication problems	3.100000	2.966667	3.188889
Flexibility of supply	3.070000	3.000000	3.116667
Assortment errors in deliveries	2.993333	3.008333	2.983333
The limited production capacity of suppliers	2.953333	2.833333	3.033333
Technological problems	2.866667	2.750000	2.944444
No emergency delivery plans	2.830000	2.708333	2.911111

Source: results of the empirical study

Table 2. The importance of risks in relationship with suppliers (comparison between the segments depending on the number of employees, ranking using the Likert scale, correlations)

Risks in relationship with suppliers	Number of employees	
	-250 N=223	251- N=77
Timely deliveries	3.511211	3.610390
Quality defects of products	3.300448	3.363636
The financial situation of suppliers	3.112108	3.142857
Communication problems	3.089686	3.129870
Flexibility of supply	3.058296	3.103896
Assortment errors in deliveries	2.995516	2.987013
The limited production capacity of suppliers	2.950673	2.961039
Technological problems	2.834081	2.961039
No emergency delivery plans	2.766816	3.012987

Source: results of the empirical study

Table 3. The importance of risks in relationship with suppliers (comparison between the segments depending on the sector, ranking using the Likert scale, correlations)

Risks in relationship with suppliers	Sectors		
	Automotive N=99	Metal N=104	Chemical N=97
Timely deliveries	3.606061	3.423077	3.587629
Quality defects of products	3.454545	3.240385	3.257732
The financial situation of suppliers	3.313131	3.201923	2.835052
Communication problems	3.414141	2.951923	2.938144
Flexibility of supply	3.282828	2.971154	2.958763
Assortment errors in deliveries	3.080808	3.096154	2.793814
The limited production capacity of suppliers	3.030303	2.875000	2.958763
Technological problems	3.050505	2.855769	2.690722
No emergency delivery plans	2.838384	2.894231	2.752577

Source: results of the empirical study, 2017

Table 4. The importance of activities related to the evaluation of the supplier before buying (general results and a comparison between the segments depending on capital, ranking using the Likert scale, correlations)

Form of assessment	General N=300	Capital	
		Polish N=120	Foreign N=180
Testing the product batch	4.006667	4.125000	3.927778
Product certificates	3.436667	3.491667	3.400000
Audit of supplier	3.240000	3.133333	3.311111
System certificates	3.173333	3.341667	3.061111
Assessment of the supplier using the evaluation questionnaire	3.153333	3.050000	3.222222
Due diligence	3.143333	3.058333	3.200000
Reference visits	2.886667	2.758333	2.972222

Source: results of the empirical study

Table 5. The importance of activities related to the evaluation of the supplier before buying (comparison between the segments depending on the number of employees, ranking using the Likert scale, correlations)

Form of assessment	Number of employees	
	-250 N=223	251- N=77
Testing the product batch	3.955157	4.155844
Product certificates	3.390135	3.571429
Audit of supplier	3.219731	3.298701
System certificates	3.147982	3.246753
Assessment of the supplier using the evaluation questionnaire	3.134529	3.207792
Due diligence	3.112108	3.233766
Reference visits	2.852018	2.987013

Source: results of the empirical study

Table 6. The importance of activities related to the evaluation of the supplier before buying (comparison between the segments depending on the sector, ranking using the Likert scale, correlations)

Form of assessment	Sectors		
	Automotive N=99	Metal N=104	Chemical N=97
Testing the product batch	3.898990	3.942308	4.185567
Product certificates	3.393939	3.269231	3.659794
Audit of supplier	3.404040	3.192308	3.123711
System certificates	3.343434	2.971154	3.216495
Assessment of the supplier using the evaluation questionnaire	3.282828	3.067308	3.113402
Due diligence	3.333333	2.971154	3.134021
Reference visits	2.989899	2.932692	2.731959

Source: results of the empirical study

The surveyed enterprises indicted that the essential pre-purchase forms of assessment of threats related to suppliers included: testing the trial batch and possessed product certificates. These forms of assessment are particularly important for large companies (employing over 250 employees with Polish capital, mainly from the chemical sector.) As other essential forms of risk assessment related to suppliers, the surveyed business entities indicated:

supplier audit, system certificates, initial and periodic supplier evaluation using the evaluation questionnaire as well as due diligence. Detailed results of the research are presented in the tables below:

The supplier's audit is of particular importance to large enterprises with foreign capital from the automotive sector. In turn, system certificates are essential for large business entities with Polish capital from the automotive and chemical sectors. The initial and periodic evaluation of the supplier using the evaluation questionnaire as well as due diligence are focused on large companies with foreign capital from the automotive sector.

CONCLUSIONS

Recapitulating the theoretical considerations and the results of empirical study, it can be stated that the role of the risk management concept in relations with suppliers will still be significant. Risk management is still essential to ensure the safety of purchased products as well as to ensure the continuity of processes to avoid disruptions. It can also be observed that for many companies, relationships with suppliers are not limited to setting strict requirements for them and monitoring their compliance on a continuous basis. Increasingly, business customers operating on the B22 market offer their suppliers' support programs. These programs are concentrated in joint projects regarding the implementation of both product innovations (improvement of current technical parameters and implementation of new products), as well as organizational ones that contribute to improving efficiency (increasing the level of timeliness, delivery defects). These programs also focus on the efficiency of processes (reducing costs by increasing employee / infrastructure performance, or eliminating unnecessary activities and unused / underused resources). It can be noticed that the international expansion of many companies, especially global companies, increases the importance of technical standardization. This is particularly important in countries where investments are located due to lower labour costs like Central and Eastern Europe and Asia. In these countries, one could perceive a gap in the field of organizational solutions between international corporations and indigenous businesses. In many cases, this gap is outweighed by the introduction of the concept of risk management. International companies implementing this concept focus on the cooperation with their partners in the supply chain (suppliers and customers), offering them support through joint projects. These initiatives are aimed at improving common processes and developing concepts for new products. Cooperation between business clients and their suppliers undoubtedly contributes to forming long-term mutually beneficial relationships between partners. Early supplier development in R & D processes can effectively eliminate potential errors associated with new product and mitigate the risk of not guarantees of safety for users and the environment. The effects of this cooperation allow an increase in the technological and organizational capabilities of partners, which affects their competitive advantage.

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CZYNNIKI ZWIĄZANE Z RYZYKIEM WPŁYWAJĄCE NA RELACJE Z DOSTAWCAMI

STRESZCZENIE. **Wstęp:** W ostatnim okresie coraz więcej przedsiębiorstw międzynarodowych wdraża strategie oparte na koncepcji zarządzania ryzykiem. Przedsiębiorstwa te, gdy oceniają i te kwalifikują swoich dostawców wykorzystują wymagania standardów zarządzania jakością, standardów zapewnienia jakości (w poszczególnych sektorach), standardów bezpieczeństwa, a także standardów zarządzania ciągłością działania. Celem artykułu jest określenie znaczenia czynników związanych z ryzykiem w relacjach z dostawcami.
Metody: Badania zostały przeprowadzone pomiędzy październikiem a listopadem 2017 z wykorzystaniem techniki wywiadu telefonicznego wspomaganego komputerowo (CATI). Badania objęły przedsiębiorstwa z sektorów motoryzacyjnego, metalowe i chemicznego, prowadzące działalność na polskim rynku B2B.
Wyniki: Badane przedsiębiorstwa jako główne źródła zagrożeń w relacjach z dostawcami wskazały: nieterminowość dostaw, wady jakościowe produktów, sytuację finansowa dostawców, problemy komunikacyjne z dostawcami, niski poziom elastyczności dostaw, pomyłki asortymentowe w dostawach, a także ograniczone zdolności produkcyjne dostawców
Wnioski: Rekapitulując rozważania teoretyczne oraz wyniki badań empirycznych można stwierdzić, iż rola koncepcji zarządzania ryzykiem w relacjach z dostawcami jest niewątpliwie istotna. Zarządzanie ryzkiem odgrywa ciągle ważną rolę zarówno w zapewnieniu bezpieczeństwa kupowanych produktów, jak i zapewnia ciągłości procesów i unikaniu zakłóceń w funkcjonowaniu łańcuchów dostaw.

Słowa kluczowe: stosunki z dostawcami, zarządzanie ryzykiem, standardy zarządzania bezpieczeństwem w łańcuchu dostaw

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ORIGINAL PAPER

APPLICATION OF PREDICTION MARKETS PHENOMENON AS DECISION SUPPORT INSTRUMENT IN VEHICLE RECYCLING SECTOR

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ABSTRACT. **Background:** The key players in the vehicles' recycling system are disassembling facilities, which manage flows of waste and reusable parts. The focus of the company's business activity lies in stream of reusable parts, which is the most valuable, considering possibilities of selling (economic value) and resources saving (ecologic value). As a result of conducted research problem with demand forecasting was identified, which was affected by the specific domain of business. The major objective of the paper was to present how to support demand forecasting on parts in disassembling facility with the use of predictive markets.
Methods: The problem area related to the demand forecasting in the disassembling companies was identified based on the previously conducted research and observations. The desk-research method was used to verify current knowledge on the forecasting methodology. Taking it into account, the predictive markets method was chosen in a specific research problem.
Results: In the paper, the idea of predictive markets was presented. What is more, general procedure of its implementation and practical application in supporting decision in disassembling companies were described.
Conclusions: Predictive markets which are based on the idea of crowdsourcing, use collective crowd intelligence, supporting many business areas, including automotive industry. The predictive market method was successfully adopted in disassembling facility in order to support decisions on demand forecasting of reusable parts. The main challenge in introducing predictive markets for enterprises application is IT support and that outlines direction for future research

Key words: predictive markets, disassembling facility, demand forecasting, spare parts.

INTRODUCTION

Among scientific research and papers connected to the automotive industry, there may be specified few groups of issues examined from the perspective of life-cycle stage of an automobile including i) development & manufacturing, ii) use and iii) disposal (end-of-life) (Figure 1), , however complexity of a certain product affects sophistication of interrelated flows and processes.

The recent technology development has led to challenges in the use of vehicles and their disposal (e.g. in considerably reduction of vehicles life cycles [Volpato and Stocchatti 2008]. The shortening of product life cycle in the automotive industry has resulted in a growing number of vehicles at the last stage, what in authors' opinion has not drawn a lot of attention of business and academia. On the basis of research experience, it was stated that the most challenging phase is end-of-life stage.

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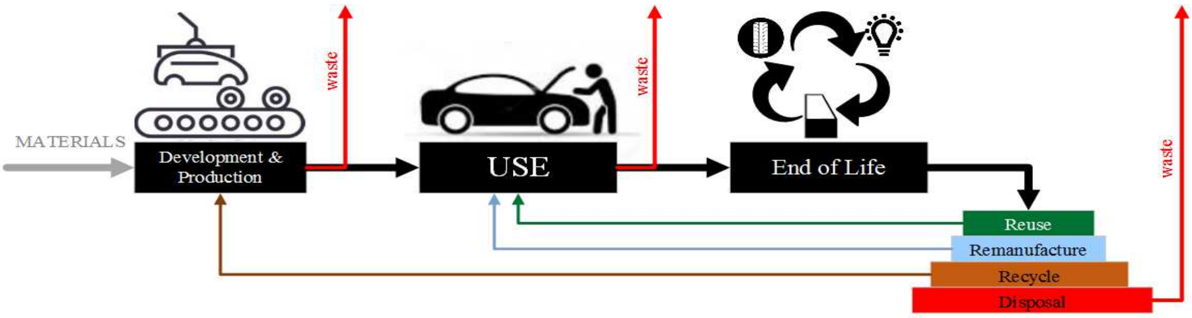


Source: own work

Fig. 1. Life cycle stages of an automobile

In previous research [Czwajda et al. 2017], it was claimed that automotive industry is one of the worldwide uppermost industry. Moreover, taking into account information about: influence of automotive industry in Polish Economy, role in the production of light vehicles in the Central Europe, total size of the vehicle fleet and age of the vehicle fleet, it was stated that there is high potential for vehicles recycling in Poland, particularly for disassembling facilities business (given in details e.g. in [Kosacka et al. 2016]). The company, which is investigated in this paper, represents a recycling sector as a disassembling facility, processing 1200 end-of-life vehicles (ELVs) per year, what makes it one of the biggest company in the recycling business in Poland.

With reference to Figure 1, authors recommended to use in the paper a ''waste recovery hierarchy'' proposed in [Gehin et al. 2008]. According to [Gerrard and Kandlikar 2007] reuse scenario should be preferable in terms of energy saving and environmental impact. In accordance to previous research, authors claimed that more than 60% of revenues of disassembling enterprises are created by selling used spare parts [Czwajda et al. 2017]. Customers are interested in purchasing used spare parts because of the lower price as well as possibility of obtaining parts which are no longer produced. To sum up, reuse scenario is the most lucrative part of disassembling company business, while it is also the most environmental friendly, however it has been also the most problematic what may be an effect of lack of demand forecasting on reusable parts, resulting in problems at the operational level.

On the basis of previous research [Czwajda et al. 2017], it was stated that demand forecasting of used parts causes many positive effects, not only economic but also social and ecologic. Thus, in the paper, there was proposed usage of virtual prediction markets to support decisions related to demand forecasting as an emerging problem area in conducting disassembling business. Authors believed that originality of work lies in proposed approach as well as object of research. In order to emphasize the essence of the issue a list of research questions (RQ1-RQ4) was prepared. The answers are presented in the next sections of the paper.

- RQ1: What methods are available for demand forecasting?
- RQ2: What is specific in demand's prediction on reusable parts in a disassembling facility?
- RQ3: How to use prediction markets in disassembling business?
- RQ4: How to apply prediction markets in order to support disassembling facility processes?

The paper was organized as follows. In the Section 2 theoretical background of demand forecasting and practice in a chosen Polish disassembling company were presented. In the Section 3, basic information about virtual prediction markets were highlighted as an support for demand forecasting. In the Section 4, information about potential applications of prediction markets in recycling business were included and guidelines for virtual prediction markets application were developed. In the conclusion, limitations as well as benefits from use of predictive markets in recycling sector were described. Moreover, authors have presented future research directions.

DEMAND FORECASTING IN DISASSEMBLING COMPANY

Demand forecasting – theoretical background

Demand forecasting plays essential role in the operations of each organization which would be integral part of actual supply chain. In general, it is understood as a process of predicting something, with considerations given to past trends, historical data and anticipated future occurring parameters. Forecasts are made over a selected planning horizons or study periods. In principle, it can be stated that their role is connected to decisions support in three primary planning horizons: operational (for one year), tactical (from one to ten years), strategic (from ten to thirty years), or in other way this planning horizons are connected to near-term, mid-range or long-range needs. The base for demand forecasting is methods based on statistics and econometrics. Forecasting methods can be divided into two main categories – qualitative and quantitative and are given in the Table 1.

Table 1. Forecasting methods and example of their usage in scientific literature

Qualitative	Quantitative	
Unaided judgement	Extrapolation	Box-Jenkins, AutoRegressive Integrated Moving Average
Judgemental decomposition (multiplicative decomposition)		Damped trend (damping a trend-series trend, damping seasonal factors, damping by averaging seasonality factor across analogous situations)
Expert survey (e.g. Delphi method)		Exponential smoothing
Structured analogies		Decomposed extrapolation
	Traditional and modified time series methods	Moving average, exponential smoothing (Single Exponential Smoothing, SES), exponentially weighted moving average (EWMA), adjusted EWMA, adjusted Holt and Holt-Winters methods, Croston method, Syntetos-Boylan Approximation (SBA), Poisson method, Grey prediction model
Game theory	Quantitative analogies	
Judgemental bootstrapping	Casual models	Segmentation
Intention survey		Regression analysis
Expectation survey		Index method
Simulated interactions (role-play)	Neural nets, Support vector machines	
Experimentation	Rule based forecasting and contrary series rule	
Experts systems	Methods of econometrics	
Focus groups	Data mining	
Scenarios	Big data analysis	
Conjoint analysis	Conjoint analysis	
Prediction markets	Computational simulation methods	

Source: own elaboration on the basis: Lawrence et al. 2009, Armstrong and Green 2017.

Group of extrapolation methods consists of Box-Jenkins, damped trend methods such as: damping a trend-series, which reduce forecasting error by almost 5% [Armstrong 2006]; damping seasonal factors [Miller and Williams 2004]; damping by averaging seasonality factor across analogous situations increased forecast accuracy by 7%, compared to using seasonal factors that were estimated individually for each precinct, according to [Gorr et al. 2003], the most widely used method of exponential smoothing [Gardner 2006] and decomposed extrapolation.

Traditional series method are subdivided into: moving average [Makridakis et al. 1998], exponential smoothing, exponentially weighted moving average (EWMA), adjusted EWMA for forecasting intermittent demand [Johnston and Boylan 1996], adjusted Holt and Holt-Winters methods [Altay et al. 2008], Croston method, Syntetos-Boylan Approximation

[Syntetos and Boylan 2001], Poisson method, Grey prediction model. Traditional time-series methods, such as moving average or single exponential smoothing are still the most used in business practices [Bacchetti and Saccani 2012].

Quantitative analogies methods are applied when analogous situation are available – it was proved by [Li et al. 2009] that this method was 2% more accurate than theoretical statistical ones, and 11% more accurate than usage of neural nets methods [Green and Armstrong 2012]. The neural nets were about as accurate as forecasts from established extrapolation methods [Crone et al. 2011] and more than 3% less accurate than damped trend-forecasts.

Casual models were applied in case of situations with large changes expected and in these cases they were more accurate than extrapolating methods [Allen and Fildes 2001]. One of the most often used methods of this group is regression analysis.

In the case of qualitative methods, given in Table 1., following can be mentioned. Structured analogies are methods that are formal and unbiased and they were 41% more accurate than unaided judgment. It is similar in the case of expert systems [Collopy et al. 2001]. Expert surveys, especially the Delphi method, avoid disadvantages of traditional group meetings – they were more accurate in 80% then the mentioned meetings [Rowe and Wright 2001].

Intention and expectation survey are often used for demand forecasting, however these methods needs similar questions in surveys to check participants answers due to their biases. Therefore, response errors in case of such are large component of forecasting errors.

The basic disadvantage of the qualitative techniques is subjectivism, however simplicity, clarity and low-cost, advocates in favors of those methods [Rosienkiewicz et al. 2017].To sum up, it can be claimed that it is difficult task to choose well-fitted forecast method and it depends on various factors, including: current market situation, the cost and time consumption of forecasts creating, and accuracy of particular forecasting methods.

In general, it can be claimed that with proper transposition of forecasting methods, each of them can be used in demand forecasting. According to [Armstrong and Green 2017], the problem is that many of these methods, are not sufficiently discussed in the literature. Armstrong and Green [2017] admitted that the most common reason forecasters avoid a scientific approach to forecasting is because the decision-makers have already made a decision and are only interested in information to support that opinion. However, it is worth noting that the degree of matching of the methods to certain aspects of defined problems and the size of the prediction errors may be different depending on the problem which is under consideration. Much also depends on the degree of accuracy of particular method used in order to predict some phenomena. An unambiguous designation of the method, that best suit to forecasting problem, requires in-depth studies and using the same data for subsequent forecasting methods. Such a task has a long time horizon, so the authors of the paper decided to start this type of research from the implementation of the prediction markets method.

The above considerations constituted an answer to the research question RQ1.

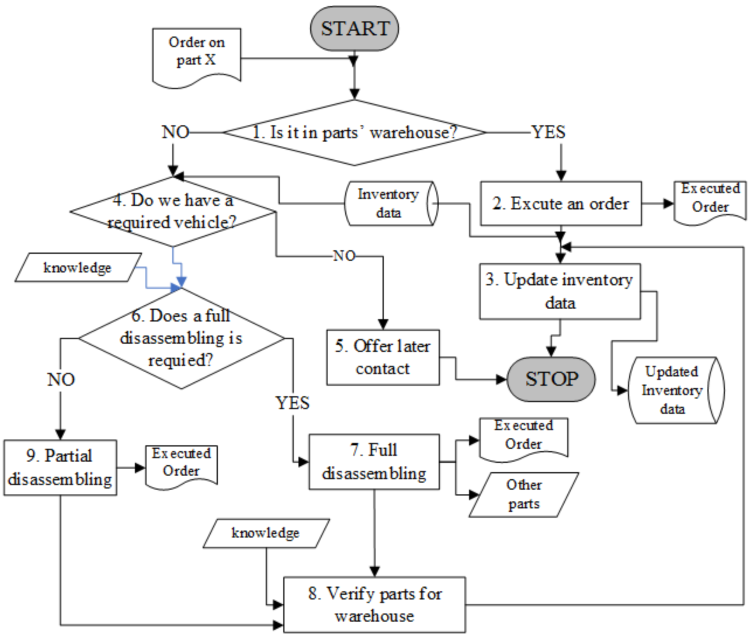
DEMAND FORECASTING IN DISASSEMBLING COMPANY – STATE OF ART

Regardless of the geographic location, disassembling companies play a crucial role in recycling network and they have to deal with illegal recycling business, what in details was presented e.g. in [Kosacka et al. 2016]. Considering the high importance level of the disassembling facility and demand forecasting, in this section, there was described a demand forecasting process.

Taking into account the fact, that reusable parts determine majority of disassembling company's profit, authors stated that the company should be focused on that material flow. The flow of parts determined for reuse scenario is affected by law requirements, because of safety factors, so there is a catalogue of parts not allowed to reuse [Directive 2000/53/EC].

Authors claimed, that considerations about reusable parts obtained from vehicle's disassembling should be always made in relation to product (vehicle) and the demand on new parts, because they demonstrate similar sale features. The list of factors affecting requirements and realization of management and demand forecasting were presented in [Czwajda et al. 2017].

The company considered in this paper is a typical representative of the disassembling companies in Polish recycling sector. The major rule determining the disassembling process is availability of parts according to customer's demand (time, quantity, technical conditions). In the Figure 2 execution of customers' orders was presented.



Source: own work

Fig. 2. Execution of customers' orders

When the order appears, the availability of particular part is verified in the company's inventory. Reusable parts are object of interest not only by end-users, but also some institutions including automobile shops or workshops. There are used two business models of parts sale, including direct sale from disassembling facility and the use of Internet distribution channel (via Internet, social media, automobile's forum). In order to save the space and fulfill legal requirements, in disassembling companies there are warehouses for parts dismantled from ELVs, however there are also full ELVs on stock. When the order is received, the part's availability is checked. Firstly, there are verified inventory in a warehouse of parts, secondly ELVs in stock. When the requested part is out of stock, company offers customer to contact later. If the part is available, in the first place it is sold from the parts' stock in the warehouse, in other case it is removed from stored ELV. Sometimes, in order to get to the particular part, there have to be made a full disassembling of a vehicle, what engaged a company's worker. Each disassembled part is tested in order to check the technical efficiency. If it is good, part may be sold, in other case it is verified in order to be repaired/refurbished.

The scope of disassembling, used methods and tools is determined by customer's needs, part's technical condition and implicit knowledge of the employees about market demand [Czwajda et al. 2017].

In author's opinion the major problem is that, the last factor is the most influential, what makes the disassembling process dependent on subjective opinions of workers. Moreover, the company may have a direct impact on employees and it may indirectly affect the technical condition of parts, however there is lack of influence on the market demand. Although, the knowledge of the market is available (e.g. sales figures), it is not used to predict future demand. In the result, in may cause wrong decisions made on warehousing.

To sum up, authors stated that:

- there is lack of methods or tools used in order to forecast market demand,
- the most frequently used data source for making decisions on parts in stock is implicit knowledge of employees,
- demand forecast affects decisions on inventory management what has an influence on company's profit, environment condition and people's comfort due to the resources consumption.

Authors claimed, that demand forecasts are not a goal in and of itself, but they may be a tool supporting the planning and management of various aspects of disassembling company business. To sum up, it was claimed that in presented consideration, there was explained specificity of demand forecasting for reusable parts in disassembling facility, according to RQ2.

PREDICTION MARKETS AS A DECISION SUPPORT TOOL - ORIGIN OF PREDICTION MARKETS

Prediction markets are based on the crowdsourcing research methodology [Czwajda et al. 2017]. Crowdsourcing is the process of using the potential of knowledge and a virtual community for solving business and social problems. It requires creating easily accessible and intuitive tools that support interaction [Przybyła and Sobczak 2010]. It is based on the will of users, participating in a given project. An important aspect of this process is the motivation e.g. in the form of prizes. In this case, carefulness is required to not make it process of "buying participants" opinions In practice, crowdsourcing includes a lot of different activities described in: [Grela 2014].

However, the concept itself is not new, the growing importance of the Internet and the increase of modern technology, has opened new possibilities for the use of this tool. There are currently 14 key areas of crowdsourcing use, that are presented in Table 2. The original definitions of crowdsourcing significantly narrowed the possibilities of using this solution. This tool allows to acquire knowledge, ideas, content or solutions to problems in a faster, cheaper and better quality, than traditional models.

In the paper, there were used prediction markets to solve the problem of forecasting demand on parts.

On the predictive markets, platform users try to predict the probability of certain events. Literature research shows that the predictive market gives the possibility of better assessment than questionnaire surveys. This is the result of asking participants not only to perceive reality, but also to estimate probability of the event appearance on the market. Considering that, it was found that such approach requires a rational look at the facts and gives the opportunity to assess the event that affects the outcome of the market event [Wolfers and Zitzewitz 2004]. The advantage of predictive markets is so-called wisdom of the crowd, that leads to use of a diversified knowledge.

However, there are a lot of advantages of predictive markets use, authors of the paper are aware of weakness related to crowd's requirement. If the number of players is small, the answers received will not be so reliable. Moreover, there is also the risk of market manipulation, when access to the market is too easy, however this aspect is not covered by literature.

Table 3. Possibilities to use crowdsourcing

Type	Principle of operation	Example
CrowdIntelligence	Collective intelligence of the community.	Quora
Open Innovation	Using resources outside the company's direct environment, in order to create innovative solutions.	Procter&Gamble PG Connect+Develop
Crowd Causes	Units or charities supporting projects aimed at social welfare-oriented aid.	XPrize
Crowd Tasks & Creativity	Projects aimed at performing tasks, providing services through a large and dispersed internet community.	Amazon Mechanical Turk
Social Business	Companies focused on authentic listening, engaging through open social channels.	Dell
Customer Co-creation	Cooperation between the company and the consumer group focused on developing a joint solution.	Company Citroen
Citizen Engagement	Involving residents to jointly manage the city.	WeDundee (Scotland), Open Warsaw Project
Mass Collaboration	Independent cooperation of a large number of users on the one project.	Wikipedia
Online Communities	Internet communities characterized by a high interaction rate between them, which share a common idea, interest or idea.	Reddit platform
Sharing economy	An economy based on sharing.	Uber Organization, Hotel Airbnb
Non-Equity Based Crowdfunding	The members of the community financially support the project or project in exchange for the rewards of being able to use the service.	Kickstarter platform
Equity-Based Crowdfunding	Community members become shareholders of a project or project.	Crowdcube
Peer-to-Peer Lending	Social lending money without the participation of a financial institution.	Lending Club
CrowdCurrencies	Alternative currency systems created by online communities.	Bitcoin

Source: own on the basis of Kasprzycki-Rosikoń, 2016

In recent years, there has been a dramatic increase in research using predictive markets. They were used in predicting: future events, presidential elections in the USA [Forsythe et al. 1992] anticipation of the Taiwan epidemic [Tung et al. 2015] and in supply chain management [Hedtrich et al. 2009]. Prediction markets are commonly used in a business practice e.g. by companies such as: Hewlett Packard [Ho and Chen 2007] or Microsoft [Grela 2014]. In Poland, in 2014, the Agency for Industrial Development S.A. and the Center for Applied Mathematics and Systems Engineering PAN launched the prediction market, which has been used to predict the development of modern technologies with particular emphasis on grapheme [Czwajda et al. 2017].

PREDICTION MARKETS IMPLEMENTATION – CASE STUDY

In the Introduction, there were mentioned factors proving problems with demand forecasting for reusable parts, including lack of impact on input material stream (ELVs), influence of limited space, subjective decisions of employee's on the basis of their implicit knowledge, and at almost marginal access to information on market demand. Considering the fact that, there is lack of access to the records of sold parts, it was claimed that, the possibility of analysis and verification of the quantity of stored parts/vehicles is decreasing. Prediction markets are specific forecasting tools, which use the implicit knowledge of their users to predict the occurrence of various events. What is more, in order to verify the forecasts obtained from the markets, there may be used data given from reports, statements and intermediate data, with appropriate references to the subject of the event.

The diversity brands and models of vehicles intended for re-use has a vital impact on disassembling business. In the examined enterprise there are on average about 100-200 different vehicles ("temporary warehouse") and about 40 types of different parts, that can be obtained from one vehicle [Czwajda et al. 2017]. Considering that, it was stated that there is a need for solution dedicated for demand on spare parts forecasting.

The market for demand forecasting for vehicle's parts/vehicle, consists of the following elements:

- precisely defined object to be foreseen,
- market's participants,
- set of rules,
- network communication platform available for project participants,
- market provider that defines, enforces and maintains an internet platform.

The prediction market has been used in the presented research.

It was stated, that prediction markets may be used not only for forecasting trends of the new technologies development in the automotive industry, but also for demand forecasting on parts from stored vehicles (ELVs).

Source: own work

Fig. 3. Ideological scheme of using the functionality of the prediction market to determine the number of stored cars / parts at disassembling enterprise

With reference to Figure 3, there were determined six steps necessary to use the functionality of the prediction market in the research on disassembling company, including:

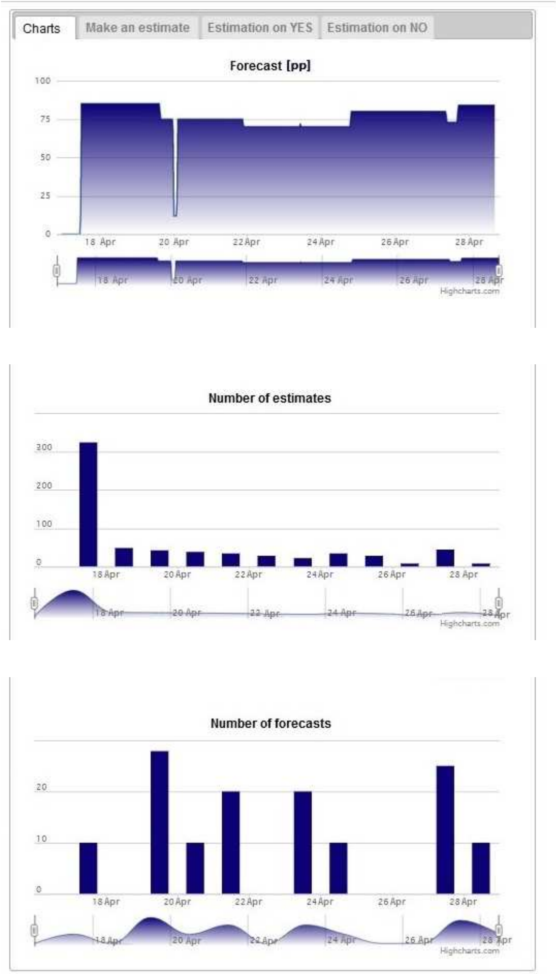
Step 1. Creating and placing a question on the market

- The research was carried out on the currently operating research predictive market and consisted of the following steps:
- A representative group of users consists of: dismantling company employees who are responsible for the dismantling process and the distribution process – these people have knowledge about the market demand for particular parts (treated as experts) [Czwajda et al. 2017]. Four events concerning on the sale of new passenger cars of particular brands were placed on platform, in order to examine the trends in their sales. The limitation of the research was questions' introduction on the existing market. At the stage of questions definition, there were considered the following issues: the inability to verify the event by records of sold parts and the subject of current questions. The structure of the question placed on the market was as follows: Will the car brand increase their new cars' market share in Poland?
- The event was introduced to market for a period of 1.5 months. During that period of time, users are expected to make predictions at least once a week for each event. Events on the platform are resolved 10 days after they are closed.

Step 2. Actual monitoring

Prediction markets provide the possibility of ongoing monitoring of the size of the forecasts and their quantity. Visual data presentation from the market, makes it possible to observe the current trend of occurrence of a given event (Figure 4.)

What's more, the forecasting markets also enable the creation of current summaries of all open events on the market, which allows the simultaneous monitoring of the values of forecasts for all open events.



Source: website of the predictive market used in the research

Fig. 4. The level of the forecast of a given event, the number of estimates and forecasts

Step 3. Event's resolution

Forecast's accuracy is determined on the basis of a comparison of the value of the last forecast and its result obtained from the verification of data obtained from reliable sources, e.g. reports, lists, press reports. Owing to the fact that, there are problems with reporting in Polish recycling system, there was impossible to get information about the number of sold, used spare parts in particular time intervals. As the result, it was assumed that the increase in the number of cars of particular brands on the market, will cause demand for spare parts from the disassembly station. Taking into consideration fact, that majority of Polish recycling companies represent small and medium sized enterprises, which operate in the grey marketplace, there were identified problems with access to the sold parts records. Predictive markets give the possibility to use related data to verify the accuracy of the obtained forecasts, which was the major reason for using in the conducted research reports on registration of new passenger cars, in order to resolve the event.

Step 4. Determining the accuracy of forecasts based on historical data

The market archive of platform currently consists of more than 270 settled events connected to various issues concerning new technologies with their number, the size of the last forecast and the obtained result. Based on the already settled events, it was possible to estimate the accuracy of the forecasts for directions of new technologies development. An accurate forecast is considered to be the one in which, after the event's settlement, it turned out, that the event occurred in accordance with the predictions of users playing in the prediction market. The event on the prediction market is settled on YES, if the value of the last forecast is above 0.50, if the forecast result is below this value, then the event is defined as such which will not take place [Czwajda et al. 2017].

Relevance of the forecasts made with use of the platform is as follows. The Table 3 presents the accuracy of forecasts, expressed as a percentage, depending on the three ranges of the quantities of forecasts for a given events. The accuracy of predictions is determined for resolved events analyzed on the platform. A total of 277 settled events from this platform were analyzed. According to the content of Table 3, the accuracy increases while the quantity of forecasts increases, which corresponds to the idea of the wisdom of the crowds. In the case of the analysis of the accuracy of forecasts concerning the directions of new technologies development, the verification of forecasts is mainly based on press reports and published articles. It is because of the fact that data, on which forecasts are made, are characterized by limited access. Therefore, it was assumed that the accuracy of the forecasts achieved at the level of 74.3% could be considered as a good result (the value of 72.6% refers to the percentage of accuracy without considering the division into the range of small, medium and large forecasts). The authors of the paper, based on the analysis of events' relevance resolved within the prediction market, stated that with the ease of access to data, the accuracy of forecasts is increasing. Owing to this reason, the prediction markets method can be the subject of research, analysis and application in the aspects considered in this paper.

Table 4. Accuracies of forecasts depending on the quantity of forecasts of occurrence of a given event

Quantity of predictions for the event	Accuracy of forecast [%]
1-75 (small)	66.7
75-200 (medium)	69.1
> 200 (large)	74.3

Source: own work

Step 5. Setting sales trends for particular car brands

Predictive markets provide the opportunity to simultaneously evaluate the best-selling brands/car models, develop new trends and technologies in the automotive industry, such as electric and autonomous cars.

There have been introduced few events on the market, investigating the sales trends of currently best-selling car brands. The purpose of this action was to anticipate the demand for spare parts from these car brands. It resulted from the assumptions made by authors of the paper, that the greater the share of cars of a given brand on the market, the greater the need for spare parts of that brand.

Taking into account the fact that the Polish fleet of passenger vehicles is quite numerous, it was found that the greater the number of vehicles on the roads is accompanied by a higher risk of collisions and accidents. As a result, it was stated that there will be provided greater input stream for processes carried out at disassembling facility. In authors opinion, adopted approach convince of the rightness of questions put on the platform.

Step 6. Determination of the number of stored cars / parts at dismantling stations

After forecasts' accuracy establishment from the selected research area, it is possible to undertake activities aimed at the current assessment of inventory, demand monitoring and inventory level updating with the specific frequency e.g. every two weeks.

Predictive markets with unlimited access to cyclic data, e.g. records / reports on the sale of used spare parts, can be used, among others to update the level of stored inventory depending on the size of the obtained forecast, however, it requires further research.

Activities included into this step are particularly important for the examined enterprises, what results from the limited warehouse space. It is noteworthy that, according to the law, parts should be stored in a roofed building, however, due to space constraints, it is not respected requirement (on the basis of the Directive 2000/53/EC). This results in operating costs climb by the environmental penalties.

To sum up presented procedure, following six steps described in details in this Subsection, there was introduced the application of predictive markets in demand forecasting for parts in disassembling business. Consequently, the RQ3 and RQ4 were answered contemporaneously.

CONCLUSIONS

In authors opinion, predictive platform have many advantages, what justifies their use in the conducted research. There were indicated the following advantages of predictive platform use:

- the prediction platform accurately predicted the results of 3 out of 4 events regarding car sales;
- current market situation consideration, what is an advantage of predictive platform in comparison to mathematical models, that are based on fixed conditions. It should be noticed, that the demand on used spare parts

is variable, what convinces of the superiority of the proposed solution in relation to mathematical models;
- possibility of use indirect data, which require appropriate establishment and construction of a questions on the market;
- possibilities of research on various aspects of disassembling company's activity. It is possible to introduce a lot of questions on the platform, related to one specified area or various business activities, including trends and technologies development in the automotive industry. As the result, it allows to analyse recycling company in Poland from different problem areas, in order to improve realized processes. While there are no technical limits to the number of questions, which can be asked on a prediction market simultaneously, market administrator must customize the number of questions to the number of current market participants, so that the number is neither too small (which makes the market not interesting), neither too large (which makes the market overwhelming);
- operating on the principle of the crowds' wisdom, allows to use the implicit knowledge of platform users and to carry out the gradation of obtained data;
- design on the principle of gamification, makes it possible to create mechanisms that motivate users to play and share knowledge;
- possibility of use the implicit knowledge of employees by employers and to shape their knowledge sharing attitude;
- use the knowledge of experts which are the direct stakeholders of recycling companies, including customers and suppliers, as well as employees or station owners, activating them and people indirectly associated with the recycling industry, such as car users, motoring enthusiasts, people associated to the automotive industry: bloggers, researchers, etc.

Considering specific factors of disassembling business, authors selected predictive market as appropriate tool for demand for reusable parts forecasting.

Taking into account the significance of the disassembling facility, in the context of the company's activities, there was identified a need to support the decision-making process related to forecasting the demand for spare parts. It was stated, that uncertainty and problems with reliable data are premises for predictive markets use in the vehicles recycling sector.

Authors are aware of predictive markets limitation including the originality of recommended tool. However, use of internal and external experts becomes an opportunity to better utilize people's knowledge, which has been already the base for demand forecasting in the disassembling business.

The main challenge in introducing predictive markets for use is the cost of analysis, the requirement for IT support and the introduction and motivation of participants to play on the platform.

Authors' future direction of the research include: use of predictive markets to monitor the level of spare parts stocks, assessment of the level of risk occurring in various areas of the disassembly station's operation.

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WYKORZYSTANIE RYNKÓW PREDYKCYJNYCH JAKO NARZĘDZIA WSPIERAJĄCEGO PODEJMOWANIE DECYZJI W SEKTORZE RECYKLINGU SAMOCHODÓW

STRESZCZENIE. Wstęp: Kluczowym ogniwem w systemie recyklingu samochodów są stacje demontażu, zarządzające przepływami odpadów oraz części zamiennych. Przedsiębiorstwa te w swojej działalności skoncentrowane są na strumieniu części zamiennych jako że jest on najbardziej wartościowy, mając na uwadze możliwości sprzedaży (wartość ekonomiczna) jak również oszczędzanie zasobów naturalnych (wartość ekologiczna). Zważywszy na wartość przepływu części zamiennych, zidentyfikowano problem związany z prognozowaniem zapotrzebowania, co związane jest z charakterem prowadzonej działalności. Biorąc pod uwagę fakt, że strumień wejściowy samochodów przetwarzanych w przedsiębiorstwie, jest poza jego kontrolą, podjęto próbę wspierania prognozowania zapotrzebowania na części (strumień wyjściowy) za pomocą wykorzystania rynków predykcyjnych.
Metody: Na podstawie wcześniej przeprowadzonych badań, zidentyfikowano problem związany z prognozowaniem w stacji demontażu pojazdów. Wykorzystano metodę analizy i krytyki piśmiennictwa w celu zbadania istniejących opracowań w zakresie metod prognozowania. Mając na uwadze wyniki badania literatury, wykorzystano metodę rynków predykcyjnych, którą wykorzystano w wybranym obszarze badawczym.
Wyniki: W pracy przedstawiono ogólną procedurę dotyczącą wykorzystania i wdrożenia rynków predykcyjnych w procesie wspierania podejmowania decyzji w stacji demontażu pojazdów, w obszarze prognozowania.
Wnioski: Rynki predykcyjne, opierające się na idei crowdsourcingu, wykorzystują tzw. „mądrość tłumu", wspierając zróżnicowane obszary działalności biznesowej, w tym również branżę motoryzacyjną. Publikacja może być traktowana jako przewodnik w zakresie użycia rynków predykcyjnych w specyficznym obszarze problemowym, w tym również tak skomplikowanym jak prognozowanie zapotrzebowania na części zamienne w stacji demontażu pojazdów.

Słowa kluczowe: rynki predykcyjne, stacja demontażu pojazdów, prognozowanie, części zamienne

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ORIGINAL PAPER

THE DIAGNOSIS OF ORGANIZATIONAL CULTURE AS A CHANGE'S FACTOR IN THE CONTEXT APPLICATION OF DESIGN THINKING

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ABSTRACT. **Background:** Literature studies and analysis of the situation in business practice indicate the organizational culture as an important determinant that can inhibit or assist in the implementation of adaptive, proactive and proinnovation changes. New situations appearing in the external and internal environment as well as new conditions created by technical and technological progress oblige enterprises to adapt or even anticipate changes. Readiness for modification occurs when employees are not satisfied with the existing organizational culture and they prefer a different one. The diagnosis of the discrepancy between the existing and expected organizational culture allows us to assess the willingness to change the situation in the enterprise. This article presents a case study focused on identifying the actual and desired organizational culture in order to diagnose the crew's readiness for changes in the company and possibility an application of design thinking as a as a way to implement innovative solutions.
Methods: The study was conducted in was used OCAI questionnaire, whose authors are: K.S. Cameron and R.E. Quinn. While using the questionnaire, the current and desired state of the organizational culture of the analysed enterprise has been determined. Based on literature studies, the possibilities of using design thinking in the process of changing the organizational culture were verified.
Results and Conclusions: The research results reveal dissonance between the existing and desired state and enable the assessment of the willingness and readiness of the company's staff to change and the possibility of using design thinking. The aim of study was to identify a research gap a diagnosis organisational culture as a factor in change and a possibility of using design thinking in process change. Organizational culture in the course of changes in an enterprise has a decisive impact on employees' abilities and inclinations to develop and implement new ideas.

Key words: organizational culture, changes in organization, design thinking, competing values model, innovations.

INTRODUCTION

Organizational culture is a phenomenon (state of things and managering processes in the enterprise), which is made up of the activities of the members of the organization. Includes the system of values and any standards of behavior people forming. Manifests its self in the manager's proceed and thinking, created developed and adopted by a team of people. Can help or hinder in the implementation of the formal objectives of the Organization [Wyrwicka, 2014]. Culture have a to maintain the unity of the Organization through the creation of a suitable atmosphere of cooperation and through the acceptance of the common objectives.

At the present time in the continuing changes in the external and internal environment and the rapid progress of the technical and technological the companies have to a deal with adaptation to constant changes. The follow on the news and the ability to predict the future is currently it is a big challenge for companies that want to survive and succeed. According to Lorsch and McTague (2016) it should a take a look at culture as a the effect of the changes, and not

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a the cause trouble or remedy, because the culture is not something that can "be repaired" and should not be viewed as a target area of transformation. Modification of the organizational culture is the key to the successful implementation of any programs designed to bring of efficiency, as well as a prerequisite for adaptation to an increasingly variable environment in which companies operate [Cameron and Quinn, 2006]. It is significant that some of the most important figures of the organizational culture reform movement - individuals such as Peter, Drucker and Senge - have recognized the importance of design as a key element of cultural change. For example, Peter Drucker's seminal work, Innovation and Entrepreneurship [Buchanan, 2015].

This article presents a case study focused on the identification of organizational culture, showing that her knowledge is an essential prerequisite for the changes of the company and authors analyzed possibility use design thinking as a supports in process change. Striving to achieve the company purpose usually is associated with the implementation of the changes and their acceptance by the crew. Later in this article shows: basic definitions, concepts and research tool and findings were presented and described research's conclusions for the analyzed production company.

CHANGES IN THE ORGANIZATION

With the opinion of Peter Drucker, we live in the period of deep transformations, but the change probably more radical than the ones which initiated the second Industrial Revolution of the half of the 19th century or the transformations caused by the Great Depression and the outbreak of the World War II [Jaśińska, 2015]. Harry I. Ansoff notes that "ambient turbulence has increased, which have four trends: the growth of the modern changes, and the increase in the intensity of the ambient place the increase in the rate of change, the increase in the complexity in place" [Ansoff, 2013]. Change can be planned or not, it can be done systematically or spontaneously [Flamholtz and Randle, 2018]. The dynamics of changes in many dimensions (economic, political, social, environmental, technological) that organizations today have to face is unprecedented [Magruk, 2018]. In a rapidly changing environment, a big threat is the lack of management skills and the anticipation of uncertain changes that are often treated as accidental phenomena [Wilson, 2013].

The change in the organization focuses primarily on the social aspect of, above all, the orientation on man as the main object of interest. Every organization, thanks to its human potential, is able to assimilate changes and organize its activities to improve oneself [Jasińska, 2015]. Introducing changes to the organization means not only the implementation of new technologies, procedures, structures and logistic modifications. This is primarily an effect on the people who create the organization, on their beliefs, attitudes, behaviors and values. The result of the experience resulting from the internal interaction of the organization's members is its organizational culture. Any changes in the companies should be based on the knowledge of the existing culture, because thanks to this you can choose appropriate tools to modify people's behavior in the organization and thus support the implementation of changes in innovation. Among these soft areas of management, leading organizational culture takes place. Due to the fact that one increasingly hears about this issue, and on the other hand, a lot of people still do not see this area or do not realize the importance of the process of change. The changes are usually in terms of two extremes - as revolutionary or evolutionary [Alvesson and Sveningsson, 2016]. Identification of the organizational culture is a very important element in the process of change in enterprises. Changing organizational culture entails the transformation of values, beliefs and myths characteristic of the organization. It is a difficult and lengthy process.

Deserti and Rizzo see a great opportunities for the expansion of knowledge about how design practice and organizational change can be carried out simultaneously. Intriguing opportunities are arising to discuss from a new perspective the relationship between design culture as one of the relevant domains of competence and knowledge that addresses innovation and the phenomenon of organizational change [Deserti and Rizzo, 2013].

In the further part of the study, the authors attempted to define such concepts as organizational culture and design thinking.

ORGANIZATIONAL CULTURE – DEFINITION

The term "culture" is one of the most ambiguous and variously defined concepts of what can be found in the literature. It is difficult to cite a single, common and recognized definition of organizational culture. According to Schein, an organization's culture is influenced by historic events, religion, and group decisions, contributing to a type of organizational identity. Further, Schein offered a helpful distinction between:

1. the visible organizational structures and processes;
2. the strategies, goals, and philosophies or espoused justifications of the organization;
3. the unconscious or taken-for-granted beliefs, perceptions, thoughts, and feelings that ultimately shape the values and actions of an organization [Schein, 2010].

Hofstede and Hofstede (2005) say organization culture is the shared mental software of the people in an organization and though it is treated as a soft concept, it is known to have hard, tangible consequences on performance of organizations [Chatterjee and Pereira and Bates, 2018].

Organizational cultures are often understood as somewhat unique to a given organization, having been developed over time as members solve problems and act on priorities [Schneider and Barbera, 2014].

Among the many ways of understanding the organizational culture of the most useful for the discussion of organizational culture are the shots that emphasize the subordination of the standards as a feature of cultural behavior. They focus on human behavior and not the objects are the result of these behaviors, and stress integrates the functions of culture and cultural phenomena treat only the behavior that has become a social habit, which is characterized by regularity for the appropriate number of members of a particular group [Nogalski, 1998].

Many values derive from the personality and beliefs of the founder and influential members of an organization and are in a sense beyond the control of the organization. Organizational cultural, ethics, norms and values (beliefs and the rules) establish the appropriate way for organizational members to deal with one another and wish all other members of the organization's environments (both internal and external) [Cruz-Cunha and Moriera and Varajao, 2014].

Culture is also commonly observed and reported as practises an entities such as family, school, works organizations, economic and legal systems, political institution and the like [Chhokar and Brodbeck and House, 2008].

The essence of organizational culture can best be explained by comparing it with the manners of a man [Chuda and Wyrwicka, 2013]. Organizational culture manifested in shared values and beliefs, the assumptions, language and symbols, as well as methods of procedure used by members of the organization.

Since it is not possible to focus simultaneously on all aspects of the organization, the correct diagnosis of culture requires strict selection of certain specified dimensions, which will be examined. It is worth mentioning two kinds of dimensions of culture: its content and patterns. Content is everything included in the scenarios that are to help participants recognize the cultural values of their organization. These patterns are profiles of culture, which are obtained by a summary of the results obtained through questionnaires to assess culture. Profiles can be used to make a diagnosis of culture [Cameron and Quinn, 2006].

E. Schein points out that one of the functions of management is the skillful use of culture to development activities [Zbiegień-Maciąg, 2013].

Each organization should establish and improve their organizational culture. The success of the organization decides harmony between organizational culture and its strategy, especially in the change process.

Diagnosis of organizational culture, associated with assigning it to a specific type is particularly useful when changes are planned because the management and staff have different ideas about the needs and directions of transformations.

The later in the article presents case study concerns a production plant operating in Wielkopolska.

DESIGHN THINKING

Tim Brown defines design thinking, saying it is "the discipline that benefits common sense and designer methods to meet the needs of people using what is technologically possible and what a reasonable business strategy can change in value for the client, and chance market" (2008).

According to Brown (2009), the design thinking process consists of three main phases:

1. Inspiration (identifying a problem or opportunity that motivates you to search for solutions);
2. Ideation (the process of generating, developing and testing ideas);
3. Implementation (implementation of the solution on the market).

Top management support for quality excellence acts through people, whether they are internal employees (employee relations) or external customers (customer relationship management). Well-operating processes and advanced technologies are not enough to be ready for the change due to new quality initiatives. To build and sustain a culture of quality excellence, people have to be a major part of the solution. This finding is in accordance with the previous change readiness research that link employee behaviors and commitment to organizational change [Uluskan and McCreery and Rothenberg, 2018].

Practices associated with design thinking can help address the demands placed on those undertaking organizational change. Design thinking is an iterative, exploratory process involving visualization, experimentation, the creation and prototyping of models, and gathering feedback [Glen, Suciu, Baughn, 2014].

Design thinking is human-centered. It couples ethnographic methods to develop an understanding of the needs and problems experienced by users, and visual methods represent and share insights. Rapid learning is facilitated through this process, as insights are rapidly translated into tangible outcomes for testing and feedback . While design thinking has generally addressed product and service innovation, a design approach to organizational change would build on these same practices—but with innovation of the organization itself as a key target [Suciu and Baughn, 2016].

Recognizing organizations as collections of human beings who are motivated by varying perspectives and emotions, design thinking emphasizes engagement, dialogue, and learning. By involving customers and other stakeholders in the definition of the problem and the development of solutions, design thinking garners a broad commitment to change. And by supplying a structure to the innovation process, design thinking helps innovators collaborate and agree on what is essential to the outcome at every phase. It does this not only by overcoming workplace politics but by shaping the experiences of the innovators, and of their key stakeholders and implementers, at every step. That is social technology at work [Liedtka, 2018].

Practices associated with design thinking can help address the demands placed on those undertaking organizational change. Design thinking is an iterative, exploratory process involving visualization, experimentation, the creation and prototyping of models, and gathering feedback [Glen and Suciu and Baughn, 2014].

The focus on the project management and project manager's competencies must fall within the core interest of company managers. This means that management of projects implies constantly risks monitoring, resources optimization, taking care of contractual relations [Gablas and Ruzicky and Ondrouchova, 2018]. Design thinking is a way to creative, innovative and creative problem solving. It is a people-oriented, prototype based innovation process. The roots of design thinking date back to the 1960s, when it was mainly used in the design of products and services. Currently, its role becomes much more universal. The design thinking pattern is built on three key pillars [Karwowska, 2019]:

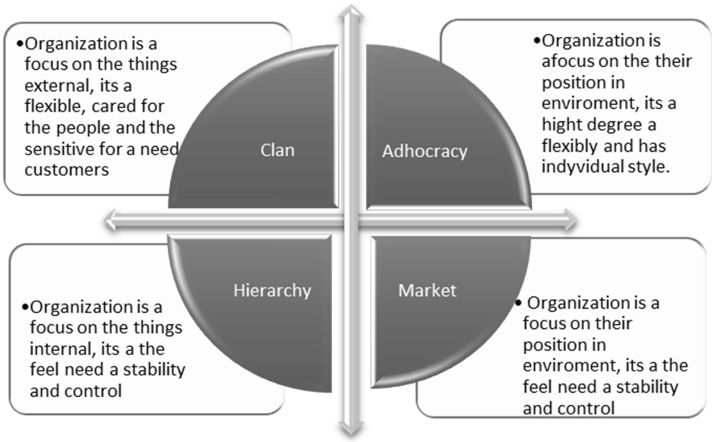
1. the attitude on for the on needs of the recipient,
2. approach to the problem from different points of view, involvement in the project of a team of people with diverse competences, experiences and views,
3. testing or checking whether the solution will work in the real world – asking for not clients, recipients, probing, doing surveys.

The design thinking process is divided into 5 stages: empathy, defining the problem, creating ideas, building a prototype, testing [Karwowska, 2019].

According Starostka (2015) empathic understanding user's point of view, quick solution check or interdisciplinary, holistic a look at innovation - these are some of the most important, much wider the context of benefits from which the change in the organizational culture seems to be the most interesting [Starostka, 2015].

A MODEL OF COMPETING VALUES/ COMPTEING VALUES FRAMEWORK

A model of competing values arose as a result of research on main features of effective organization. It has been developed based on the main assumptions regarding organization and management, it's also describes precisely other important aspects as: organizational leadership, organizational effectiveness, management rules and quality management [Cameron and Quinn, 2006].



Source: Cameron and Quinn, 2006

Fig. 1. Types of cultures by Cameron and Quinn

Culture is characterized by this model on the two axes containing opposite dimensions: one dimension presents at one end of the scale: efficiency criteria with in indication of flexibility, independence and dynamism. On the other side criteria that emphasise immutability, order, stability and control. This means that some organizations consider themselves to be effective when they change, adapt and their degree of formalization is minimal, while others consider it to be efficient when organization is stabile, predictable and with an unchanging structure. The second dimension collates efficiency criteria that focus on: orientation on internal affairs, integration and unity with criteria related to the orientation on the position in the environment, differentiation and competition on the other side. This means that some organizations are considered to be effective when they form a harmonious whole and the other organizations stands for efficiency as a result of being focused on cooperation or competition with others. The obtained two dimensions – axes - divide the plane into four quadrants, each of which describes separate indicators regarding the organization's effectiveness.

Described axes divide the plane into four quadrants, corresponding to various – often opposite – phenomena; hence the name: „competing values framework". Each quadrant represents the views, assumptions and dimensions that make up the organizational culture. Individual quarter have been assigned names that reflect the most characteristic features of the organization [Wyrwicka, 2014].

According to the typology of K.S. Cmaeron and R. E. Quinn we can distinguish four main types of cultures: the clan's culture, the culture of adhocracy, hierarchy culture and market culture. The figure 1 below presents the characteristics of particular types of cultures.

K.S. Cameron and R. E. Quinn believe that organizational culture is an essential factor affecting the efficiency of any organization. In their theoretical model of competing values that characterize the cultures of an organization they indicate that it significantly affects performance and can obtain competitive information and benefits [Miroshnik, 2013].

According to K.S. Cameron and R.E. Quinn all kinds of efforts related to improving efficiency in organizations based on the use of various tools and techniques and implementing change strategies are wasted if the organizational culture – the system of values, way of thinking, management style – remain unchanged. Modification of the organizational culture is the key to the successful implementation of all programs aimed at increasing efficiency, as well as the condition for adapting to the increasingly volatile environment, in which enterprises operate [Cameron and Quinn, 2006].

Organizational Culture Assessment Instrument is necessary to diagnose organizational culture (the abbreviated name OCAI is used hereinafter).

ORGANIZATIONAL CULTURE ASSESSMENT INSTRUMENT (OCAI)

The diagnosis of organizational culture in a selected company was made using OCAI questionnaire, which allows determining the dominant orientation in a particular organization based on these main types of cultures. It also helps in assessing the strong points of the organization [Cameron and Quinn, 2006]. The questionnaire focuses on sic elements and makes it possible to determine what the current state of culture is and what is the desired state. Questionnaire consists of six questions such as:

1. What are the general characteristics of the organization?
2. What is the style of leadership in the organization?
3. What is the style of employee management?
4. What ensures the cohesion of the organization?
5. What is the main emphasis focused on?
6. What are the criteria for success in the organization?

For each of the above questions are given four responses, between which 100 points is divided depends on the extent to which answer situation of the company reflects the most. The highest number of points assigned to the answer means its suits best for the current conditions in the company. The questionnaire comes in two versions, each of them contains the same questions and answers. The difference between these versions is that one of them examines the 'present state' of culture, and the other one 'the desired state'.

DIAGNOSIS OF THE ORGANIZATIONAL CULTURE OF A SMALL ENTERPRISE

The object of the analysis was the manufacturing plant, specialized in production industrial machines, located in Greater Poland. The analyzed company directs its activities to the needs of clients. Considering the fact that the company produces specialized machines the product must meet all customer expectations. By definition, the client is the last user of the good produced by the enterprise [Wyrwicka, 2014]. In the enterprise in question, the quality of the offered products is very important and treated with priority. The company tried to modify and adapt manufactured machines to the customer's needs, if possible.

The company was founded in 2013, the legal form of the company is Sp. z o.o. The subject of the study has no formal organizational structure. Currently the company employs fifteen people, although company is in the growth phase and there is a prospect of increasing employment in a short period of time. The average age of employees is 33. The person managing the plant is also the main engineer and machine designer for the plant. Therefore, in this situation, everything must be properly planned and organized, which means that the production process should be well ordered and widely recognized production management is needed [Scott and Cummings, 1983]. It is important because in the context of production each order is a virtually separate project that requires planning and organizing newer processes which should result in a product of the highest quality.

The study involved nine people, including three women and six men, which is 60% of the crew. Among the participants, three people have managerial functions (including the director of the plant).

Mapped out research results based on the OCAI questionnaire are presents graphically in the forms of graphs (coordinate systems in Fig. 2) and present the current state of culture inside the analyzed company. Drawing up the charts is an important stage during the initiation of changed in the company. Presenting it in the form of a graph is more useful for diagnostic purposes than tables. Applying data on the current and desired state to the same graph allowed to find differences between what is and what should be. This course of action also makes it possible to determine how and where changes should be made to the company.

All analyzed features in the present and desired state were presented using the figure 2.

It can be concluded that the dominant type of organizational culture in the present profile is the clan while the clan and adhocracy are desirable. Only in the case of the characteristic of the coherence of the organization in the desired state we can find culture of the hierarchy.

Analyzing individual features, it can be noticed that the clan culture profile is dominant both in the present and desired state.

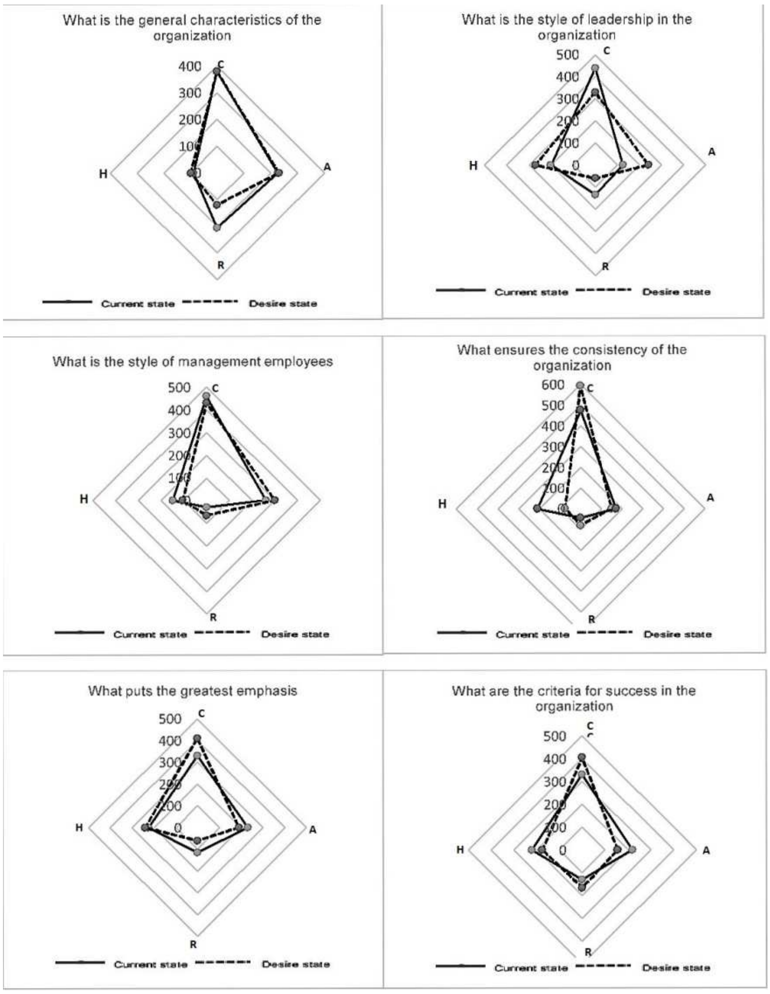
Discrepancies in the profiles of organizational features appear in the style of leadership, management style and the cohesion of the organization. In the case of leadership and management, the change indicates adhocracy. This may mean that one should think about the future and increase the emphasis on innovation and encourage employees to look for creative solutions. Flexibility and the ability to adapt to change will also be important. In the culture of adhocracy, the dominant values that are important performance indicators are: innovative ideas, innovative solutions and creativity.

The style of employee management in the diagnosed enterprise both in the present and desired state indicates the culture of the clan. The plant manager supports his employees, motivates them to actively participate and act. Another analyzed feature of the organizational culture in which there are discrepancies is: what ensures the cohesion of the organization. In this case, the most important is loyalty, mutual trust and commitment. The profile of the desired culture indicates a slight change towards the hierarchy which is related to the improvement of elements related to the organization of work. This would have a significant impact on improving the company's operations. Important factors affecting effectiveness in the culture of the hierarchy include punctuality, efficiency and uninterrupted work. The other features did not indicate a change to another type of culture.

Identification of the existing culture and examining what type of culture is preferred by employees are the basis for susceptibility to changes envisaged in the company's strategy [Chuda and Wyrwicka, 2013].

Research shows that employees are satisfied with work, they are loyal and committed. The company has a friendly atmosphere that favors good cooperation. Employees also have development opportunities. These factors have a big impact on efficiency.

Because each production environment is significantly different from the other, they are not standard solutions that fully meet the requirements at the operational level. Probably in any case, industrial practice, the process of developing tailored solutions is necessary, based on general guidelines of established planning and production control systems [Hadaś and Cyplik, 2012].



Source: own work

Fig. 2. Profiles the culture of the distinct organizations

The production process and technology used are other factors affecting the organizational culture. Their specificity is reflected in the organizational structure and it is a visible measure of differentiation. In large and medium-sized enterprises, there is a tendency to use bureaucratic, hierarchical structures, which is largely forced by the production process. It seems, therefore, that organizational culture will also be largely based on hierarchy and bureaucracy [Aniszewska, 2014].

The company being the subject of the research due to the specificity of the product range requires continuous extension of knowledge about the latest technologies and modern solutions in the industry. When introducing any changes to the company, it is the most important that the product manufactured is of the highest quality and highest quality. Diagnosis organizational culture in the case of leadership and management, the change indicates adhocracy. This may be a reason for creative solutions. Flexibility and the ability to adapt to change will also be important.

In the type organizational culture as an adhocracy, the dominant values that are important performance indicators are: innovative ideas, innovative solutions and creativity would like state desired for adhocracy. Design thinking to where interdisciplinary teams, rapid prototyping, user co-creation solutions are just some examples of specific methods promoted by designers and design thinkers that can leverage innovative activities of the organization.

According authors on it use design thinking can give in organizational a lot of benefits.

CONCLUSIONS

Organizations that are part of the real world are subject to change. Changes are classified in different ways. However, in most cases they take the form of a certain process, and their success is conditioned by a lot of factors. The numerous conditions on which the ability to effectively carry out changes in the enterprise depends on its culture. It is a specific creation of the organization, which is a collection of patterns of thinking, behavior and action of all its members.

Based on the analyzed enterprise, it can be noticed that the identification of culture is an important element during changes in the enterprise. The dominant type of organizational culture was determined using the competitive value model. An attempt was made to indicate activities that affect on changes and introduction of design thinking supporting this process.

In the course of the conducted research, it was stated from the information obtained that employees are satisfied with work in the enterprise; they are committed, ambitious and also focused on cooperation and mutual assistance. Organizational culture in the course of changes in an enterprise has a decisive impact on employees' abilities and inclinations to develop and implement new ideas.

In order to effectively support the introduction of changes in the company, it is necessary to make a diagnosis of the culture that is in it and to determine its type. Awareness of this fact allows to pay attention to the organizational culture and undertaking in its area such activities that will make it a factor supporting changes in the enterprise, necessary to achieve its goals. Bearing in mind the specificity of the company and its method of operation the introduction design thinking can give many benefits.

This article presents the results of the analysis of organizational culture in a selected company. The obtained results allow to develop conclusions about the current state and the desired organizational culture. The analysis of individual features of the organizational culture allows to formulate and present selected guidelines on how to go through the change process in an enterprise to obtain measurable benefits in implementing the strategy, as well as in the development of communication.

A case study related to the use of the competing Cameron and Quinn values model showed problems in the analyzed enterprise, which can be solved by introducing changes. The authors noticed that the diagnosis of the organizational culture based on the model used shows the differences between the present state and the desired state. Based on the research carried out by the authors, in which the organizational culture was identified and the differences between the current and desired state were identified, it is possible to determine the direction of further actions related to the introduction of changes in the company using design thinking but important is for to innovation needs to be embedded in an organizational culture capable of continuously anticipating and adjusting to change.

According to Elsbach and Stigliani on the use of design thinking in organizations provides new insight into the value of this increasingly popular approach to problem solving. In general, it suggests that the use of design thinking tools in organizations triggers an experiential learning process that ultimately supports the development of organizational cultures defined by a user-centric Focus, collaboration, risk taking, and learning, which in turn support the further use of design thinking tools [Elsbach and Stigliani, 2018].

The authors of the study noticed during the analysis of literature and research that applications of design thinking in the analyzed company could contribute to changing expected organizational culture.

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DIAGNOZA KULTURY ORGANIZACYJNEJ, JAKO CZYNNIK ZMIANY W KONTEKŚCIE ZASTOSOWANIA DESIGN THINKING

STRESZCZENIE. **Wstęp:** Badania literatury i analiza sytuacji w praktyce biznesowej wskazują, że kultura organizacyjna jest ważnym wyznacznikiem, który może hamować lub pomagać we wdrażaniu zmian adaptacyjnych, proaktywnych i proinnowacyjnych. Nowe sytuacje pojawiające się w otoczeniu zewnętrznym i wewnętrznym, a także nowe uwarunkowania wynikające z postępu technicznego i technologicznego zobowiązują przedsiębiorstwa do adaptacji, a nawet przewidywania zmian. Gotowość do modyfikacji występuje, gdy pracownicy nie są zadowoleni z istniejącej kultury organizacyjnej i wolą inną. Diagnoza rozbieżności między istniejącą a oczekiwaną kulturą organizacyjną pozwala nam ocenić chęć zmiany sytuacji w przedsiębiorstwie. W artykule przedstawiono studium przypadku skupiające się na identyfikacji faktycznej i pożądanej kultury organizacyjnej w celu zdiagnozowania gotowości załogi do zmian w firmie i możliwości zastosowania myślenia projektowego jako sposobu wdrażania innowacyjnych rozwiązań.
Metody: W badaniu wykorzystano kwestionariusz OCAI, którego autorami są: K.S. Cameron i R.E. Quinn. Korzystając z ankiety, określono aktualny i pożądany stan kultury organizacyjnej analizowanego przedsiębiorstwa. Na podstawie badań literaturowych zweryfikowano możliwości wykorzystania myślenia projektowego w procesie zmiany kultury organizacyjnej.
Wyniki i wnioski: Wyniki badań ujawniają dysonans między stanem obecnym a pożądanym i umożliwiają ocenę chęci i gotowości pracowników firmy do zmiany oraz możliwość wykorzystania myślenia projektowego. Celem badań było zidentyfikowanie luki badawczej jakim jest diagnoza kultury organizacyjnej jako czynnik zmian oraz możliwości wykorzystania myślenia projektowego w procesie zmiany. Kultura organizacyjna w trakcie zmian w przedsiębiorstwie ma decydujący wpływ na zdolności pracowników oraz skłonność do opracowywania i wdrażania nowych pomysłów.

Słowa kluczowe: kultura organizacyjna, zmiany w organizacji, myślenie projektowe, konkurencyjny model wartości, innowacje

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ORIGINAL PAPER

THE NEXUS BETWEEN CORPORATE SOCIAL RESPONSIBILITY AND CORPORATE PERFORMANCE: AN EMPIRICAL EVIDENCE

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ABSTRACT. **Background:** This study investigates the relationship between CSR (corporate social responsibility) practices and enterprise performance. We have collected the data from 248 different enterprises located in different industrial areas of Karachi, mainly including S.I.T.E industrial area, Federal-B industrial zone, and West Wharf industrial area, Karachi Export processing zone, Bin Qasim industrial zone, and Korangi industrial zone.

Methods: The study mainly employed SEM (structural equation modeling) to test hypotheses in AMOS software. The practices of CSR were measured through 'green design of products', 'ethical leadership', 'building school and hospital infrastructure', and 'environmental protection training'.

Results: The findings revealed that ethical leadership is strongly and positively correlated with CSR practices, which confirmed that ethical leadership has strong potential to implement CSR practices inside and outside of the firms. The results further indicate that CSR practices enhance enterprise performance.

Conclusions: This research provides insight into the relationship between CSR practices and enterprise performance. Further, this study will help senior managers, and practitioners to understand the significance of CSR practices.

Key words: Corporate social responsibility, Green product design, Ethical leadership, Enterprise performance.

INTRODUCTION

During 1952, the concept of CSR introduced by Brown states that while adopting business strategies and decision, enterprises need to focus on social and environmental sustainability [Bowen, 1953]. In simple words, firms need to work on triple bottom line (economic, social and environment). Hossain & Siwar, [2009] highlighted that the key objective of CSR is to improve the lifestyle of people through different charity works including building a school, providing scholarships and medical treatment to needy people, and fixing water cleaning plants.

Since the last couple of decades, a number of Pakistani firms have started to adopt CSR ideology through different charity works. In light of the EU, CSR is an idea that enterprises integrate social and environmental concerns into their business strategies, decision, and operations for the betterment of society Elasrag H. [2015]. It is necessary for the business community to be well aware of the role and responsibility it has toward the local community. Corporate social responsibility not only contains participating in charitable events, but also includes implementing the self-responsibility to build a better society through foreseeing/envisioning blueprint, strategies, and policies for socio-economic justice, and being aware of their responsibility for the local community welfare [Zinkin 2004]. Incontrovertibly, the business community has been highly educated to make a plan for changing society, align and combine their

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firms' development objectives with a social plan of local government for maximum output [Zinkin 2007, Khan et al. 2016].

EDHI foundation is one of the biggest welfare organization in Pakistan. The organization was established by Abdul Sattar Edhi and his wife Bilquis Edhi in 1951. It provides 24-hour emergency assistance across the country and even abroad. EDHI foundation was held in the "Guinness Record" for the world's largest volunteer ambulance. The organization has two private jets, one helicopter, 28 rescue boats, and thousands of ambulances to assist in victim areas [Edhi 2018]. On the other hand, Saylani is a nonprofit organization established in 1999 by Maulana Bashir Farooq Qadri. The organization mainly focuses on emerging services, providing free food, education, and health care services to needy and poor people. The Saylani is second biggest welfare organization in Pakistan and the funding of organization came from the different corporate sector and rich people under the name of donations and Zakat. The organization has planned to build "Saylani University" where students can get higher education including master and Ph.D. without spending a single penny. [Saylani 2018].

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

In the Pakistani community, thousands of enterprises are spending money on different CSR projects mainly including environmental protection training and donating money for building school and hospital for needy and low wage people. To assessing Pakistani enterprises achievement in CSR projects, we have decided some parameters that will be used to collect data from different firms.

ETHICAL LEADERSHIP

According to the stakeholder theory, ethical management and corporate social responsibilities are positively correlated. The theory mainly addresses values of supervision on an enterprise between all of its stakeholders [Zhu et al. 2013]. Undeniably nowadays corporate managers operate in a very complex global environment and it is supportive to deliberate leadership in the background of stakeholder theory because the firm is defined as a group of managers, employees, suppliers, distributors, and community, who have a legal and moral role in the enterprise. In other words, it is suggested that firms should balance the interests of all the stakeholders [Zhu et al. 2013].

Brown, [2005] highlighted that ethical leadership is “the demonstration of normality appropriate behavior” throughout interpersonal relationships, and motivate employees through appropriate rewards and appreciations for their involvement and efforts in the CSR projects. The idea ethical leader lives with principles and values and has the potential for contribution to the improvement of the community [Reynolds and Ceranic, 2007. In the perspective of stakeholders, ethical leaders are the ones that know the art of creating a good relationship with all major stakeholders and they enhance motivation and commitment by incentives to encourage coordination, information sharing and collaboration for attaining sustainable change outside and inside of the firm. For instance, ethical leaders would take moral responsibility to fulfill the needs of their customers by providing safe and green products [Khan and Dong 2017].

There are numerous empirical studies conducted to observe its antecedents and results/outcomes. The personality traits of firm leaders like conscientiousness, moral values and principles are found to be positively correlated with ethical leadership [Mayer et al. 2012]. A number of researchers study on Chinese firms to examine the nexus between ethical managerial role and corporate social responsibility practices. Their results indicate that ethical leadership is strongly and positively correlated with CSR activities [Zhu et al. 2013, Liu et al. 2013, Groves et al. 2011, Vitell et al. 2003]. Therefore, we formulate the following hypotheses:

H1a: Ethical leadership is strongly and positively associated with Green product design

H1b: Ethical leadership is strongly and positively correlated with environmental protection training and scholarships

H1c: Ethical leadership strongly and positively participate in building school and hospital infrastructure.

GREEN PRODUCT DESIGN

Enterprises adopt a green design in their products to satisfy the needs of their consumers and improve environmental and social sustainability in terms of reduction in hazardous materials, and pollution free environment [Khan, Dong 2017]. In addition, green product design significantly contributes to economic benefits through cost reduction, recycling, and remanufacturing [Stanaland 2011]. Green practices in product design and business operations build customer trust and play a vital role in building a positive image of firms [Fombrun, Shanley 1990]. An empirical study conducted by Ehsan and Kaleem [2012] to investigate the effect of CSR on firms' performance. The results confirmed that CSR activities related in terms of greening business operations and product design significantly helps the enterprise to improve their profitability, increase firm reputation, and eliminate waste from different business processes. [Khan et al. 2016] highlighted that green practices adoption in supply chain and business operations are mainly based on managerial decisions, which is the reflection of their awareness on environmental issues, ethical and moral values.

Firms adopt different CSR projects and practices in their business operations including, recycling, green design, usage of renewable energy, providing training and scholarships to poor and needy students, building school and hospital in different rural areas for the betterment of society [Ehsan, Kaleem 2012]. Büyüközkan and Çifçi, [2012] claimed that due to the proper implementation of the green design in their products, firms may mitigate and/or control 80% negative effect on the environment, which will noticeably build a positive image of the firm. Furthermore, the green design minimizes the purchasing and production costs and increases the value of products. Thus, we propose the hypothesis given below:

H2: Green design of a product is strongly and positively associated with enterprise performance

ENVIRONMENTAL PROTECTION TRAINING

The concept of environmental protection training and programs is to understand the sensitivity of environmental sustainability. A number of environmental awareness training contain the necessity of corporate sector to protect the flora and fauna lives. In Pakistan, a number of enterprises have implemented ISO 14001 to mitigate the harmful effects of their manufacturing and supply chain operations. The ISO 14001 basically assists enterprises with a framework for better management control on their business operations. As different business operations mainly logistics and production emit heavy carbon emissions, nitrogen, and Sulphur, which not only damage to environmental sustainability but also create numerous health problems [Sheldon 1997].

Pakistani companies are aggressively contribution to CSR activities such as providing training and scholarships to poor and needy students. Engro Corporation, one of the leading firm in the fertilizer industry provides scholarships to poor students for continuity of their education. In addition, the firm also conduct free technical training on livestock and farming, which is helping poor people to find technical jobs and contribute to country GDP [Engro Corporation 2018]. A study conducted by Manrique, [2017], to investigating the effect of corporate social responsibility in terms of environmental protection training on the financial performance of firms. The results revealed that environmental training improves enterprise performance and help to build a competitive edge. In the similar line, Rodriguez-Fernandez, [2016] results show that environmental friendly training provided by enterprises allow employees to undertake responsibility and also make it easier for enterprises to shift their polluted processes towards green and efficient processes. On the basis of the above-cited papers, we develop the following hypothesis:

H3: Providing environmental protection training to employees and customers have a positive effect on firm performance.

BUILDING SCHOOL AND HOSPITAL INFRASTRUCTURE

WBCSD (World Business Council for Sustainable Development) highlighted that CSR is integrating the social, economic and environmental aspects of any firms, and causing sustainable development in long run [Yawar 2009]. There is no doubt that Pakistan is suffering from serious environmental and social problems including shortage of clean drinking water, climate change, air and water pollution, the unsatisfactory rate of literacy, and limited medical treatment machines available in hospitals [Khan, Dong 2017, Abdullah et al. 2017]. On the other hand, CSR activities also enhance employees' job satisfaction, customer and suppliers trust, and create a positive image and good reputation in the domestic and international arena. [Hameed 2010].

Many Pakistani firms have a separate department of CSR such as Agha Steel Industries, Berger Paints Pakistan Limited, Fauji Foundation, and Engro Corporation, who plan their own CSR programs and monitor the effectiveness of their programs. The CSR projects not only bring about community sustainable development but also improve firm economic performance in terms of customers and employees satisfaction, which build a competitive edge and create a positive effect on firms' long-term profitability. In a similar line, Zhu [2013] conducted empirical research in southern China. The findings revealed that CSR projects strongly create a positive effect on firm performance, and also help firms to explore new opportunities. Thus, we propose the hypothesis given below:

H4: Participating in building school and hospital infrastructure help firms to improve their performance.

PROPOSED METHODOLOGY

This research investigates the impact of corporate social responsibility practices on Pakistani enterprises performance. Initially, we create a pre-test questionnaire for a pilot study, and after consultation with industry experts, we built new questionnaire for this research on the basis of four-point Likert scale (4= strongly agree; 3= agree; 2= disagree and 1=strongly disagree). The questionnaire is based on 'Ethical leadership', 'Building school and hospital infrastructure', 'Environmental friendly training and scholarships', ' Green product design', and 'firm performance'. The definitions of the construct are given in Table 1, and the proposed model is drawn in Fig. 1.

Table 1. Definitions of Constructs

Variables	Abbreviations	Definitions
Ethical leadership	EL	Ethical leaders have desirable behaviors and qualities such as honesty, trustworthiness, and fairness in taking responsibility for their own actions, as well as using two-way communication, reinforcement, and appropriate appreciations, awards and punishments to hold subordinate accountable for their actions (Zhu et al., 2013).
Firm performance	FP	Firm performance shows the economic, operational performance, and environmental performance of the firm as compared to the industry average (Khan & Qianli, 2017).
Green design of products	GDP	Green design facilitates the remanufacturing, recycling, reuse, and recovery of component parts. Moreover, an ecological design also avoids the use of harmful materials and chemicals in manufacturing processes (Khan et al., 2017; Khan & Qianli, 2017).
Environmental training and scholarships	Env.P	Environmental protection training and providing scholarships to needy students enhancing the knowledge and evoking the responsibility of employees and consumers to protect the natural beauty. In addition, scholarships help needy people to get a higher education.
Participating in building school and hospital infrastructure	BSH	Firms' involvement and participation in building school and hospital infrastructure in rural areas facilitate poor people to get an education and medical treatment.

During September 2017 to March 2018, the questionnaire was sent to the 520 enterprises operating in different industrial areas of Karachi, mainly including S.I.T.E industrial area, Federal-B industrial zone, West Wharf industrial area, Karachi Export processing zone, Bin Qasim industrial zone, and Korangi industrial area. These companies completed questionnaires with non-probability convenience sampling (Gray, 2004). A total of 248 questionnaires filled completely were received, while the effective response rate was 46.7%.

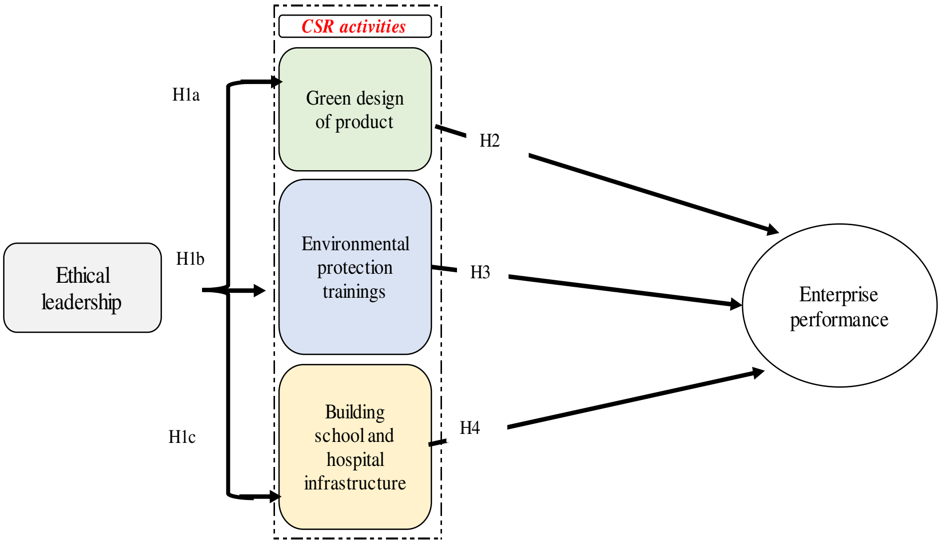

Fig. 1. The proposed model

Table 2. The demographic profile

Demographics	Frequency	%
Firm category		
Food manufacturing	9	4
Beverage product manufacturing	5	2
Tobacco product manufacturing	3	1
Electronics products	27	11
Rubber manufacturing	29	12
Artificial leather firms	19	8
Chemical manufacturing	64	26
Plastic manufacturing	31	13
Machinery manufacturing	11	4
Furniture manufacturing	8	3
Paper manufacturing	15	6
Steel and Iron manufacturing firms	4	2
Fertilizer industry	6	2
Wood product manufacturing	13	5
Transportation equipment manufacturing	4	2
Age of firm		
Less than 6 years	11	4
6 to 10 years	71	29
11 to 15 years	122	49
16 to 20 years	29	12
More than 20 years	15	6
Level of responsibility		
Senior managers	26	10
Middle managers	98	40
Supervisors	124	50
Experience of respondents in their field		
Less than 3 years	9	4
Between 3 to 5 years	97	39
Between 6 to 10 years	125	50
More than 10 years	17	7

The respondents were selected from 15 different industries, including steel and iron, chemicals, rubber, plastic, electronic products, and fertilizer manufacturing firms. Mainly the questionnaires were filled by a supervisor, middle and senior managers. The SEM

(Structural Equation Modeling) method has been adopted in AMOS (Analysis of Moment Structure) to test study hypotheses. The firm demographic profile is given in Table 2.

RESULTS AND ANALYSIS

The research performed reliability, descriptive statistics, correlation matrix, and EFA and CFA analysis to proceed with structural equation modeling. We performed the exploratory factor analysis to categorize Likert-scale questionnaire items into the 5 dimensions (i.e. ethical leadership, enterprise performance, green product design, environmental protection training, and building school and hospital infrastructure). The Kaiser-Meyer-Olkin and Bartlett's measure of sampling adequacy (84.1) shows that the sample is suitable for EFA analysis because greater than 0.70 value of KMO was suggested by Leech et al., (2005). Furthermore, the KMO test reveals that matrix cannot be seen as an identified matrix and these five constructs satisfactory are related with each other to complete a significant and meaningful factor analysis.

Table 3. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.841
Bartlett's Test of Sphericity	Approx. Chi-Square	5412.3
	df	485
	Sig.	0.000

Moreover, through the application of an orthogonal (varimax) rotation with Kaiser Normalization, the early solution of EFA was rotated, which extracted the required five unlinked factors. They made up the variance of enterprise performance 26.11, green design of products 19.14, ethical leadership 15.02, environmental protection training 13.41, and building school and hospital 10.35. However, 84.03 cumulative percentage of the total variance was explained by these five constructs. The totally 25 items were loaded onto their respective variables.

Table 4. Exploratory Factor Analysis (N = 248)

Items		Components				
	Alpha	1	2	3	4	5
Enterprise Performance 1		0.795				
Enterprise Performance 3		0.822				
Enterprise Performance 2	0.838	0.811				
Enterprise Performance 4		0.817				
Enterprise Performance 6		0.867				
Enterprise Performance 5		0.841				
Green design 4			0.812			
Green design 1			0.795			
Green design 2	0.853		0.813			
Green design 5			0.846			
Green design 3			0.847			
Ethical leadership 2				0.812		
Ethical leadership 1				0.897		
Ethical leadership 4	0.781			0.836		
Ethical leadership 5				0.796		
Ethical leadership 3				0.777		
Env. protection training 1					0.817	
Env. protection training 4					0.786	
Env. protection training 5	0.862				0.862	
Env. protection training 3					0.855	
Building school & hospital 3						0.816
Building school & hospital 2						0.872
Building school & hospital 1						0.841
Building school & hospital 6	0.799					0.789
Building school & hospital 7						0.821
Eigenvalues		3.621	2.518	2.316	1.881	1.746
% of variance explained		26.11	19.14	15.02	13.41	10.35
Cumulative % of variance explained		26.11	45.25	60.27	73.68	84.03

Note Extraction method: principal component analysis.
Rotation method: Varimax with Kaiser Normalization.
Factor loadings less than 0.40 are omitted to maintain clarity

Table 5 demonstrates descriptive statistics and correlation. Hair et al., (2010) suggested that the confirmatory factor analysis model is established before the structural model is well checked/tested. Therefore, we perform a CFA model to validate the measurement model.

Table 5. Exploratory Factor Analysis (N = 248)

	Mean	Std. Dev.	1	2	3	4	5
Enterprise performance	3.12	0.87	1				
Ethical leadership	2.94	0.76	0.381*	1			
Green design of products	2.88	0.71	0.163	0.322**	1		
Env. protection training	2.75	0.68	0.391*	0.411	0.211*	1	
Building school and hospital	3.11	0.85	0.267**	0.374*	0.307	0.216	1

**p 0.05 (2-tailed); **p< 0.01 (2-tailed)*

Table 6 indicates the results of average variance extracted and composite reliability. The value of CR (composite reliability) and AVE (average variance extracted) of the five constructs is greater than 0.70 and 0.50, which shows good reliability and good convergent validity respectively [Molina et al., 2007]. In addition, Chi-square statistics to the degree of freedom, five further goodness-of-fit measure were checked to assess whether the measurement model was fit or not. According to Byrne, [2010], these goodness-of-fit measure includes GFI, AGFI, NNFI/TLI, CFI, and RMSEA.

Table 6. Reliability and Validity

	Composite Reliability	Average Variance Extracted
Enterprise performance	0.92	0.69
Ethical leadership	0.89	0.78
Green design of products	0.77	0.64
Env. protection training & programs	0.76	0.61
Direct support to community	0.85	0.63

Table 7 indicates the measurement model of CFA, and its CMIN's ratio to the DF is 2.18 ($p < 0.05$) which is less than 3 as suggested by Hair et al., [2010]. Further model fit indices contain GFI = 0.91, AGFI = 0.86; TLI = 0.91, RMSEA = 0.07, and CFI = 0.95.

Table 7. Measures of the Model Fit (CFA and SEM)

Goodness-of-fit measures	Recommended Values	CFA Measurement Model	SEM Structural Model
CMIN		241.88	191.14
DF		116	103
CMIN/DF	< 3	2.18	1.79
P Value	<0.05	0.000	0.001
GFI	≥0.90	0.91	0.92
AGFI	≥0.85	0.86	0.88
TLI	≥0.90	0.91	0.94
CFI	≥0.95	0.95	0.96
RMSEA	≤0.08	0.071	0.058
ECVI	Lowest value	1.259	1.092

Note: a = Byrne (2010); b = Hair et al. (2010); c = Bagozzi and Yi (1988); d = Bentler and Bonett (1980); e = Browne and Cudeck (1993); f = no dertermined suitable range of values.

STRUCTURAL RELATIONSHIP BETWEEN ETHICAL LEADERSHIP, GREEN PRODUCT DESIGN, ENVIRONMENTAL PROTECTION TRAINING, BUILDING SCHOOL, AND HOSPITAL INFRASTRUCTURE, AND ENTERPRISE PERFORMANCE

The SEM has been adopted to examine the structural relationship among all the five constructs without removing the effect of any construct during testing hypothesis. According to the Lei & Wu, [2007] structural equation is a large sample technique, which is suitable for greater than 200 sample size. A sample of 248 valid responses seems suitable for adopting SEM in this research. Table 7 illustrates that the model is satisfactorily fit, determined by the index of Chi-square (CMIN/DF) = 1.79 and other indices contain CFI = 0.96, GFI = 0.92, TLI = 0.94, AGFI = 0.88, RMSEA = 0.058 with insignificant PCLOSE. Each model-fit indices' cut-off value was reasonably exceeded, which portrays a very good model fit (Sit, 2009).

The research findings indicate that all statistically significant for predicting enterprise performance by using a combination of green design in products, ethical leadership, building school, and hospital infrastructure, and environmental protection training. Table 8 demonstrates the testing results of hypotheses. In order to measure the effect (R2), the squared multiple correlations for variables (green design of products, environmental protection training, building school and hospital infrastructure, and enterprise performance) were also calculated as displayed in Figure 2.

DISCUSSION AND CONCLUSION

The findings of SEM revealed that there is a strong positive association between ethical leadership and CSR practices including green design of products (standardized regression estimate = 0.212, $p < 0.000$), environmental protection trainings (standardized regression estimate = 0.126, $p < 0.000$), building school and hospital infrastructure (standardized regression estimate = 0.165, $p < 0.001$). In a similar line, Zhu et al., [2013] conducted a study on CSR practices and firm performance in the context of China and their results revealed that ethical leadership role is significantly important to adopt CSR practices. Tekin and Tozan, [2015] highlighted that ethical leadership acts a crucial part in the adoption of social practices inside and outside of the firm. In addition, ethical leadership balances the social, economic and environmental performance of the enterprise. Ethical leadership not only considers the legitimacy required to manage business objective but also assists as an effective way to adopt socially responsible practices such as green manufacturing, green design and packaging, and providing environmental friendly trainings to employees and customers, which enhance their knowledge and motivation to work more sustainably [Sama, Shoaf 2008].

Table 8. Results of Hypotheses with Remarks

Hypothesis	SEM Regression Path	Standardized Coeffient	P-value	Remarks
H1a	EL → GDP	0.212	0.000	Supported
H1b	EL → Env.P	0.126	0.000	Supported
H1c	EL → BSH	0.165	0.001	Supported
H2	GDP → FP	0.347	0.002	Supported
H3	Env.P → FP	0.139	0.000	Supported
H4	BSH → FP	0.331	0.000	Supported

The results revealed that 'green design of products' is strongly and positively associated with enterprise performance (standardized regression estimate = 0.347, $p < 0.01$). The results are supported by previous studies including Khan and Dong [2017] and Khan et al. [2016]. They found that the ecological design of products has a positive impact on enterprise economic, operation and environmental performance. On the other hand, enterprises adopt the green design of products and other green practices in their business operations to improve financial and environmental performance, while green practices also build a positive image and reputation. Ecological design plays a vital role in controlling environmental degradations through recycling, remanufacturing, waste management, reduction in hazardous and toxic materials. Dekker et al. [2012] highlighted that unsustainable design and polluting activities of firms are mainly responsible for air and water pollution, which not only damaging natural beauty but also being the cause of several health problems such as weakening of lung function, birth defects, immune system defects, and asthma attacks.

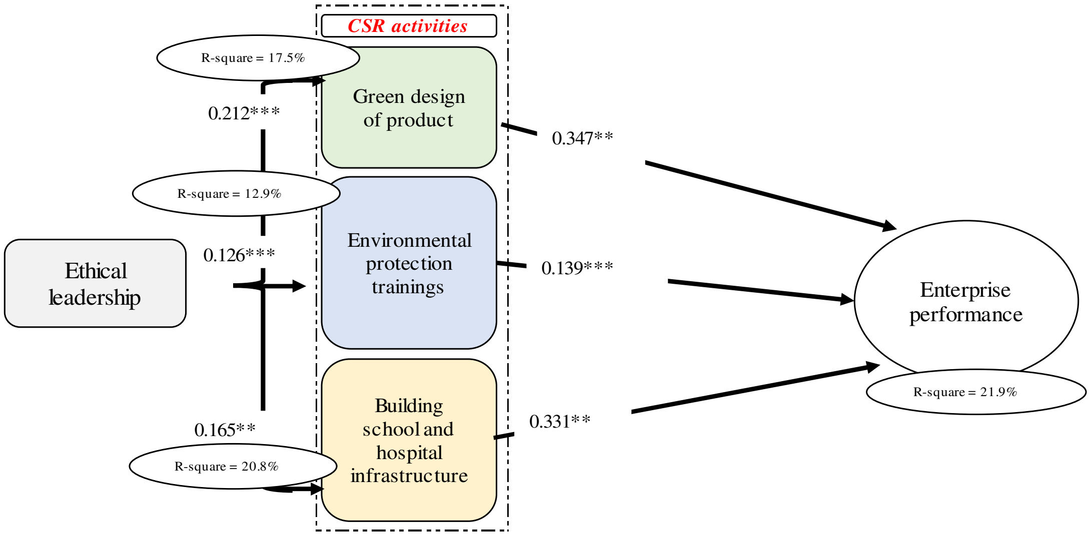

Fig. 2. Model with Coefficient values

The findings revealed that 'environmental protection training' are positively correlated with enterprise performance (standardized regression estimate = 0.139, $p < 0.001$). The key objective of providing environmental protection training is to enhance the knowledge of customers and employees and also motivate them to put efforts in CSR activities. Zhu et al. [2008] enterprises may face difficulty in adopting green practices including green product design if employees do not have sufficient knowledge of environmental-friendly practices and their social advantages. In fact, there is a prevailing consensus that CSR practices can result directly in enterprise performance. The study provides support for the significant and positive association between corporate social responsibility and firms' performance. Environmental protection training significantly motivates employees and customers to be involved in CSR initiatives [Cook, Smith 1992]. However, many constraints can hinder to the enterprises shifting from polluting practices towards social and environmentally friendly practices such as organizational culture. To overwhelm these challenges, enterprises need to provide environmental protection training to their employees [Perron et al. 2006].

The results indicate that firms' participation in 'building school and hospital infrastructure' helps to improve enterprise performance (standardized regression estimate = 0.331 p 0.004) through positive image building and capturing of customers' sympathy. In Pakistan, a number of firms are directly involved in different CSR programs such as providing clean drinking water in rural areas, and each year many firms' CSR team visit to different villages for survey purposes, which are translated into building primary schools, medical camps/clinics and/or donating money to the local community union. CSR practices not only bring about community sustainable development but also improve employees and customer satisfaction. Zhu et al. [2013] conducted an empirical study in the context of China. Their findings revealed that

CSR activities significantly improve firm reputation and performance. In addition, the results confirmed that due to CSR activities, firms can easily build customers' trust and receive different benefits from governmental bodies such as low import duties, appreciations, and involvement in governmental CSR projects.

This study adopts structural equation modeling in order to estimate the association between CSR activities (green product design, building school and hospital infrastructure, and environmental protection training), and firm performance. The findings revealed that CSR practices significantly and strongly correlated with enterprise performance. In addition, the results of our research is also supported by previously published studies [Khan, Dong 2017, Khan et al. 2017, Hertel and Wiesent 2013, Murovec et al. 2012, Pereira-Moliner, 2012, Seggie 2007, Hartley, Choic 1996, Liu et al. 2012]. Further, this study explored that CSR practices not only help society and protect environmental sustainability but also build customers' trust and increase employees' job satisfaction.

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ZWIĄZEK POMIĘDZY ODPOWIEDZIALNOŚCIĄ SPOŁECZNĄ FIRMY A JEGO SPOSOBEM DZIAŁANIA

STRESZCZENIE. **Wstęp:** W pracy zaprezentowano analizę zależności pomiędzy praktykami CSR (społeczna odpowiedzialność przedsiębiorstwa) a sposobem działania przedsiębiorstwa. Zostały zebrane dane z 248 przedsiębiorstw zlokalizowanych w różnych przemysłowych obszarach Karachi, głównie w obszarze przemysłowym S.I.T.E, obszarze

przemysłowym Federal-B, obszarze przemysłowym West Wharf, obszarze przetwórstwa Karachi Export, obszarze przemysłowym Bin Qasim oraz obszarze przemysłowym Korangi.
Metody: W pracy zastosowano SEM (modelowanie strukturalne) dla testowania hipotez za pomocą programu AMOS. Stosowanie praktyk CSR było oceniane poprzez „zielone zaprojektowanie produktu", „przywództwo etyczne", „budowanie infrastruktury szpitalnej i szkolnej" oraz „kształcenie w obszarze ochrony środowiska".
Wyniki: Otrzymane wyniki wykazały, że przywództwo etyczne jest silnie pozytywnie związane z praktykami CSR, co potwierdza, że etyczne przywództwo posiada silny potencjał wdrożenia praktyk CSR w ramach firmy oraz w jej otoczeniu. Wyniki wskazują również, że praktyki CSR wzmacniają działanie przedsiębiorstwa.
Wnioski: Zaprezentowane w pracy badania wskazują na zależność pomiędzy praktykami CSR oraz sposobem działania przedsiębiorstwa. Dodatkowo, są one pomocą dla zarządzających wyższego szczebla dla zrozumienia istotności praktyk CSR.

Słowa kluczowe: społeczna odpowiedzialność przedsiębiorstwa, zielone zaprojektowanie produktu, przywództwo etyczne, sposób działania przedsiębiorstwa

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ORIGINAL PAPER

THE EFFECTS OF DEMAND PLANNING ON THE NEGATIVE CONSEQUENCES OF OPERATIONAL RISK IN SUPPLY CHAINS

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ABSTRACT. **Background:** Although extant studies have highlighted the importance of specific demand planning practices in risk mitigation, there is a scarcity of research that shows the simultaneous effects of demand planning practices on the disruptions induced by operational risks in supply chains. In order to reduce this gap, this paper aims to explore the impact of the demand planning process on operational risk, and thereby reveal if operational risk factors and their negative consequences may be mitigated through the application of specific demand planning practices in supply chains.

Methods: The study involves two stages of multivariate statistical analysis. In stage one, independent and dependent variables are reduced through factor analysis in order to highlight the main, underlying, multi-item factors. In the second stage of the study, a multiple regression analysis is conducted to compare the general contribution to variance in operational risk accounted for by demand planning practices and their combinations. The conducted analysis provided regression models for particular operational risks.

Results: The study reveals that all activities in the demand planning process contribute more or less to lower operational risk in the examined supply chains. In particular, there are strong relationships between demand planning practices and both control and demand risks. On the other hand, the lesser effects of demand planning may be observed in process and supply risks.

Conclusions: The study shows that different managerial instruments, which are not inherently dedicated to risk management, when appropriately applied, may have an indirect impact on the mitigation of supply chain risk. In particular, the concept of demand planning might be very helpful for managers when dealing with demand and control risks.

Key words: planning process, demand, risk, supply chain.

INTRODUCTION

The demand planning process, as a component of the concept of Sales and Operations Planning (S&OP), encompasses the set of processes and technologies which enable a supply chain to effectively address the issue of supply and demand [Muzumdar, Fontanella 2006]. Extant studies have highlighted the importance of specific demand planning practices in risk mitigation [Blome, Schoenherr 2011, Jonsson, Mattsson 2013, Petropoulos et al. 2014, Blackhurst et al. 2011]. Despite a large body of research on the relationships between individual demand planning practices and risk consequences, there is a scarcity of studies that show the simultaneous effects of demand planning practices on the disruptions induced by risks in supply chains. In order to reduce this gap, the current research attempts to demonstrate whether demand planning contributes to mitigating the consequences of operational risks in supply chains. So as to bridge this gap, we solicited a sample of companies operating in European supply chains. The obtained survey data were then used to perform a multivariate statistical analysis to yield findings and test hypotheses. This paper is

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organized into several sections. Following the introduction, we distinguish major practices in the demand planning process and theoretically justify their hypothesized impact on the consequences of operational risk factors. After developing the methodology, we finally depict empirical findings derived from the statistical analysis, draw conclusions and demonstrate the implications for further empirical research.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Definition of the demand planning process

There are a number of previous studies demonstrating individual practices of the demand planning process. Among them, the strand of research dealing with forecasting practices prevails [Lockamy, McCormack 2004]. Kahn and Mentzer [1996] emphasize that a company ought to be capable of forecasting its market opportunities in order to make demand planning accurate. However, forecasting, though important, is not the sole activity in the demand planning process. There are several other activities of strategic and operational characteristics, including goal formulation, data gathering, demand forecasting, communication of demand predictions and determination of synchronization procedures [Croxton et al. 2001, Crum, Palmatier 2003, Croxton et al. 2008].

The overriding goal of demand planning is to ensure the balance between supply and demand in a supply chain [Croxton et al. 2008]. However, from the standpoint of demand planning, the goal is not principally to generate the sale, but rather to provide a portfolio of the most beneficial clients. The pertinent activities are embedded in the process of physical distribution, especially in its three dimensions of availability, timeliness and delivery quality [Lockamy, McCormack 2004]. Each customer's expectations in these three dimensions may differ. Therefore, the goal of the demand planning process is neither to meet customers' expectations more effectively, nor to serve customers more cheaply, but to offer superior value as a result of a meticulous understanding of market requirements, possible benefits and requisite supply abilities [Juttner et al. 2007]. In other words, the goal of the demand planning process consisting in balancing supply and demand means that the organization advantageously caters to different market requirements with diverse supply chain capabilities.

Data sources used in forecasting usually cover historical data on demand volume or sales, data from production (e.g. production capacity, line loads, current schedules), warehouses (e.g. storing capacity, inventory level), marketing department (e.g. historical and future marketing activities for products and services) and financial records [Tuomikangas, Kaipia 2014]. Data from several sources are then used in qualitative and quantitative demand forecasting [Moon 2013], involving causal models [Cohen et al. 2013], and time series models [Moon 2013]. The use of quantitative methods of forecasting should be extensively supported by computerized applications [Waller, Fawcett 2013]. The following four categories of forecasting are commonly used: software spreadsheets (e.g. Excel), broad-based statistics (e.g. SAS, SPSS, Minitab) – designed to offer a wide range of tools confined into modules – forecasting modules, and business forecasting packages dedicated to forecasting, such as Box-Jenkins, Forecast Pro, Autobox, SmartForecats, and forecasting engines [Snapp 2012]. The completed forecasts should then be transmitted to the other companies in a supply chain and/or other departments of the organization, as they offer essential input for matching customer demand with the firms' supply ability [Croxton et al. 2001]. Finally, the last activity of demand planning is to determine synchronization procedures. Generally, decision synchronization seeks to facilitate a harmonization of planning and decision making between supply chain partners [Simatupang et al., 2002]. As independent decisions may not generate an optimal result, the joint decision-making process produces synergistic benefits for the companies in a supply chain [Lee et al. 1997]. Synchronization requires balancing the demand forecast with the manufacturing, supply and logistics capabilities of the supply chain [Cloxton et al., 2008]. In other words, the synchronization procedures in demand planning cover the identification of a supply chain's operational capacity and flexibility at all points in its structure [Croxton et al. 2001].

The relationships between demand planning and operational risks

Contemporary supply chains are challenged to identify an infinite number of different risks emanating from many sources. The negative effects of risks may be triggered by external or internal risk factors. External risk factors are located outside the supply chain, while internal ones remain within the supply chain [Rao, Goldsby 2009]. In the opinion of Mentzer et al. [2004], internal risk factors in supply chains should be referred to as operational risks. Based on the literature review, we follow a two-dimensional approach while identifying the operational risk factors in supply chains [Cavinato 2004, Christopher, Peck 2003]. The first approach posits that operational risk factors encompass the potential and actual negative consequences in supply and customer demand [Tang, 2006], whilst the second one argues that the group of operational risk factors includes process and control risks [Rapana 2009]. Christopher and Peck [2003] notice that process and control risks are internal to the firm, while demand and supply risks are external to the firm, but internal to the supply chain. Based on this classification, in our study we identify the following operational risk factors: supply risks, demand risks, process risks and control risks.

Supply risk describes disruptions affecting the activities performed in the flow of products, information and money. Accordingly, it deals with the negative consequences of risk occurring in the links located upstream in supply chains. In order to mitigate supply-side risks, upstream supply chain links should establish integrative relationships [Swink et al. 2007]. Consequently, Lin and Zhou [2011] argue that many focal supply chain companies establish long-term partnerships with their suppliers in order to decrease a certain level of supply risk. In the same vein, Donovan [2015] argues that demand planning helps to mitigate supply chain disruptions and costs by reducing demand variability and improving its planning and flexibility upstream in the supply chain. In other words, demand planning efforts put upstream supply chain partners in a better position in order to grasp the requirements of subsequent links, and thus alleviate the negative consequences of risks [Swink et al. 2007]. Therefore, we define the following hypothesis:

H1. The demand planning practices decrease the disruptions driven by supply risks.

Similarly, demand risk is the downstream equivalent of the above, and concerns disruptions to the activities performed in the flow of products, information and money within the supply chain, downstream of the focal firm [Christopher, Peck 2003]. In order to reduce the disruptions caused by demand-side risks, supply chain companies ought to develop integrative relationships with their customers [Manuj, Mentzer 2008]. Consequently, the integration of downstream players into a supply chain is strongly linked to demand planning as it contributes to a greater visibility in sharing information on future demand [Boon-Itt, Wong 2011]. Following the opinion of Giunipero and Eltantawy [2004], we allege that demand planning seeks to reduce risks and their negative effects by strongly integrating inner functions within a focal company and successfully linking them to the outside operations of downstream players in a supply chain. Accordingly, we offer the following hypothesis:

H2. The demand planning practices in supply chains mitigate the disruptions driven by demand risks.

Process risk refers to disruptions in the sequence of value-adding activities undertaken by individual companies in a supply chain. The execution of value-adding activities is usually dependent upon owned or managed assets, as well as on infrastructure. Therefore, both assets and dependability of infrastructure should be carefully considered while analyzing process risk [Christopher, Peck 2003]. Among the concepts that contribute to mitigating the disruptions induced by certain process risk factors is demand planning [Fuchs, Otto 2015]. The link between the negative consequences of risks emanating from the physical operations and selected practices of demand planning is also mentioned by Ma Gloria [2015]. In light of the presented evidence, we offer the following hypothesis:

H3. The demand planning practices alleviate the negative consequences of process risks in supply chains.

Control risk concerns disruptions in the methods, techniques and procedures that govern the processes. From the perspective of a supply chain, they are manifested by errors in order quantities, misconceptions in batch sizes, mistakes in determining safety stock, deviations in future customer demand, etc. [Christopher, Peck 2003]. The intervening role of demand planning in mitigating the negative consequences of control risks is described by Stitt [2004]. He provides several examples of disruptions driven by control risks that may be reduced by demand planning. The relationship between the consequences of control risks and selected practices of demand planning is also mentioned by Zhao et al. [2013]. In a similar vein, Lambert et al. [2006] argue that the success of planning is determined by the consequences of control risk generated by managers. In light of this, we advance the following hypothesis:

H4. The demand planning practices in supply chains mitigate the disruptions driven by control risks.

RESEARCH METHODOLOGY

Questionnaire design and variables

Data for the study were gathered from a questionnaire that consisted of three sections covering the demography of the sample, demand planning practices and the negative consequences of operational risks (disruptions). The first section included variables examining the general demographic characteristics. Two demographic variables, industry type and firm size, were used as control variables to offer a test of the hypothesized conceptual relationships.

As the study involved a sample of firms operating in many industries, it is possible that effects from the sector may have a significant impact on such an investigation of a multilateral issue of supply chain risk [Juttner, 2005]. Therefore, the first control variable was measured using a nominal scale, whose role was to identify and classify objects belonging to the specific industry types. On the other hand, firm size is usually measured by the number of employees [Cui and Jiao, 2011]. The second and third sections of the questionnaire included 44 items for measuring operational risk and 36 items for measuring demand planning practices. The variables grouped into these two sections were an input in the survey via literature review.

Sample characteristics and study setting

The sample was compiled from surveys of European supply chains and originally consisted of 371 organizations. The questionnaires were usually filled in by a director of logistics, manufacturing, marketing or distribution.

The process of data gathering consisted of two stages. In the first stage, the subsample was obtained using purposive sampling. The questionnaire was sent out to 231 Polish companies. In the second round, we adopted a convenient sampling method. First, using Europe's 500 List and national company lists, we identified a group of 584 companies from Germany, Czech Republic, Italy and the Netherlands. Then, the survey instrument was forwarded to these companies via electronic mail or fax. The obtained response rate was roughly 24 percent and formed the second subsample. The data retrieved from two survey rounds were combined and underwent an initial analysis which produced a group of 293 valid responses. It included companies from Poland (53 percent), Czech Republic (17 percent), Germany (12 percent), the Netherlands (9 percent), and Italy (9 percent). The majority of surveyed companies were engaged in supply chains operating in the manufacturing industry (51%), followed by the commercial sector (38%) and the service industry (11%). In terms of the number of employees, the sample is mostly composed of medium and large companies. The prevailing share of 47 percent of the sample employed from 50 to 249 persons, followed by 44 percent of the companies employing above 250 people, and 9 percent of the companies with 10 to 49 employees.

First, we addressed the problem of common-method bias at an early stage of the study. Following the view of Podsakoff et al. [2003], we separated the measurement items at the stage of questionnaire design. With the aim of recognizing the potential effects of common-method bias, we carried out a single factor analysis [Podsakoff et al. 2003]. Accordingly, the set of variables was loaded into the Exploratory Factor Analysis (EFA), however, not a single factor was derived from the analysis. This suggested that there was no general factor that may give rise to the majority of covariance. This may evidence that a considerable amount of common-method bias is absent in the study. Additionally, since two different samples were combined in the study, the findings need to be controlled for by including a dummy variable manifesting if the companies belong to the first or second subsample. Through introducing this control variable, we wanted to test whether our results were consistent across two subsamples. In order to investigate the effects of the demand planning process on the consequences of operational risk in supply chains, we carried out a statistical analysis consisting of two stages [Hair et al., 2017]. In the first stage, we reduced independent variables through factor analysis in order to highlight the major factors. In the second stage of the study, we carried out a multiple regression analysis to compare the contribution to variance in operational risk accounted for by the demand planning practices and their combinations (Hair et al. 2017). The analysis provided regression models of particular operational risks.

Measurement of dependent variables

We grouped the dependent variables into four constructs reflecting the disruptions driven by certain operational risks – control, process, supply and demand. The respondents were asked to determine the level of risk impact by assessing seven-point Likert-type scale items. The scales were anchored by "1 – strongly disagree […] 7 – strongly agree" for all constructs. In order to verify the internal consistency, we calculated Cronbach's alpha for each construct. Their values in all instances were above .7 and may thus be considered to be reliable [Hair et al., 2017]. The coefficients of CR estimated for the underlying constructs were above the value of .7, which is considered to be a satisfactory result [Hair et al. 2017]. The values of an average variance extracted (AVE) exceeded .5 across all constructs, which is an acceptable outcome. It suggests that, on average, all factors are capable of explaining more than half of the variance of its indicators. We also assessed the unidimensionality of the key constructs using Principal Component Analysis. It enabled a verification of whether or not the variables load sufficiently onto their hypothesized factors. All factor loadings for particular variables in their constructs exceeded .5. The Kaiser-Meyer-Olkin measure scores, ranging from .76 to .87, suggest a middling or meritorious result which supports the use of factor analysis in the sample of companies (Schmidt and Hollensen, 2006). Twelve variables that measure the negative consequences of control risk formed a single factor and explained 54 percent of variance. Similarly, nine variables for disruptions driven by process risk, twelve items for the consequences emanating from supply risk and eleven variables for disruptions originating from demand risk, each grouped into single factors, accounted for 41, 49 and 63 percent of variance, respectively. The obtained classification of variables indicate a good level of adequacy in terms of the operational risk factors in the conceptual model. The factors capture most of the variation of their constituent variables and indicate the overall operational risk.

STATISTICAL ANALYSIS

Exploratory Factor Analysis (EFA) for independent variables

A Factor Analysis was performed to summarize the information manifested by many variables and compress them into a smaller set of constructs. In order to perform the Exploratory Factor Analysis for the group of independent variables, a Principal Component Analysis (PCA) with a Varimax Rotation was employed. The factor analysis produced a clear pattern of constructs with minimal cross-loadings and high loading on one construct. The individual sampling adequacy scores exceeded .5 across all variables. Based on the Kaiser criterion, the analysis conducted on 36 items, revealed four factors. The obtained factors explain 63.12 percent of variance. With the results of the factor analysis, KMO coefficient was calculated. It accounts for .685, which is a middling result, indicating acceptable suitability of the sample for factor analysis. Regarding the content-related aspect of the classified variables, the analysis produced the following factors: Formulating the goal of demand planning (GDP), Data gathering (DG), Demand forecasting (DF), Communicating the forecasts and synchronizing demand with supply (C&S).

The first factor refers to formulating the goal of demand planning. The analysis suggests that this construct generates the greatest value of 27.36 percent. The second factor pertains to data gathering. The outcome of the analysis shows that this factor accounts for 13.83 percent of the information. The third construct links to demand forecasting and covers 12.71 percent of the information. The fourth factor includes the two following activities of demand planning - communicating the forecasts and synchronizing demand with supply and explains the value of 9.22 percent of total variance.

For an assessment of reliability, we calculated internal consistency and composite reliability (CR). For each of the four constructs, internal consistency, as measured by the Cronbach's alpha, exceeded .7 and coefficients of CR estimated for the four constructs were above .7. Accordingly, the results of reliability may be considered satisfactory at this initial stage of the study [Nunnally, Bernstein 1994]. In order to determine validity, we calculated both convergent and discriminant validity. The average variance extracted (AVE) measuring the convergent validity, was above .5 for all constructs. This indicates that all constructs are capable of explaining, on average, more than 50 percent of the variance of its indicators (Chin, 1998). Thus, a set of variables reflect the same major factor that may be depicted through unidimensionality. The constructs have an appropriate discriminant validity when the value of AVE for each construct is larger than the squared correlations between the construct and any other considered construct. All constructs analyzed in the study met this criterion.

Multiple regression analysis

In the following stage of the analysis, we developed multiple regression models, used to test the hypotheses. The models enabled a comparison of the contribution of disruptions driven by the operational risk factors to variance. Only the variables with p-values of less than .05 were maintained in the model. We developed models for each of the four response variables indicating specific types of disruptions induced by operational risks in supply chains.

In general, the regression analysis revealed that each analyzed type of the consequences of operational risk has a model with significant independent variables and adjusted coefficients of determination (R2adjusted) ranging from .042 to .340. The strongest model, as measured by R2adjusted, was developed for the consequences of control risk. The second model in terms of R2adjusted is demonstrated by the disruptions originating from demand risk, followed by two remaining models that show the negative consequences of supply and process risk, though with clearly lower coefficients of determination. It is also interesting to highlight that two first regression models for the consequences of control and demand risks contain all four significant factors indicating the demand planning activities. The explanatory variables are negatively associated with the response variable in both models. This suggests that, generally, the more intense demand planning practices, the lower the level of the strength of disruptions driven by either control or demand risks in supply chains. Three control variables (industry type, firm size and subsample number), though positive, are insignificant in two models. Two other models developed for the consequences of process and supply risks do not indicate significant relationships with any demand planning practices. They are accompanied by a low value of adjusted coefficients of determination for these two models. In addition, some control variables may influence the relationships in the proposed models.

DESCRIPTION OF THE FINDINGS

The effects of demand planning practices on the consequences of control risk

The regression model developed for the consequences of control risk demonstrates the negative and significant relationships with all demand planning practices – Table 1. Therefore, the obtained findings lend a support to H4 and demonstrate that the sequence of demand planning practices contribute to mitigating the negative consequences of control risk, regardless of industry type, company size and subsample number.

Table 1. Regression analysis for H4

Dependent variable	Independent variables	Std. Coef.	t-value	Sig.	adj. R sq.*
Control risk	F1: Formulating the goal of demand planning	-.314	-2.13	.034*	.340
	(GDP)	-.675	-4.08	.000**	
	F2: Data gathering (DG)	-.013	-1.98	.048*	
	F3: Demand forecasting (DF)	-.334	-3.25	.001**	
	F4: Communicating the forecasts and synchronizing demand with supply (C&S)				
	Industry type	.031	.433	.665	
	Company size	.006	.091	.928	
	Subsample number	.051	.893	.373	

* p-value <.05
** p-value < .01

The most influential factor for the disruptions induced by control risk is data gathering (-.675, .000). This may suggest that intense data gathering contributes to a mitigation of the negative consequences driven by the control risk factors. First of all, this activity might decrease the systematic forecast error while developing predicting models in demand planning. Data gathering may also mitigate the negative consequences of an inadequate employment policy and mistakes made by top managers in the decision-making process, by providing a wide range of detailed data. Similarly, the demand planning activity of communicating forecasts and synchronizing demand with supply seems to play a vital role in mitigating disruptions (-.334., .001). This construct is especially important while reducing the negative consequences of inefficient information and communication systems, mistakes in order transmission and data processing, inefficient communication links and data transfer. The intense activity of communicating forecasts and synchronizing demand with supply might also be significant while reducing the detrimental consequences of mistakes made by regular employees and mismatch between their qualifications and imposed tasks. The next activity of formulating the goal of demand planning also significantly mitigates the disruptions induced by control risk (-.314, .034). In particular, this factor might play a vital role while reducing the consequences of inadequate employment policy and mistakes made by top managers in the decision-making process. Additionally, this activity also contributes to lowering the perturbation caused by systematic forecast errors. Interestingly, demand forecasting contributes to a decrease in the negative effects of control risk, though this activity seems to be less significant in the whole model (-.013, .048). The factor of demand forecasting is particularly important while mitigating the negative consequences of inventory control inaccuracy and inadequate or unsound scheduling methods.

The effects of demand planning practices on the consequences of demand risk

Similarly to the control risk model, there are four significant constructs demonstrating predictive capability for demand risk – Table 2.

Table 2. Regression analysis for H2

Dependent variable	Independent variables	Std. Coef.	t-value	Sig.	adj. R sq.*
Demand risk	F1: Formulating the goal of demand planning (GDP)	-.617	-4.35	.000**	.214
	F2: Data gathering (DG)	-.150	-1.99	.047*	
	F3: Demand forecasting (DF)	-.178	-2.07	.039*	
	F4: Communicating the forecasts and synchronizing demand with supply (C&S)	-.587	-3.85	.000**	
	Industry type	.018	.285	.776	
	Company size	.024	.304	.761	
	Subsample number	.015	.221	.825	

* p-value <.05
** p-value < .01

The obtained findings give support to H2 and evidence that the sequence of demand planning practices contributes to mitigating the negative consequences of demand risk, regardless of industry type, company size and subsample number. In particular, formulating the goal of demand planning has the strongest impact on the negative consequences induced by demand risk (-.617, .000). This demand planning activity might be significant while reducing the difficulties to meet certain logistics service levels. It stems from the fact that one should consider the standards of logistics service while formulating the goal of demand planning. Moreover, formulating the goal of demand planning contributes to a mitigation of the negative consequences of greater seasonality and volatility of product demand, as well as larger product variety/volume, and uncertainty of customer demand. The other demand planning activity that mitigates the disruptions stemming from demand risk is communicating forecasts and synchronizing demand with supply (-.587, .000). This construct is particularly important while reducing difficulties in meeting certain logistics service levels and other disruptions in a delivery process. Communicating forecasts and synchronizing demand with supply may also reduce the negative consequences of greater seasonality and volatility of product demand, as well as helping to overcome the obstacles of new product adoptions. Two remaining demand planning activities, data gathering and demand forecasting, have a substantially lower impact on the consequences of demand risk ((-.150, .047) and (-.178, .039), respectively). These two constructs seem to play an important role while reducing the negative consequences of greater seasonality and volatility of product demand, as well as mitigating the disruptions caused by product variety, volume and a short product life cycle. Data gathering may also contribute to lowering the perturbations caused by competitors' promotions, market rivalry and the emergence of substitute products.

The effects of demand planning practices on the consequences of supply risk

The findings suggest that there is a lesser number of significant demand planning practices that have an impact on the disruptions driven by supply risks – Table 3. Generally, the research results show that not all of the demand planning practices are addressed to mitigate and limit the consequences of this type of risk. The smaller number of predicting variables stems from the fact that the disruptions driven by supply risk are not inherently associated with demand planning practices, as they are rather related to the upstream part of supply chains. Therefore, the obtained findings do not offer support to H1 and demonstrate that only a portion of demand planning practices contribute to mitigating the negative consequences of supply risk. Moreover, the influence is dependent upon the company size. In the case of the supply risk model, there are three significant constructs demonstrating demand planning activities, namely data gathering (-.512, .000), demand forecasting (-.410, .000) and communicating forecasts/synchronizing demand with supply (-.417, .000). Data gathering may offer up-to-date, specific and precise information that may have a mitigating influence on the negative consequences of supply risk. Moreover, intense demand forecasting may result in lesser disruptions in the seasonality and volatility of material demand and decrease the uncertainty of supply chain requirements.

Table 3. Regression analysis for H1

Dependent variable	Independent variables	Std. Coef.	*t*-value	Sig.	*adj. R sq.**
Supply risk	F1: Formulating the goal of demand planning (GDP)	-.007	-0.165	.869	.156
	F2: Data gathering (DG)	-.512	-5.35	$.000^{**}$	
	F3: Demand forecasting (DF)	-.410	-4.31	$.000^{**}$	
	F4: Communicating the forecasts and synchronizing demand with supply (C&S)	-.417	-4.55	$.000^{**}$	
	Industry type	.241	1.92	.056	
	Company size	.371	2.18	$.030^{*}$	
	Subsample number	.008	.480	.632	

* p-value <.05
** p-value < .01

Finally, demand forecasting may also contribute to mitigating the consequences stemming from the variety and volume of purchased materials, and deal in a much better way with the disruptions caused by a short product life cycle. Although, as the findings report, demand forecasting may offer support in mitigating the consequences of supply risk, it might be difficult to translate some qualitative demand forecasts that do not take a numeric form and make them usable. Furthermore, forecasting concerns customer demand and does not refer directly to supply. This may limit the potential effects of demand forecasting in mitigating the consequences of supply risk, as demonstrated by the low value of the standardized regression coefficient (beta) in the model. It is also worth noting that communicating forecasts and synchronizing demand with supply may contribute to decreasing the negative consequences originating from the seasonality and volatility of material demand, as well as the variety and volume of the purchased materials.

The effects of demand planning practices on the consequences of process risk

As demonstrated by the results of the study, there are only two significant factors negatively associated with the consequences of process risk, namely formulating the goal of demand planning and communicating forecasts and synchronizing demand with supply ((-.218, .000) and (-.324, .000), respectively – Table 4). Since process risk rather concerns the physical flow of products in supply chains, disruptions cannot be fully mitigated by performing regulatory practices of demand planning. Consequently, the obtained findings do not support H3 and show that a limited number of demand planning practices contribute to mitigating the negative consequences of process risk. This impact is dependent upon company size and industry type. It means that the intensity and scope of demand planning practices used to mitigate the negative consequences of process risk might differ regarding their contextual variables. In particular, formulating the goal of demand planning in a more explicit and precise way, as well as more intense processes of communicating forecasts and synchronizing demand with supply, may contribute to a mitigation of the disruptions caused by lower quality, and rework issues associated with the internal manufacturing and technical processes, mistakes of employees performing specific technical operations, and mismatch between employees' qualifications and tasks.

Table 4. Regression analysis for H3

Dependent variable	Independent variables	Std. Coef.	t-value	Sig.	*adj. R sq.**
Process risk	F1: Formulating the goal of demand planning (GDP)	-.218	-3.82	.000**	.042
	F2: Data gathering (DG)	-.041	-0.85	.396	
	F3: Demand forecasting (DF)	-.019	-0.31	.756	
	F4: Communicating the forecasts and synchronizing demand with supply (C&S)	-.324	-4.42	.000**	
	Industry type	.185	2.31	.021*	
	Company size	.198	3.48	.000**	
	Subsample number	.015	.027	.787	

* p-value <.05
** p-value < .01

Moreover, an intense communication of forecasts and synchronization of demand with supply may decrease the negative consequences of variation in manufacturing yields. The two remaining factors, data gathering and demand forecasting, indicate no significant association with the negative consequences of the process risk model. This probably stems from the fact that these two constructs are more connected with customer demand than with the physical flow of products in supply chains. As such, there is a lack of coherence between demand forecasting data, which are more externally oriented, and the information needs of process risk management, which are required to be focused more internally. Consequently, in order to reduce the disruptions caused by process risk factors, other managerial methods that refer to manufacturing and logistics ought to be applied. Data gathering and demand forecasting probably enrich the management of the flow of products and make decision processes more effective and efficient. However, on the other hand, the output of forecasting is not usable while mitigating the consequences of process risk.

DELIVERABLES AND MANAGERIAL IMPLICATIONS

The findings of the study show that there is a sequence of specific demand planning practices which contributes to the mitigation of disruptions induced by some operational risks in supply chains. Table 5 summarizes the deliverables obtained from the study with the corresponding hypotheses. The most noticeable effects of demand planning might be observed in mitigating the negative consequences of control and demand risks. This is confirmed by a number of significant and negatively associated constructs forming a sequence of demand planning practices and strong regression models for these two types of disruption.

Table 5. Summary of the results

Hypothesis		Results
H1.	The demand planning practices decrease the disruptions driven by supply risks	Not supported
H2.	The sequence demand planning practices in supply chains mitigate the disruptions driven by demand risks	Supported
H3.	The demand planning practices in supply chains alleviate the negative consequences of process risks	Not supported
H4.	The demand planning practices in supply chains mitigate the disruptions driven by control risks	Supported

This is a very important contribution of our study as, even though previous research investigated the effects of demand planning on the negative consequences of risks, they usually employed a very general perspective and did not examine a holistic structure of practices forming the process of demand planning. Moreover, when mentioning the relationships between disruptions and demand planning, the extant studies, based on theoretical considerations, offer conceptual propositions that are not supported by the findings of quantitative research. Accordingly, the coherence and robustness of the obtained deliverables are confirmed by the findings of statistical tests, conducted to determine the significance of the estimated coefficients. In addition, the results of our study do not differ in terms of sample, company size or industry type. On the other hand, the lesser impact of demand planning is noticed in the case of disruptions driven by process and supply risks. There is a limited number of significant and negatively related demand planning practices that contribute to mitigating the negative consequences of risks. This finding confirms the results derived from previous studies. However, our findings, in contrast to the results derived from other research, employ the demand planning perspective. In other words, the study does not investigate loosely coupled practices, but a specific sequence of demand planning practices forming the whole process. Also, the strength of the models for process and supply risks is much less when compared to other regression models, as measured by adjusted coefficients of determination. In addition, the effects of selected demand planning practices on the disruptions in both models are dependent upon the contextual variables of industry type and company size. This finding highlights that there is not any uniformity or standardization in terms of the role of demand planning in alleviating the negative consequences of supply and process risks.

In light of the aforementioned, the research results provide valuable suggestions for managers that tend to apply demand planning in order to mitigate the disruptions caused by operational risks in supply chains.

Managers should be aware that applying an effective demand planning process may contribute to a reduction in the level of disruptions caused by operational risks. In particular, the concept of demand planning might be very helpful for managers when dealing with the consequences of demand and control risks. In addition, the model relationships among demand planning practices and consequences of control and demand risks were found to be robust, regardless of the settings of the contextual variables, such as industry type, company size and subsample number.

Understandably, the conducted research showed that demand planning is not the only concept that is dedicated to alleviating disruptions. The coefficients of determination obtained in the study suggest that there are other variables and constructs that have potential predictive capability with reference to the disruptions caused by operational risks. In other words, the strength of the negative impact of certain risk factors is not explained only through the lens of demand planning practices. In fact, there are activities performed in supply chain management that might have a more direct impact on the disruptions caused by operational risks. Arguably, the practices of risk management seem to play the most significant role. In light of this, managers should pay attention to the fact that the demand planning process, as a managerial concept, embraces a number of specific activities in order to deal with demand. However, performing these activities might also complement the risk management concept and lead to a mitigation of the negative consequences of operational risks. In other words, different managerial instruments, which are not directly linked to the risk management concept, when appropriately applied, may also have an indirect impact on the mitigation of the consequences of risk. It is worth saying that the demand planning process should not act as the sole tool for the mitigation of risk consequences, but rather as a complementary concept reinforcing the effectiveness of appropriate risk management. All these implications would require further in-depth investigation regarding the different sources of risk and their mutual relationships that have a potential and actual impact on supply chains.

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WPŁYW PLANOWANIA POPYTU NA NEGATYWNE SKUTKI RYZYKA OPERACYJNEGO W ŁAŃCUCHACH DOSTAW

STRESZCZENIE. **Wstęp:** Mimo faktu, że w literaturze przedmiotu podejmowano problem dotyczący roli określonych czynności planowania w łagodzeniu ryzyka i jego skutków, niemniej wciąż brakuje badań podejmujących problematykę jednoczesnego wpływu czynności w planowaniu popytu na zakłócenia wywołane przez czynniki ryzyka operacyjnego w łańcuchach dostaw. W związku z tym celem artykułu jest identyfikacja wpływu procesu planowania popytu na zakłócenia wywołane przez ryzyko operacyjne. Innymi słowy, celem niniejszej pracy jest rozpoznanie czy operacyjne czynniki ryzyka i ich negatywne konsekwencje mogą zostać ograniczone za pomocą aplikacji czynności w procesie planowania popytu w łańcuchach dostaw.

Metody: W artykule przeprowadzono dwa etapy wielowymiarowej analizy statystycznej. W pierwszym etapie zmienne zostały zredukowane za pomocą analizy czynnikowej w celu identyfikacji podstawowych konstruktów. W drugim etapie badania, przeprowadzono analizę regresji wielorakiej po to, aby porównać wpływ poszczególnych czynności w planowaniu popytu na konsekwencje ryzyka operacyjnego.

Wyniki: W rezultacie przeprowadzonego badania stwierdzono, że czynności planowania popytu w mniejszym lub większym stopniu przyczyniają się do ograniczenia ryzyka operacyjnego w łańcuchach dostaw. W szczególności, istnieją silne relacje między planowaniem popytu i konsekwencjami ryzyka decyzyjnego oraz ryzyka popytowego. Z drugiej strony, mniejszy wpływ planowania popytu można obserwować w przypadku ryzyka związanego z fizycznym przepływem produktów oraz ryzyka w sferze dostaw.

Wnioski: Badanie pokazuje, że metody zarządzania, niekoniecznie dedykowane dla potrzeb ograniczania ryzyka, mogą istotnie przyczyniać się do zmniejszenia jego konsekwencji w łańcuchach dostaw. W szczególności koncepcja planowania popytu może zostać wykorzystana przez menedżerów w przypadku ograniczania konsekwencji ryzyka decyzyjnego i ryzyka popytowego.

Słowa kluczowe: proces planowania, popyt, ryzyko, łańcuch dostaw

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ORIGINAL PAPER

THE ROLE OF ENVIRONMENTAL COOPERATION AND COLLABORATION IN SUPPLIER RELATIONSHIP MANAGEMENT

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ABSTRACT. **Background:** This article aims to determine the role of environmental cooperation and collaboration in supplier relationship management. The following concepts are introduced: supplier relationship management, environmental cooperation and environmental collaboration. Supplier relationship management aims at building bonds with suppliers that exceed the transactional approach to market cooperation. Environmental cooperation and collaboration involve all operations that are performed with the active or passive involvement of suppliers and their clients. Firstly, the concept of supplier relationship management is described. Secondly, the characteristics of environmental cooperation and environmental collaboration are introduced. Next, the observations and findings are presented. Finally, the conclusions and recommendations for future research are described.

Methods: The research method used is an analysis of Polish and foreign literature related to the subject of environmental cooperation and collaboration in the context of supplier relationship management.

Results: The results concern the validity of considering environmental cooperation and collaboration as a significant field of supplier relationship management and developing a conceptual framework for environmental cooperation and collaboration in the context of building relationships with suppliers.

Conclusions: The conclusions concern the types of environmental interaction and relationships with suppliers, taking into account the role of mutual trust, commitment and goal consistency between buyer and supplier.

Key words: environmental cooperation, environmental collaboration, supplier relationship management, building relationships with suppliers, buyer-supplier relationships.

INTRODUCTION

The rapid development of information technology, telecommunications and business interdependencies has accelerated globalization. Progressing globalization has led to the deeper integration of supply chains, resulting in the building of stronger relationships, cooperation and collaboration between participants in those chains. The idea of buyer requirements regarding environmental issues and supplier readiness to meet them is supported by Caniëls et al. [2013]. On the other hand, the growing environmental consciousness of end customers, corporate social responsibility and the concept of sustainable development highlight environmental issues in the supply chain. This article aims to determine the role of two forms of interaction with suppliers: environmental cooperation and collaboration (ECaC) in supplier relationship management (SRM).

Cooperation with suppliers is seen as a way to provide alignment in the supply chain [Vachon et al. 2009]. In contrast to cooperation, collaboration requires active engagement from all sides involved [Polenske 2004]. It includes maintaining standardised operations, joint planning, sharing knowledge, information and processes, synchronizing, interfacing and investing for better operations, systems and processes in the supply chain [Soosay et al. 2008]. Furthermore, there are theories that environmental collaboration is

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positively related to logistical and technological integration with suppliers [Vachon and Klassen 2006]. Moreover, Vachon et al. [2009] support the statement that a high degree of cooperation with suppliers is linked with a greater supply chain alignment regarding competitive priorities.

SUPPLIER RELATIONSHIP MANAGEMENT

Managing cooperation with suppliers is strictly related to managing the relationships with them. It has become a crucial issue in modern supply chain management and a key area of many enterprises. In addition to customer relationship management, SRM "forms critical linkages that connect firms in the supply chain" [Lambert, Schwieterman, 2012]. Inter-firm linkages were confirmed to enhance firm performance in the context of environmental collaboration [Grekova et al. 2016]. Schuh et al. [2014] formulated a list of questions to be answered by the company that wishes to establish SRM:

1. At the company level, what do we want from this supplier?
2. What type of behaviour do we want to drive with this supplier?
3. How do we want to structure the relationship with this supplier?
4. How do we ensure we are aligned internally when dealing with this supplier?
5. What are the appropriate tools and models for managing the interactions with this supplier?

When considering answers to those questions, the company should decide whether it wishes to concentrate on cooperation or collaboration with suppliers – if any, since cooperation does not necessarily require the active participation of the supplier in an operation, e.g. supplier assessment or organizing training for the suppliers. In that case, the supplier can only disclose the necessary information or take part in an activity coordinated by its client company. Cai and Yang [2008] support the significance of cooperative norms in supplier performance. They propose such norms to be an effective governance form to manage relationships with suppliers.

SRM has been proved to provide many benefits for the company, e.g.: minimalizing transaction costs, creating value through internal capabilities and external resources and reducing risks of dependency and availability [Lintukangas 2010]. Piercy [2009] pointed out that in order to form an alliance or joint-venture with a partner-supplier, the client company needs to convince its supplier that it is a reliable way to invest resources. In other words, the client company must "sell the customer to the company", as well as "sell the company to the customer". Similar issues can be encountered in any cooperation. Liu et al. [2012] show that many aspects of SRM, such as knowledge sharing, continuous commitment and relationship investment might be affected by justice and fairness perceived mutually by both supplier and client. Furthermore, Hill et al. [2009] illustrate that other factors affecting SRM are trust and unethical behaviour.

Autry and Golicic [2010] show that the relation between supplier relationship strength and supplier performance might be presented using a relationship-performance spirals model. Miocevic and Crnjak-Karanovic [2012] indicate that there is a correlation between SRM practices and organizational buying effectiveness. Emiliani [2010] underlines the connection between SRM and ethical aspects of purchasing, including non-zero-sum and win-win methods.

The framework developed and tested by Nyaga et al. [2010] points out that there is a positive relation between conducting collaborative activities and the building of successful relationships with suppliers. The above considerations show that building relationships with suppliers involves many types of cooperation and collaboration with them. Therefore, managing relationships with suppliers and cooperation and collaboration with them are parallel concepts.

ENVIRONMENTAL COOPERATION WITH SUPPLIERS

Cooperation with suppliers in the B2B market concentrates on economic issues. However, environmental issues in the B2B market are getting more and more significant for many reasons, e.g. the growing environmental consciousness of end customers. One of the areas of cooperation most pertinently discussed with suppliers is environmental cooperation. Activities such as eco-design, end-of-life management and other environmental joint goals and activities might be perceived as essential elements of relationships with suppliers.

The following areas of environmental cooperation with suppliers can be distinguished [Sosnowski 2018]:

- research and development,
- building an environmental protection strategy in the global supply value chain,
- ecodesign,
- environmental innovations,
- fulfilling the environmental requirements of clients,
- implementation of green supply chain management practices,
- implementation of ISO 14001 environmental management system,
- joint planning of environmental goals and activities,
- greening the suppliers,
- green purchasing,
- green supplier development.

De Marchi [2012] pointed out the relevance of such areas as environmental innovation and R&D cooperation in environmental cooperation with suppliers. Zhu et al. [2010, 2011] show the developing role of green purchasing and circular economy practices, such as internal environmental management, eco-design and investment recovery, as factors influencing environmental cooperation with suppliers. Many factors are affecting environmental cooperation with suppliers. Bala et al. [2008] referred to greening suppliers as a form of environmental cooperation. Chiou et al. [2011] also highlighted the importance of greening suppliers and green innovation. Environmental innovation is also pointed out by Yarahmadi and Higgins [2012] as an element of the framework for multiparty cooperation that is positively related to supplier cooperation. Wong et al. [2012] discussed the possibility of improving supplier performance with environmental cooperation. Implementation of the ISO 14001 environmental management system might also be a critical factor in environmental cooperation with suppliers. Nawrocka et al. [2009] described its role in this context as "facilitating". De Marchi et al. [2013] pointed out the role of suppliers in building the environmental strategy in the global value chain.

Concepts such as green supply chain management (GSCM) and green purchasing also support environmental cooperation with suppliers. Zhu et al. [2008], Chan et al. [2012] and Ninlawan et al. [2010] listed environmental cooperation with suppliers as a measurement item for the implementation of GSCM practices.

It can be concluded that some of its activities require the active participation of both sides (supplier and its client) while some require the active participation of one side and only passive participation (e.g. sharing environmental information and good environmental practices) of the other side.

ENVIRONMENTAL COLLABORATION WITH SUPPLIERS

Vachon and Klassen [2008] define environmental collaboration as: "the direct involvement of an organization with its suppliers and customers in planning jointly for environmental management and environmental solutions". Such solutions include joint environmental activities and joint planning of environmental goals [Vachon, Klassen 2008]. The significant impact that collaborative planning has on supply chain performance is supported by Petersen et al. [2005]. Soosay et al. [2008] developed a classification of different types of collaboration in the supply chain: strategic alliances, joint ventures, cooperative arrangements, virtual collaboration and vertical, horizontal and lateral integration. All of the above types of collaboration differ in characteristics and potential benefits, but all types may concern environmental issues.

The following dimensions of collaboration exist in the supply chain: information sharing, goal congruence, decision synchronization, incentive alignment, resource sharing, collaborative communication, and joint knowledge creation [Cao, Zhang 2011]. The issue of their role in interactions with suppliers might provide a vital research area.

The following significant barriers to collaboration within the supply chain were identified by Barratt [2004]: lack of attention regarding front-end agreements and the choice of a partner to collaborate with. However, Vachon and Klassen [2008] support the statement that there is a positive relation between environmental collaboration and different dimensions of manufacturing performance. On the other hand, Green et al. [2012] show that environmental collaboration and monitoring practices among supply chain partners have been found to lead to improved environmental and organizational performance. Furthermore, Albino et al. [2012] support the statement that there is a positive linkage between improving the environmental performance of a company and the development of collaborative partnerships with its suppliers.

Gunasekaran et al. [2015] developed an environmental collaboration research framework that places environmental collaboration as the highest level of interaction with suppliers. The question that remains open is if there might be other higher levels of interaction with the supplier: environmental supplier development and environmental supplier integration.

RESEARCH METHODOLOGY

In order to achieve the aim of this paper, a review of literature related to the discussed topic was performed in October of 2018, using the following scientific databases: Science Direct, Emerald Insight, Wiley, Springer and Taylor and Francis. Articles from 2008-2018 were taken into account. The following keywords were used:

- “environmental cooperation” AND “suppliers”,
- “environmental collaboration” AND “suppliers”.

Then an analysis of the chosen sources with a particular emphasis on the potential linkages between ECaC and SRM was performed. In order to do so, the snowballing approach was used. The results are presented in Table 1 and in the Observations and Findings section of this paper.

Table 1. The results of the literature review

Database	Number of records for the keywords (years 2008-2018)	
	“environmental cooperation” AND “suppliers”	“environmental collaboration” AND “suppliers”
Emerald Insight	23	47
Science Direct	53	138
Springer	69	42
Taylor & Francis	26	34
Wiley	52	22

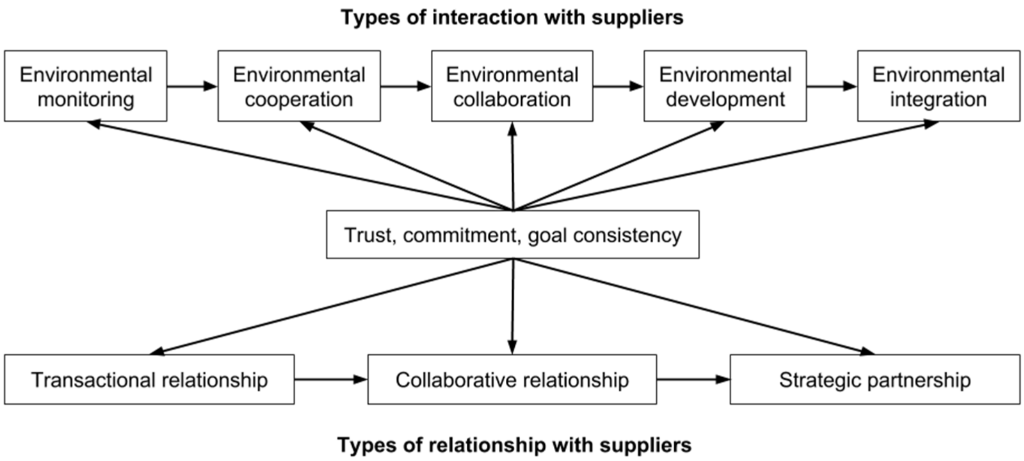
Source: own elaboration

OBSERVATIONS AND FINDINGS

There are theories that environmental cooperation and collaboration are linked with the development of relationships with suppliers. Thus, they might play an essential role in supplier relationship management provided that the focal company attaches importance to its environmental performance.

As a result of the above considerations, a conceptual framework for environmental cooperation and collaboration in the context of building relationships with suppliers was developed (see Fig. 1).

Nyaga et al. [2010] developed a model that linked collaborative activities with relationship outcomes using trust and commitment and proved that collaborative activities are positively related to relationship outcomes and that buyers might gain performance benefits from collaborative relationships with suppliers. Fawcett et al. [2012] came to analogical conclusions with trust as a catalyst of collaborative relationships with suppliers. The significance of building trust in order to develop cooperative relationships with suppliers is also supported by Johnston et al. [2004]. Furthermore, Kim et al. [2010] show that one of the significant determinants of interfirm cooperation is goal consistency.



Source: own elaboration

Fig. 1. Framework for environmental cooperation and collaboration in the context of building relationships with suppliers

Table 2. Literature review – supplier relationship management

Authors (year)	Focus
Autry, Golicic (2010)	Linkage between relationship strength and performance of a buyer-supplier relationship
Cai, Yang (2008)	Development of cooperative norms in the buyer-supplier relationship: the Chinese experience
Emiliani (2010)	Examination of the key recommendations of purchasing management regarding supplier relationships
Hill et al. (2009)	Trust in buyer-supplier relationships
Johnston et al. (2004)	Role of trust in cooperative relationships with suppliers
Lambert et al. (2012)	Macro level cross-functional view of SRM
Lintukangas (2010)	SRM capability
Liu et al. (2012)	Influence of justice on dyadic relationship performance in the buyer-supplier context
Miocevic et al. (2012)	Relationship between supply chain orientation and key supplier relationship management
Nyaga et al. (2010)	Collaborative relationships in buyers' and suppliers' perception
Piercy (2009)	Impact of strategic relationships between functions in supplier organizations

Source: own elaboration

Table 3. Literature review- environmental cooperation and collaboration

Authors (year)	Focus
Albino et al. (2012)	Role of inter-organizational collaboration in environmental performance
Bala et al. (2008)	The strategy and procedures to spread green purchasing practices
Barratt (2004)	Context for collaboration in supply chain
Caniëls et al. (2013)	Supplier participation in green initiatives
Chan et al. (2012)	Relationship among environmental orientation, green supply chain management (GSCM) activities and corporate performance
Chiou et al. (2011)	Relations between greening the supply chain, green innovation, environmental performance and competitive advantage
De Marchi (2012)	Relationship between firms' R&D cooperation strategies and their propensity to introduce environmental innovations
De Marchi et al. (2013)	Environmental management at the value chain
Fawcett et al. (2012)	Role of trust in collaborative relationships with suppliers
Green et al. (2012)	Impact of green supply chain management practices on environmental and organizational performance
Grekova et al. (2016)	Potential of environmental collaboration with suppliers and customers to induce environmentally sustainable improvements
Govindan et al. (2015)	Green supplier selection and evaluation
Gunasekaran et al. (2015)	Trends and future research directions in green supply chain collaboration and incentives
Kim et al. (2010)	Inter-organizational cooperation in buyer-supplier relationships
Nawrocka et al. (2009)	Role of ISO 14001 in environmental supply management practices
Ninlawan et al. (2010)	Green activities evaluation of green supply chain management
Petersen et al. (2005)	Impact of collaborative planning with suppliers
Polenske (2004)	Competetive, collaborative and cooperative relationships within the networks of firms and regions
Razaei et al. (2016)	Environmental criteria of supplier selection

Authors (year)	Focus
Soosay et al. (2008)	Role of collaborative relationships in continuous innovation in the supply chain
Vachon, Klassen (2006)	Environmental collaboration and integration in supply chain
Vachon, Klassen (2008)	The impact of environmental collaborative activities on manufacturing performance
Vachon et al. (2009)	Linkage between strategic alignment in the supply chain and the type of interactions with suppliers.
Wong et al. (2012)	Role of green operations and the influence of environmental management capability of suppliers on firm performance and pollution reduction
Yarahmadi (2012)	Green innovations and environmental cooperative activities of firms
Zhu et al. (2010)	Environmental-oriented supply chain cooperation
Zhu et al. (2011)	Environmental supply chain cooperation
Zhu et al. (2008)	Evaluation of green supply chain management (GSCM) practices implementation

Source: own elaboration

Hence, trust, commitment and goal consistency were used as factors affecting the development of environmental cooperation and collaboration in the context of building relationships with suppliers.

The following types of interaction with suppliers are distinguished: environmental monitoring, environmental cooperation, environmental collaboration, environmental development and environmental integration. The types of relationships with suppliers were also listed: transactional relationships, collaborative relationships and strategic relationships. They illustrate the level of involvement of buyer and supplier in the mutual interaction and in the mutual relationship, which is affected by trust, commitment and goal consistency.

CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

The presented framework for environmental cooperation and collaboration in the context of building relationships with suppliers uses a different kind of interaction with suppliers. The questions that remain unanswered and might provide a basis for future research are the following:

1. Are there any premises for developing a conceptual framework for environmental (or green) supplier development and environmental supplier integration as an extension of the proposed framework for environmental cooperation and collaboration in the context of building relationships with suppliers?
2. What specific activities or practices are companies using in environmental cooperation with their suppliers in terms of the implementation of such concepts as GSCM or green purchasing?

The answers to the above questions might provide a valuable supplement for research on the topic of environmental issues in the supply chain, such as green supply chain management and green purchasing.

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ROLA WSPÓŁPRACY I WSPÓŁDZIAŁANIA ŚRODOWISKOWEGO W ZARZĄDZANIU RELACJAMI Z DOSTAWCAMI

STRESZCZENIE. Wstęp: Niniejszy artykuł ma na celu określenie roli współpracy środowiskowej i współpracy w zarządzaniu relacjami z dostawcami. Wprowadzono następujące pojęcia: zarządzanie relacjami z dostawcami, współpraca środowiskowa oraz współdziałanie środowiskowe. Zarządzanie relacjami z dostawcami ma na celu budowanie więzi z dostawcami, które wykraczają poza wymianę handlową. Współpraca i współdziałanie środowiskowe obejmują wszystkie operacje wykonywane przy aktywnym lub pasywnym zaangażowaniu dostawców i ich odbiorców. Na początku opisano koncepcję zarządzania relacjami z dostawcami. Następnie wprowadzono cechy współpracy środowiskowej i współpracy w zakresie ochrony środowiska. Dalej przedstawiono obserwacje. Na końcu opisano wnioski i zalecenia dotyczące przyszłych badań.
Metody: Zastosowaną metodą badawczą jest analiza literatury polskiej i zagranicznej związanej z tematyką współpracy i współdziałania środowiskowego w kontekście zarządzania relacjami z dostawcami.
Wyniki: Wyniki dotyczą znaczenia współpracy i współdziałania środowiskowego jako istotnego obszaru zarządzania relacjami z dostawcami oraz opracowania ram koncepcyjnych dla współpracy i współdziałania środowiskowego w kontekście budowania relacji z dostawcami.
Wnioski: Wnioski dotyczą rodzajów interakcji środowiskowych i relacji z dostawcami, z uwzględnieniem roli wzajemnego zaufania, zaangażowania i spójności celów między nabywcą a dostawcą.

Słowa kluczowe: współpraca środowiskowa, współdziałanie środowiskowe, zarządzanie relacjami z dostawcami, budowanie relacji z dostawcami, relacje dostawca-odbiorca.

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ORIGINAL PAPER

CONCEPT FOR IDENTIFYING PROBLEMS IN SUPPLY CHAINS IN OMNI-CHANNEL SYSTEMS

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ABSTRACT. **Background:** In a rapidly changing competitive environment and increasing customer expectations, an efficient supply chain is a very important success factor. What should be avoided and what should be considered during planning and supply chain management? Is it possible to apply the same solutions to each business model (B2B/ B2C)? The following article presents the perspective of manufacturing companies. In the current situation there is less and less space for companies operating according to only one model. Each company is considering strategies: low profit in B2B models, which due to greater predictability of demand gives lower risk of production planning and omni-channel in B2C models, which by definition are more profitable, but are associated with a higher risk of demand change. The article presents problems and challenges during supply chain management in manufacturing companies that use both business models in the era of e-commerce market.

Methods: Based on the available literature, the problems of supply chain management in B2B and B2C relations are presented. The frequency of their occurrence was surveyed and the level of risk of negative impact on the company and its environment was presented.

Results: The survey identified the challenges and problems that companies face when managing their supply chains, and those that pose the highest and lowest risks.

Conclusions: This article presents the concept of identification of problems and challenges faced by manufacturing companies and models of actions to be applied in order to minimize their effects. The article is two-dimensional, showing a perspective for simple supply chains (B2B) and omni-channel chains (B2C).

Key words: SCM problems, SCM challenges, SCM production companies, B2B, B2C, DRP, Supply chain tailored to the needs of omni-channel, e-commerce.

MAIN ISSUES DURING MANAGING SUPPLY CHINS FROM B2B PERSPECTIVE

Functional instead of process approach

The Chain is generally defined as a combined sequence of organizational units composing a sequence. The supply chain has traditionally been divided into planning, procurement, logistics and services, with individual managers focusing on extrusion of maximum value in their own departments. Initially, this approach was impressive in terms of improving overall financial performance, but today, when it is much more difficult, companies should stop treating the supply chain as a simple sequence and start to see it as a multifunctional process and organizational structure. The difference seems small, but for many companies it means very serious challenges. Supply chain managers now go far beyond their internal activities and relationships to deal with B2B and even B2C processes and interactions. This of course requires the ability to deal with external partners.

The new approach includes listening to customers' voices and integrating marketing processes and consumer research into the

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supply chain. This change in approach not only squeezes more out of the internal supply chain, but also creates a collaborative structure that generates new value in the systems between the different "silos", while bearing in mind the "total cost of the ownership structure".

Another serious shortcoming is that you follow a well-established path that has its advantages: employees are confident in comfort and their leaders do not have to change their market strategies. The problem is that this attitude can block extensive transformation processes that require fundamental changes in the interactions between the supply chain and other business functions of the company, and can also prevent the chain from adapting to the optimal use of closer interactions with consumers. For example, we would achieve little if we did not manage to move away from a centralized push system based on the concept of supply and towards a decentralized pull system based on point-of-sale signals. Forecasts of processes aimed at minimizing missed deliveries from factories or warehouses are not the same as forecasts of supply chain processes, but using data from points of sale. Many companies measure their success not with the number of units of goods they produce, but, like our retailers, with the number of units sold.

Insufficient transparency of data

Each supply chain works with a certain inertia, not faster than the slowest of its devices or processes. Effective supply chain management practitioners are constantly looking for a balance between the effort required to gather information and the benefits of being able to respond in real time. This approach works well when, for example, we collect inventory information for our warehouse management program from suppliers via business partners. In this case, it is worth receiving information daily, but it is more convenient to update it weekly because the response time of transport networks is typically three days (two for transport and one for collection and packaging of goods).

Observation shows that ERP systems, which collect data about the company, give a certain picture of the (transactional) activities of the company's client. However, many users of such systems do not take the necessary further action, so they have a lot of data "in stock" but little knowledge. All information about customer transactions, production plans and logistics solutions should be available almost immediately. The resulting data can then be analyzed with supply chain planning tools and transformed into useful knowledge. Too many companies have made a costly mistake assuming that the right ERP package from the right supplier will solve all problems immediately [Kot et al. 2011].

Real-time mass data does not necessarily have to be immediately useful. It is important to determine where in our extensive supply chain such a data resource could really be useful in the company.

The bullwhip effect

Due to the distributed distribution structure of several warehouses, there are many connections between the market and the manufacturer that mediate the exchange of information. This fact, together with the variability of demand, reduces the efficiency of the information flow in the supply chain and leads to the so-called bullwhip effect. It was Jay Forrester who, in his 1958 investigation, found that the accumulation of surplus stocks in the early stages of the supply chain was the result of the gradual distortion and amplification of information about small changes in demand. The relatively small fluctuation in demand reported by end-users increases significantly as demand is reported in the supply chain, i.e. to the manufacturer and further to the suppliers. Demand data is overestimated (distorted) at each subsequent level of the distribution channel. This leads to excessive investment in equities to meet uncertain and diversified demand. Consequently, stocks at the upstream end of the supply chain are actually larger than the fluctuations in demand at the downstream end of the supply chain require [Costantino et al. 2011].

Similarly, procurement policy depends on companies' internal procedures. As a rule, large consignments of goods are regularly ordered for the following reasons, among others:

- high cost and high labor intensity of frequent order processing,
- a desire to save on transport costs (full vehicle transport),
- the willingness to take advantage of discounts granted when ordering large quantities,
- the size of the set logistical minima dictated by the suppliers,
- activation of sales related to the willingness to implement the assumed sales plans (increased order placement at the end of the settlement period).

Technology is not the key to everything

IT solutions must be implemented in the most complex supply chain processes. Someone has noticed that every business event is an IT event. This cannot be denied, but it is important to know that while a robust IT platform is undoubtedly necessary, it is not the only prerequisite for the success of a project.

We easily succumb to the charm of IT solutions and forget that the real key to the success of the transformation process is the transformation of business processes supported by the implemented technology. We can also easily forget that the transformation into small quantities will not take place without the links between the different "silos" in the supply chain. The best recipe for success is to create a solid technology platform that is available to the right people, who can implement and adapt business processes that enable the implementation of the business strategy. However, the worst solution is to remember the technology platform itself.

Choosing appropriate indicators

Key performance indicators are financial and non-financial indicators that are used as measures to measure the achievement of an organization’s objectives. They support the achievement of the company's operational and strategic objectives. They are important for building a results-oriented organizational culture, as they provide employees with objective feedback on their work, costs and quality.

KPIs are also an instrument of management control. They enable fast decision making, prioritize activities, react early to problems and support processes for continuous improvement and effective use of the organization's resources.

It is very important to select the indicators that illustrate the functioning of the supply chain. Too many indicators can lead to individual targets for the indicators that exclude the achievement of the other targets. Too few indicators distort the perception of supply chain efficiency [Milczarek 2017]. In this case, the Balanced Score Card (BSC) method can be used.

Trade off in supply chain

Links between logistics and production systems often lead to "cost conflicts", so improvements in one part of the system can lead to deterioration in another part of the system. However, if this increases the benefits of the entire system, it is beneficial. On the cost side, this means that reducing the operating costs of one element of a system can lead to an increase in the costs of another element.

These relationships are often associated with different types of inventories, due to the fact that inventories are located at the meeting point of different elements of the systems and that cost conflicts occur exactly at the meeting points of different areas of business, if not just.

Of course, the total costs are somewhat different in terms of quality. It should be noted that, in addition to the costs of ensuring an adequate level of quality (e.g. prevention and control costs), there are also costs of poor quality (internal - need for corrections, waste of materials, time, etc.) and external - related to complaints, loss of customers, etc.).

Similarly, the cost of logistic support - the total cost of logistic support - is both the cost of ensuring an adequate level of logistic service (transport costs, stockpiling of finished goods, etc.) and the cost of not having an adequate level of service. For the supplier it is the loss of a customer, for the customer it is the cost of maintaining safety stocks in the event of delivery delays. The costs associated with a lack of quality increase with the number of errors. The relationship between the cost of quality assurance and the lack of quality is often illustrated in Figure 5 and is therefore also a consideration. Therefore, in the past it was considered uneconomical to strive for 100% quality (implementation quality) because the associated costs (e.g. control costs) would eventually outweigh the benefits. Today, however, the idea of zero defects is increasingly being pursued and it is suspected that quality deficiency costs too much. These costs can decrease despite the increase in quality. It will be a trade-up relationship. The same can happen with logistics customer service - there may be situations where customer service increases and costs decrease at the same time. Both the quality costs and the costs for logistic customer service can therefore be determined not only by the trade-off, but also by the trade-up principle.

Risk sharing

A decisive factor for the success of the supply chain is the exchange of information between the different parts of the chain. The exchange of information on market needs provides the opportunity to respond to changing market needs. The fact that customers are confronted with the manufacturer's competitors can be used to use this knowledge to change their supply chains.

At the same time, participation in the supply chain requires risk sharing. This risk sharing diversifies the costs of implementing new solutions and enables shared responsibility and benefits from the measures taken.

However, inadequate risk sharing or incorrect risk placement can destabilize the chain. Cells that feel that the risk is greater for them than for the rest of the chain can form sub-alliances.

Implementation of changes

Change processes are a daily reality in every organization. However, effective change management is no longer so widespread [Wieczerniak et al. 2017]. Change processes often lead to unintended results: Inertia instead of forward movement. Without the ability to anticipate and prepare, companies fall into traps that are normally predictable and avoidable. Organizations can be confronted with the following common traps:

- Insufficient preparation time
- Incorrect communication lines
- Insufficient support from change agents
- Wrong style of crisis management
- Warnings without further delay
- Profits matters, not people.

Disregard for the human factor

Often employees cannot adapt to a new business model or use new tools and processes in the old way. The "good, because that's how we always did it" attitude is the main reason why many changes in the supply chain have failed.

Traditional approaches to change management rely on a wide range of training and provide individuals with the new skills they need to perform their new roles. These are necessary, but not enough. The traditional approach should also take into account the fact that not every employee can be properly trained and not everyone can learn the skills his or her superiors just wanted. There are people who are unable to think analytically, or who lack the technical knowledge to master new ways of doing things. Such employees often feel very uncomfortable at work, and their incompetence irritates their superiors. If such tensions are not quickly reduced, the resulting situation could seriously affect the transition process.

Workers can be divided into four categories: first, "guns" who love change, who catch it in flight and want it to happen frequently, then "opportunists" who accept change when they give them something, "marauders" who are waiting very far advanced and only then do they start working in it, and "others" who either don't understand it or don't want to understand it and want to fight it off to the end. It is extremely important to know who will contribute to our supply chain transformation and who will be affected. This will help us to divide roles correctly and form effective teams, which will increase our chances of success.

Incorrect perception of concern for one's own interests

During the mass production period, many companies were themselves involved in production and believed that this would help them control their own destiny. In some places, there is still a belief that virtual companies, or those that have decided to outsource activities that are not part of their core business, are giving up some of their power over themselves. Meanwhile, the entire modern net-based economy has the results it needs because it is about maximizing the basic skills of our business partners and focusing primarily on what is best for us.

Not all companies can become virtual companies, and not all companies should try. Even a comprehensive supply chain management star like Cisco Systems does not want to give up strategic control and planning of its operations or tactical management of key elements of the supply chain. In the future, however, the effectiveness of the supply chain is expected to depend primarily on the degree of collaboration between companies that form large value chains.

MAIN ISSUES DURING MANAGING SUPPLY CHINS FROM B2C PERSPECTIVE

With omni-channel logistics, companies can adapt the purchasing and delivery of their products to the needs of modern customers. Consumer expectations are evolving, product searches should be ensured both in the traditional way in the shop and on the Internet. With a finger or a few mouse clicks, the products will be purchased and delivered within 24 hours [Brynjolfsson et al. 2013]. Expecting immediate customer satisfaction means that companies need to develop their supply chain to minimize costs while providing the same level of customer service. A omni-channel logistics system is based on these assumptions.

The "Omni-channel Logistics" strategy aims to synchronize the work of the various logistics departments in all distribution channels. The primary objective is to meet the needs of consumers. Retailers, manufacturers and wholesalers develop complex, multi-level logistics solutions. These solutions are designed to ensure that the supply chain at the lowest cost meets the customer's needs at the assumed service level. For example, it is more economical to deliver a product from a local retail store to a customer than to deliver it individually to multiple customers from a distribution centre tens of kilometres away.

Omni-channel logistics has many applications:

- Internet order is delivered directly to the customer home.
- The online ordered product is sent to the shop, the consumer receives it in the shop (thanks to which the customer visits the shop and gets acquainted with its offer).
- To purchase an item that is not currently available in the warehouse of this store, to deliver the item at a later date to the selected store or directly to the consumer's home.
- Online ordering via eRetail and delivery to the buyer's home via the eRetailer distribution channels or to the seller.
- Order the product via the online shop and ship the order directly to the consumer from the manufacturer of the product.

Omni-channel Logistics allows to synchronize the flow of products in all distribution channels but poses unique challenges [Chopra and Meindl 2007]. If they are overlooked, they can lead to increased costs and weakened brand competitiveness. In this article, a list of the 9 most important challenges facing the omni-channel system has been compiled.

Lack of inventory visibility and metrics structure

In omni-channel logistics, it's all about inventory consistency and knowing where your inventory is, whether it's a distribution centre or a retail outlet. Companies can't promise their customers the next day's delivery and can't execute it. The place where there is a stock in omni-channel logistics is a particular challenge during the Christmas shopping season. To meet this challenge, companies need to develop an efficient ordering process using a coordinated warehouse management system (WMS).

Companies that make proper use of the omni-channel system will use the transparency of inventories to accurately forecast demand and plan their product flow activities. Companies that make maximum use of omni-channel can sell orders online without physically taking over the product [Piotrowicz and Cuthbertson 2014]. Electronic order management systems are synchronized so that online orders run directly from the manufacturer and are handled by an external partner in the company's supply chain.

When it comes to inventory transparency, the statement "You can't manage what you don't measure" applies. It is important to establish performance indicators associated with inventory, such as the cost of inventory, the percentage of perfect order and the percentage of orders executed from the ideal storage location. For indicators to be important, they need to be consistent with financial and strategic objectives and with the level of customer service. In an omni-channel supply chain, indicators must show how efficiently products flow through distribution networks to multiple retailers, retailers and wholesalers, and consumers.

Poor transparency of stocks in transport

Like large companies and start-ups, there is usually a relatively weak inventory mix in transport. It has led to an increased demand for cargo visibility solutions in real time. Omni-channel logistics solutions provide visibility into shipments and trucks, and also into orders and warehouse units [Tetteh and Xu 2014]. These solutions also include optimization and collaboration functions that improve the exchange of data and information between links in the supply chain. The best solutions began to take advantage of machine learning opportunities and a wider range of data sources including traffic, location, weather to enable forecasting and more accurate estimation of arrival times.

Segmented supply chain processes

When different supply chain processes in a company do not work together, customer satisfaction cannot be guaranteed consistently. Larger companies usually have many private warehouses and distribution centres, managed by different internal and external operators, operating on different systems [Tetteh and Xu 2014]. This is why they use different tactics to ensure a smooth supply chain. The key to solving this segmentation of the supply chain is to consolidate these processes instead of allowing them to work in silos.

Unreliable order fulfillment processes

If a company tells its customers that delivery should be the same day or the next day, it must keep that promise. Unreliable order processing can lead to delays in shipping, which can discourage customers from doing business with the company in the future. To ensure a smooth order fulfillment process, you can use the right technology to anticipate future delays in handling or shipping.

Selecting the right transport

Delivery of a product from a distribution centre or a stationary store to a customer's front door can be done in many ways. The challenge for supply chain managers is to find the most efficient transport solution that satisfies customers without increasing product costs [Kuźmicz 2015]. Choosing the right shipping channel for the customer is essential for omni-channel logistics.

Return logistics

The return procedure for each product should be as efficient as for the delivery of the product. In an all-channel system, customers expect returns to be possible in store, by mail or courier. Companies that do not offer omni-channel returns will largely be unable to encourage customers to make further transactions. Implementing a robust return logistics infrastructure is essential for good customer service in omni-channel logistics.

Manual processes

The main sources of inventory imbalances between links in the supply chain are the continuous use of manual processes for recording inventory data. Implementation of the WMS system with the use of Wi-Fi network and scanning of bar codes and 2D codes is the first step. The next step in order to automate stock counting is the use of RFID tags and drone systems. This automation allows you to compare results, detect discrepancies and create a more accurate picture of inventory levels.

Overlooked Physical Transformation

Digital transformation of analysis and technology companies is the most popular, but companies need to be careful not to overlook the physical transformation. The model of moving trucks with products from distribution centers to stores is outdated. Companies need to update their distribution network and management processes to survive in this new market where inventory reduction and speed are paramount. Leaders are testing new sales strategies to become more efficient and better meet customer expectations for faster delivery.

Implementing the 3PL strategy

The success of 3PL is an operational manager, strategic advisor and IT supplier in one. It is particularly valuable, with optimized inventory and implementation of all channels. The key competences of 3PL in the implementation of tasks is the selection of parameters that should be measured and that can help companies to fill the gap in performance.

Omni-channel logistics aims to provide consumers with shopping in a convenient distribution channel. This experience can only be achieved if companies use their e-commerce functions to identify the reality of both a landline store and a network of distribution centres. The optimal 3PL partner uses its knowledge and experience in the supply chain, as well as the diverse capabilities of the WMS and integration strategies to address the challenges described above [Kuźmicz 2015].

THE SURVEY "MISTAKES IN SC MANAGEMENT"

During the study, the following questionnaire (table 1) was sent to be filled in, where:

- In column 3 you should assign whether the problem occurs in B2B or B2C.
- In column 4, specify the level of occurrence by range:
  - 3 - Low probability
  - 9 – Likely
  - 21 - Already occurred
  - 30 - Almost certain or certain

- In columns 5, 6, 7 specify the impact level by range:
  - 1 - Minor
  - 3 - Moderate
  - 7 - Major
  - 10 - Critical

The risk level is calculated automatically as the product of column 4 and the sum of columns 5, 6 and 7.

Below is a gradation of risk levels for survey results:

- 0 – 81 points - Small risk
- 82 – 189 points - Moderate
- 190 – 441 points- Big
- More than 442 points - Critical

The survey performed in 2018 shown the most frequent issues which appears during managing supply chain. The issues in survey was split by place of appearance in B2B or B2C. Responders replayed where the mistake appears according their own experience. There was 65 middle and senior managers participating the research, thanks to this data was collected and the answers were analyzed. The results of the survey are presented in Table 2.

Table 1. Questionnaire model for the survey of "Mistakes in SC management"

	Mistakes in SC management	B2B/ B2C	Risk analyse				
			Appearance	Influence on customer	Influence on environment	Influence on company	Risk
1	Functional instead of process approach						0
2	Insufficient transparency of data						0
3	The bullwhip effect						0
4	Technology is not the key to everything						0
5	Choosing appropriate indicators						0
6	Trade off in supply chain						0
7	Risk sharing						0
8	Implementation of changes						0
9	Disregard for the human factor						0
10	Incorrect perception of concern for one's own interests						0
11	Lack of inventory visibility and metrics structure						0
12	Poor transparency of stocks in transport						0
13	Segmented supply chain processes						0
14	Unreliable order fulfillment processes						0
15	Selecting the right transport						0
16	Return logistics						0
17	Manual processes						0
18	Overlooking physical transformation						0
19	Implementing 3PL strategy						0

Source: the authors' own work

Table 2. Results of the survey "Mistakes in SC management"

Mistakes in SC management	**B2B**	**B2C**	**Risk**
Functional instead of process approach	54%	46%	153
Insufficient transparency of data	52%	48%	420
The bullwhip effect	35%	65%	243
Technology is not the key to everything	45%	55%	189
Choosing appropriate indicators	56%	44%	330
Trade off in supply chain	63%	37%	189
Risk sharing	59%	41%	180
Implementation of changes	45%	55%	504
Disregard for the human factor	49%	51%	315
Incorrect perception of concern for one's own interests	58%	42%	153
Lack of inventory visibility and metrics structure	23%	77%	420
Poor transparency of stocks in transport	10%	90%	180
Segmented supply chain processes	3%	97%	153
Unreliable order fulfillment processes	57%	43%	315
Selecting the right transport	35%	65%	504
Return logistics	45%	55%	180
Manual processes	52%	48%	315
Overlooking physical transformation	21%	79%	315
Implementing 3PL strategy	45%	55%	330

Source: the authors' own elaboration based on the results of the survey research conducted on 2018

In the table the risk is calculated as a the multiplication of the risk of occurrence and the level of influence on the supply chain and consumers.

It was observed as a result of the survey that the split assumed by the author, concluded on the basis of available literature, corresponds to a large extent with the feelings of managers. Seven out of ten problems assumed to occur mainly in B2B relations confirmed their occurrence in the survey. The main problem identified by the respondents is Trade off in supply chain, which affects nearly 2/3 of managers. The second most frequent occurrence in the B2B model is Risk sharing, however, both errors carry one of the smallest risks in supply chain management.

In the B2C model, the most common errors are Segmented supply chain process and Poor visibility into inventory in transit. Both errors, as in the case of the B2B model, are associated with low risk of occurrence. The third most frequent occurrence is Overlooking physical transformation. In this case, the risk of occurrence and the impact on the supply chain is at a medium level.

It is worth noting that most of the errors presented in the literature affect both B2B and B2C, and the biggest impact on the supply chain has Implementation of changes, Insufficient transparency of data and finding the right way to deliver goods to customer.

CONCLUSION

The advantage of this article is an innovative approach to systematization of problems. Most of the problems affecting the management of supply chains in both models of cooperation are presented. After analysing the available literature and conducting research in the field of senior and middle managers, the frequency of the problem occurrence and its impact on the functioning of supply chains were determined.

The Omni-channel system is much more vulnerable to a lack of information on stock levels and individual logistics units during transit. In addition, it is exposed to interruptions in the cooperation of individual channels, which until now operated separately.

To sum up, the free flow of products, which is expected by customers, is a big challenge for the organization and involves the physical integration of conventional distribution channels as well as the IT tracking of individual logistics units.

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KONCEPCJA INDETYFIKOWANIA PROBLEMÓW W ŁANCUCHU DOSTAW W SYSTEMACH OMNI-CHANNEL

STRESZCZENIE. **Wstęp:** W szybko zmieniającym się konkurencyjnym otoczeniu na tle rosnących oczekiwaniach klientów, bardzo ważnym czynnikiem sukcesu jest sprawny łańcuch dostaw. Czego należy unikać i co należy wziąć pod uwagę podczas planowania i zarządzania łańcuchem dostaw? Czy możliwe jest zastosowanie tych samych rozwiązań do każdego modelu biznesowego (B2B/ B2C)? Poniższy artykuł przedstawia perspektywę firm produkcyjnych. W obecnej sytuacji jest coraz mniej miejsca dla firm działających według tylko jednego modelu. Każda firma rozważa strategie: niski zysk w modelach B2B, który ze względu na większą przewidywalność popytu daje mniejsze ryzyko planowania produkcji oraz system multi-kanałowy w modelach B2C, które z definicji są bardziej opłacalne, ale wiążą się z wyższym ryzykiem zmiany popytu. W artykule przedstawiono problemy i wyzwania związane z zarządzaniem łańcuchem dostaw w firmach produkcyjnych, które wykorzystują oba modele biznesowe w dobie rynku e-commerce.

Metody: Na podstawie dostępnej literatury przedstawiono problemy zarządzania łańcuchem dostaw w relacjach B2B i B2C. Zbadano częstotliwość ich występowania oraz przedstawiono poziom negatywnego wpływu na firmę i jej otoczenie. Badanie przeprowadzono metodą ankietową na próbce 65 managerów wyższego i średniego szczebla z działów zarządzania łańcuchami dostaw w polskich przedsiębiorstwach produkcyjnych.

Wyniki: W badaniu zidentyfikowano wyzwania i problemy, przed którymi stoją firmy zarządzające swoimi łańcuchami dostaw. Przedstawia, które problemy wykazują najwyższy i najniższy poziom ryzyka.

Wnioski: W artykule przedstawiono koncepcję identyfikacji problemów i wyzwań stojących przed firmami produkcyjnymi. Dwuwymiarowość artykułu pozwala zademonstrować perspektywę prostych łańcuchów dostaw (B2B) i łańcuchów wielokanałowych (B2C).

Słowa kluczowe: SCM problemy, SCM wyzwania, przedsiębiorstwa produkcyjne, B2B, B2C, DRP, omni-channel, e-commerce

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THE MAIN AREAS OF METHODOLOGICAL REFLECTION IN THE SUPPLY CHAINS RESEARCH

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ABSTRACT. **Background:** The most important contemporary methodological problems in the study of supply chains include creating and verifying hypotheses and theories as well as selecting appropriate research schemes. An acceptance of the different ways to explain problems (induction, deduction or abduction) is key. It should be remembered that interesting and useful results can be achieved only with well-formulated questions and research problems. All of these issues relate to the need to strengthen methodological rigor within the research into supply chains.

Methods: The primary method employed in this article is critical analysis. This article focuses on the most important issues related to the construction of a theory and its verification, as well as the issue of the pattern of research and the cognitive scheme. In addition, the issue of the correctness of definitions has been developed, as these are often wrongly formulated and do not fulfil their role.

Results: The main purpose of this article is to indicate that supply chain research requires a change in the general model of scientific practice, assigning a higher rank to replication research and increasing the role of scientific criticism. Potential drivers of supply chain research are all types of reasoning: deduction (reasoning, checking), reduction and its special case induction (translation, command), and the systematization of knowledge. The knowledge gained from this research is so extensive and varied that its further development is possible through refutation, i.e. thesis making, defence and falsification. The aim of this article is also the systematization and analysis of theories and methodological assumptions in the area of supply chain management.

Conclusions: The analysis points to a need to structure the definitions of supply. What needs to be established is a set of basic theories useful in the study of supply chains and the assessment of the assertions formulated with regards to hypotheses. The improvement of methodological assumptions, as well as the search for methodological elements useful in this study, need to be continuously ensured. The scope of the theories used in the research should be broadened, but at the same time, new theories should be examined which also pertain to their usefulness in explaining and creating the concept and practical recommendations. It is suggested that research on supply chains needs to be approached in a slightly broader way than has been done so far in the literature. The methodology is recognized as a system of analysis in a particular area of study or activity. Therefore, the majority of publications retrieved according to this key word refer only to examples of the use of particular methods, tools for researching supply chains, or only some aspects of its functioning. However, methodology can also be understood as a philosophy of science. This approach to supply chain research methodology is an important research gap and a new view on supply chain management.

Key words: methodology, theories, reasoning, cognitive scheme, hypothesis, supply chains.

INTRODUCTION

This article contains an in-depth reflection on the usefulness of the methodological achievements of science for research on supply chains. The most important areas of this reflection have been identified. Such an approach is needed in every type of science. It is always worth pointing out the most useful and the most relevant methodological recommendations. It is further necessary to determine what this usefulness involves as well as to define the benefits of following these recommendations. Such reflection should furthermore refer to the relevance of the achievements of various schools of economics and to the applicability of different theories

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[Gligor et al. 2019]. (These issues, however, require more elaboration and can only be signalled in this article).

The classical school of economics focuses on the competitive struggle and the horizontal integration processes of organizations. This school adopts an assumption that points to the independent nature of individual transactions. In the neoclassical approach and institutionalism, much attention is paid to transactions, yet they have become the main focus of interest only in the new institutional economy and the theory of social exchange. These three schools indicate, among other things, the diversity of objectives in management. On the other hand, research into supply chains is definitely dominated by the perspective of vertical integration. The supplier vs. customer relationships are considered to be crucial, as are the relationships within the network. In other words, various schools of economics have different approaches towards competitive struggle and negotiation, whereas the issue of supply chains requires a strong negotiating perspective.

The negotiation struggle is about sharing the economic benefits of participating in exchanges between different entities. Its subject matter involves the most advantageous terms of the transaction for both parties, and it stems from the conflict of different parties' interests. There is also a very important issue here that is worth pointing out. For many years now, criticism has been levelled at classical economics, indicating the drawbacks of the homo oeconomicus concept [Urbina and Ruiz-Villaverde 2019]. On the other hand, in research practice, the assumption made by classical economics regarding the independence of transactions pose a far more important problem. The research into supply chains clearly shows the interdependence between particular transactions and it covers all aspects of business-to-business relationships. According to a literature review conducted by Spina et al. [2016], transaction cost economics and a resource-based view are the most frequently adopted frameworks.

The research in question must be carried out in a broad context as part of management science, economics, and in conjunction with the theory of networks. However, such studies form a very coherent yet separate component of economic sciences. This justifies conducting both the research and the reflection within various fields of the economic sciences.

This article focuses on the most important issues related to the construction of a theory and its verification, as well as the issue of the pattern of research and the cognitive scheme. In addition, the issue of the correctness of definitions has been developed as these are often wrongly formulated and do not fulfil their role.

SUPPLY CHAIN MANAGEMENT TERMINOLOGY

In management sciences, including the study of supply chains, there are two phenomena related to definitions:

- disregard for the definitions of terms,
- complaints about the large number of definitions for individual concepts, e.g. for the supply chain.

Disregard for definitions occurs despite the habit of quoting them by the dozen, and it is associated with the lack of analysis of the relevance of definitions to the purpose and subject of a study. This results in making somewhat bizarre definitions which undoubtedly complicates the research. However, a positive correlation is easily noticeable between the number of definitions and the relevance of specific studies (one might jokingly claim that the phenomena that have not been described by at least 50 definitions are simply irrelevant).

A very important problem is that there is a lot of unnecessary information in definitions. This can be seen in the research into supply chains as well as in management science. When reviewing the definitions of logistics and supply chains, one might get the irresistible impression that the authors wanted to include in the definition at least some basic knowledge about the notions being defined, with particular emphasis on the objectives of management.

Regardless of whether we take into account the true definition or only the nominal one, the expectations are simply too high. To be exact, it might be interesting to recall the definition of the definition. The true definition is a sentence giving the characteristics of an object or objects of some kind, which can be attributed to these and only these objects. The nominal definition, on the other hand, is an expression that in one way or another provides information about the meaning of a word or words (being defined). Here are some examples of definitions of logistics and supply chains that go beyond what is expected of them.

“Logistics is the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels in such a way that current and future profitability are maximized through the cost-effective fulfilment of orders.” [Christopher 2016]. Yet, what to call such management if, as is often the case, profitability is maximised only over short periods of time. And what to call flow management where there are many errors that increase the costs and reduce profitability?.

"In our view, logistics management is an activity that creates a comprehensive concept of logistics projects, taking into account their course both within the organization and its partners, and the coordination of the implementation (in the broad sense) of this concept by appropriate organizational units using appropriate management and control instruments". Such perfection is hard to come by.

Christopher [2016] suggests the following definition of supply chains: “the management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole.” These requirements are fulfilled by a small group of supply chains. This does not give a definition but points to the desired attributes.

The concept of an "integrated supply chain" is also difficult to define, since in any supply chain there must be some kind of cooperation between suppliers and customers. It is difficult to determine the level of cooperation that allows us to refer to a supply chain that is already integrated. Furthermore, a chain to chain competition between two rival supply chains could be considered [Nobari et al. 2019, Wu et al. 2019]. The concept of an integrated supply chain also raises a new approach to simultaneously considering facility location and inventory management problems [Diabat and Deskoores 2016]. Problems in integration and close collaboration in supply networks are often of an organization’s own making. Recently, some studies have started to scrutinize these topics, such as the role of third party organizations in lowering power differences and social distance, the importance of power in defining supply base structure [Ateş et al. 2015], power dynamics in dyads [Lacoste and Johnsen 2015] and the factor of power imbalances for supply chain collaboration in general [Brito and Miguel 2017] and in the context of sustainability [Touboulic and Walker 2015]. It is particularly crucial to extend the view from a dyadic to a network perspective [Carnovale et al. 2017, Cudziło 2018, Foerstl et al. 2016]. Looking at each of these perspectives can lead to various definitions of integrated supply chains.

CONSTRUCTING AND VERIFYING THEORIES

Many theories can be used to build the theoretical basis for supply chain research.

A comprehensive set of theories useful for research on supply chain improvement was identified by Ketchen and Hult [2007]:
- theory of transaction costs,
- agency theory,
- resource dependency theory,
- institutional theory,
- game theory,
- network theory,
- social capital theory,
- strategic choice theory.

As well as those mentioned Spin et al. [2016] have chosen:
- knowledge-based theory,

– contingency theory,
– social exchange theory,
– information processing theory and
– dynamic capabilities.

Transaction cost theory provides a general framework for the analysis of production costs and market costs, while agency theory is associated with the managerial revolution. Institutional theories and the theory of social capital fall within the humanist approach. Networks theory distinguishes between suppliers and customers in the overall buying/selling relationship, while game theory focuses on the benefits to the parties of a transaction. Finally, resource dependence theory is the basis for the analysis of resources on a network-wide scale.

All of the aforementioned theories have already passed the stage of checking their usefulness for explaining supply chain phenomena. It is to be expected that, as supply chains themselves develop, other theories will have to be used. For example, if reindustrialisation processes intensify and thus supply chains change radically, broader theoretical work will be needed to explain the phenomenon.

In supply chain research, just as in all management sciences, detailed statements, hypotheses and generalisations are formulated. Therefore, there are sentences with both a large and small quantifier and sentences with different levels of assertion (certainty that they are true). The sentences with a small quantifier are detailed sentences (e.g. some companies treat supply chain management as the basis for competition – the word "some" is important here). On the other hand, most sentences with a large quantifier (e.g. all companies competing in supply chains) have a low level of assertion [Ciesielski 2017].

In the research, a significant role is played by so-called historical generalizations – referring to the entity, which is a general historical name, or its scope is additionally limited by coordinates of time and space (e.g. in 20th century Poland, no small company has used the supply chain in competition). It is worth mentioning that many eminent methodologists believe that all sentences relating to theory are merely hypotheses. This approach seems appropriate for management science. With such an assumption, the so-called "Aydukevich's rule" must be observed. According to this rule, every sentence should be proclaimed with the force that reflects its justification. Comments on a theory determine, to a large extent, how hypotheses or detailed claims concerning supply chains are to be verified. These methods boil down to the confirmation or disconfirmation thereof, i.e. to the strengthening or weakening of the level of justification of the relevant claim. Glaser and Strauss [2017] address how the discovery of theory from data − systematically obtained and analyzed in research − can be furthered. The discovery of theory from data, i.e. grounded theory, fits empirical situations and provides relevant predictions, explanations, interpretations and applications [Hoddy 2019; Kaufmann and Denk 2011].

A commonly accepted basic scientific research scheme is shown in Figure 1.

This scheme includes building theories based on facts, deducing predictions from theories, and checking theories by confronting predictions with facts. This means going through stages: facts, theories, predictions, facts. If at the beginning of the cycle (at the facts stage) a false assumption is made (e.g. with regard to business objectives and strategies), all further steps and stages of the scheme, and in particular the deduction from the theory, may be false. This is the case, for example, with research into the pro-ecological behaviour of companies. The next step – the deduction of theoretical predictions – may or may not lead to the detection of a false conclusion. Deduction is a reliable type of reasoning, the direction of which is consistent with the direction of implications. Unfortunately, it can rarely be used in economic research. Robert Northcott [2019] states that the need for prediction is entangled with the methodological role of orthodox economic theory.

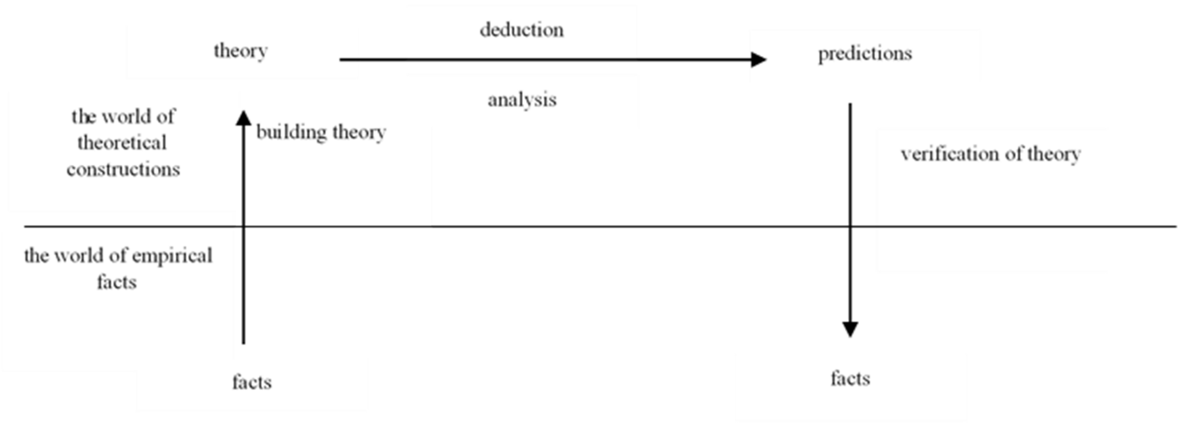
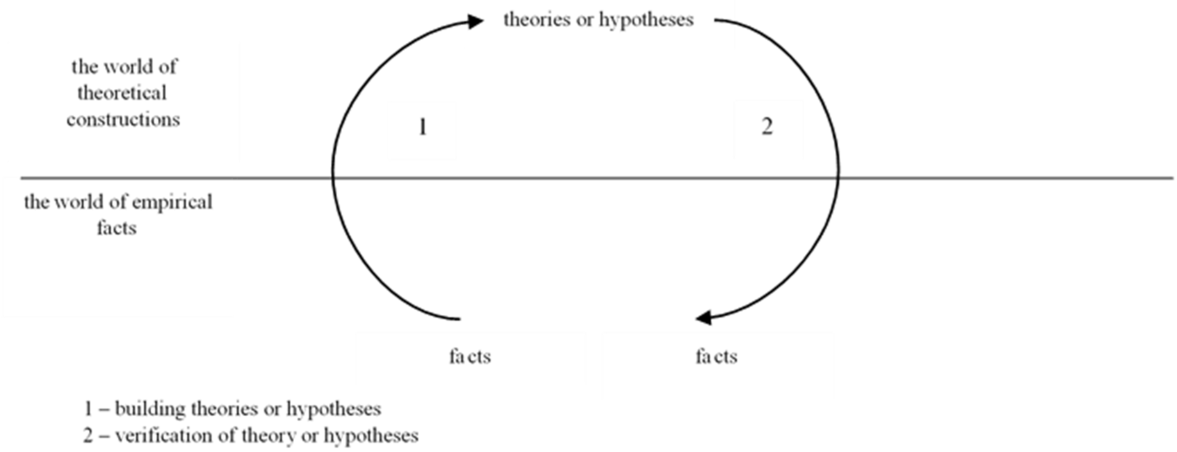


Fig. 1. Basic research scheme

It is difficult, if not impossible, to apply the above scheme in management sciences, and in particular, in the study of supply chains. Therefore, in the research practice of economic sciences, a "limited" research scheme is frequently used.

This limitation boils down to an omission of the step of deducing from theory. Thus, it is composed of two steps: building theories or hypotheses and verifying them. As in the basic scheme, reasoning begins at the level of facts. Verification is completed at the same level, though the theory being built is verified by confronting it with the facts, and not, as in the basic scheme, by confronting the predictions with the facts. A limited scheme is shown in Figure 2.

Deletion of this step means that the falsity of the facts from which the scheme originates may not be detected. The omitted step constitutes a significant barrier against the effects of falsification of the subject of research.



Source: the author's own work

Fig. 2. A limited scheme of research

In a limited scheme, verification often involves searching for more cases that are consistent with the theory, compared to the number of cases that were used to build the hypothesis. In addition, it should be considered whether the hypothesis is not simply a historical generalization, localization or a detailed opinion, i.e. it is true only in specific conditions (in a limited time and place).

It should be remembered that the phenomena discussed here may be enhanced, for example, by the epistemological attitude of the researcher or by the theorisation of research. Moreover, each sentence can be interpreted differently. At the basic level of research, the epistemological attitude is expressed, among other things, by a general approach to economic phenomena, including the type and strength of relevant factors as well as the likelihood of their occurrence. A broader issue concerning the subject matter of research is also important for the study on supply chains [Craighead et al. 2016]. This applies to all management sciences and economics and is based on the universal acceptance of the assumption of the universality of normal distribution.

In these sciences, it is generally accepted that the factors influencing the subject of research and the phenomena occurring in it are characterized by normal distribution. Gaussian distribution is characteristic of a situation where a large number of small random factors occur. However, one may also find the following views [Taleb 2015]: "In social life, almost all processes take place through shocks and changes that are rare but fraught with consequences; in the meantime, social research focuses almost exclusively on typical cases, using first and foremost the 'normal distribution' that results in as much as nothing. Why? The normal distribution ignores large deviations. It can't take them into account, and at the same time it gives us a false certainty that we have tamed the uncertainty." It cannot be ruled out that there are many reasons for such a position. The organisation's environment sometimes changes rapidly. The organisations themselves are also sometimes subject to processes that fall within the concept of the "black swan" promoted by Taleb. These issues need to be analysed at the level of social sciences. They go well beyond the scope of the discussion in this article but may be relevant to those sciences. At the moment, it is impossible to draw clear conclusions in this respect. Reindustrialisation may be the "black swan" for supply chains. If reindustrialisation acquires a global character, dramatic changes will occur in manufacturing, trade and, in particular, in the movement of goods.

THE RELEVANCE OF THEORIES

The final criterion for the value of a theory is its practical applicability [Mokhele 2018]. In the last part of this study the issue of concepts, recommendations and postulates of supply chain management was discussed. The question arises as to whether the achievements hitherto made in supply chain research allow for the use of the concept of cognitive schemata in this field. A cognitive schema is an integrated network of knowledge, beliefs and expectations concerning a specific format or aspect of reality. Managers, advisors and scientists assign different meanings to different concepts and even use different sets of concepts [Reinhold and Beritelli 2016, Simpson et al. 2015]. There are also many different opinions (e.g. process reengineering is very useful in all conditions vs. the BPR concept, which causes mainly losses), models or management frameworks and the level of their maturity could also be different (e.g. Schweiger [2015] presented a concept of an original Purchasing and Supply Management Maturity Framework). Each of the participants of the management process needs to formulate cognitive schemas regarding all its components (e.g. we have to keep large stocks as this guarantees short delivery times vs. it is possible to keep small stocks and still be able to deliver quickly). In short, a cognitive schema is a network structure referring to a specific action. It contains interconnected rules of conduct, for example the conduct of competitive struggle. In its assumptions, the theory of cognitive schemas applies to management as well.

The management concept is a different cognitive schema which, in principle, is also a good one. It may be limited to indicating the needs and benefits of benchmarking or it may be based on a single opinion, e.g. 'make or buy' decisions, which are of great importance for the competitiveness of a company, and must be made following a thorough analysis and continuous monitoring of their effects (outsourcing). The concepts of LM (lean management), BPR (business process reengineering), and TBM (time-based management) are also of a cognitive nature as they apply not only to the whole organization, but also to the network. The field of supply chain risk management (SCRM) has provided academics and managers with a range of useful models and frameworks to identify, assess and mitigate potential disruptions. At the core of these frameworks are implicit assumptions of rational decision-making. Failure to account for behavioural factors, such as risk perception and social preferences, may therefore lead to inaccurate risk management models and sub-optimal decision-making [Sarafan et al. 2019].

New concepts should be considered positive when they:

- propose cognitive patterns that are more in line with reality,
- ensure a better choice of topics and information and a better interpretation thereof,
- are independent of current managerial styles.

It must be clearly stated that the intensive development of research into and management of supply chains has already led to the formulation of many recommendations and demands, from the company's logistics systems to global supply chains. The concept of supply chain management is transformed into cognitive schemas which address all relevant issues. In the past, normative knowledge about the management of supply chains was included in the approach to these networks. Researchers stressed the need to apply a systemic, process and network approach [e.g. Wieland et al. 2016].

The strategic role of supply chain management was stressed. There were guidelines for building relationships within networks. The rapid development of knowledge already entitles us to define the general concept of supply chain management as a cognitive schema. The concept of supply chain management has two features that distinguish it from all the normative knowledge in the area of management:

- it uses numerous values contained in such concepts as LM,
- it intertwines the developed methods of analysis and management (e.g. SCOR) with the evolving normative knowledge.

The latter is particularly conducive to the emergence of best practices. The success of the Toyota Production System (TPS) is a good argument in support of the above considerations. Despite its name, TPS is a comprehensive concept of business management with clear references to network management. It should be stressed that TPS was created in opposition to the manufacturing systems that prevailed after World War II. Toyotism is the opposite of Fordism. In the 1950s, the world's leading car manufacturers relied on economies of scale. They wanted to produce a large number of cars in large batches. Due to the small domestic market and export difficulties, Toyota had to reject such thinking. A different approach was adopted in the form of the "one-piece flow" rule. The manufacturing and logistics system should be built in such a way that small batches of different products can be produced one by one. According to the name, the goal was to produce smaller and smaller batches at low cost. On one hand, the benefits of the economies of scale were lost, but other ones were gained, mainly those associated with smaller stocks. Other general principles were also original, for example: the principle of searching and solving contradictions [Liker 2005]. The basic concepts of TPS (e.g. the MUDA) have been incorporated into other management concepts, primarily to LM [Schniederjans et al. 2018]. The relation of TPS to all classical concepts and principles of management is also noteworthy.

CONCLUSIVE REMARKS

In this article, the authors point to the need to approach the research on supply chains in a slightly broader way than has been done so far in foreign literature. The methodology is recognized as a system of analysis in a particular area of study or activity. Therefore, the majority of publications retrieved according to this slogan refer only to examples of the use of particular methods, tools for researching the supply chain, or only some aspects of its functioning. However, methodology can also be understood as a philosophy of science. Then the literature in this field is very limited. This approach to the methodology of researching supply chains is presented by the authors of this article as an important research gap and a new view on supply chain management.

The overall result of this study is an indication of the need for a greater methodological order in the research on supply chains. More specifically, this primarily concerns the need to step up efforts to further systematise the scientific problems associated with the research in question. The same postulate should be directed towards organizing theoretical foundations. The third postulate is equally important; methodological problems in research and deliberations in the area of supply chains should not be avoided. As already mentioned, this concerns the perspective of the supply chains themselves and their role in the economy.

Research into supply chains has been ongoing for a relatively short time. Nevertheless, the knowledge gained from this research is so extensive and varied that its further development is possible through refutation, i.e. thesis making, and their defence and falsification. This requires a change in the general model of scientific practice, assigning a higher rank to replication research and increasing the role of scientific criticism. The use of all types of reasoning and the systematisation of knowledge are also potential drivers of supply chain research. To begin with, it is enough to boldly pose hypotheses and build hypothetical models of selected phenomena related to supply chains.

The improvement of the methodological assumptions, as well as the search for methodological elements useful in this study, needs to be continuously ensured. In future work, the scope of the theories used in the research should be broadened. But at the same time, new theories should be examined which also pertain to their usefulness in explaining and creating the concept and practical recommendations.

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NAJWAŻNIEJSZE OBSZARY REFLEKSJI METODOLOGICZNEJ W BADANIACH NAD ŁAŃCUCHAMI DOSTAW

STRESZCZENIE. **Wstęp:** Do najważniejszych, współczesnych problemów metodologicznych w badaniach łańcuchów dostaw należą: tworzenie i sprawdzanie twierdzeń oraz teorii i wybór schematów badania. Kwestią krytyczną jest też akceptacja sposobów wyjaśniania (indukcja, dedukcja lub abdukcja). Trzeba przy tym pamiętać, iż wartościowe rezultaty można uzyskać tylko przy dobrze sformułowanych pytaniach i problemach badawczych. Wszystkie wymienione kwestie wiążą się z potrzebą wzmocnienia rygoryzmu metodologicznego w badaniach związanych z łańcuchami dostaw.

Metody: W artykule podstawową metodą jest analiza krytyczna.

Wyniki: Dokonano systematyzacji i analizy teorii i założeń metodologicznych w obszarze zarządzania łańcuchami dostaw.

Wnioski: Analiza dowodzi, że wpierw należy zlikwidować bałagan w definiowaniu łańcuchów dostaw. Można odwołać się do teorii grafów i używać prostej definicji: zbiór przedsiębiorstw i relacji między nimi, w którym firmy są dla siebie dostawcami i odbiorcami. Trzeba także rozwijać zbiór podstawowych teorii przydatnych w badaniach łańcuchów dostaw i ocenić poziom asercji formułowanych hipotez. Należy stale dbać o ulepszanie założeń metodologicznych i szukać elementów metodologii przydatnych dla omawianych badań. Warto zwiększać zakres teorii wykorzystywanych w badaniach. Ale jednocześnie należy ustalić pochodzenie wykorzystywanych i nowych teorii i ich przydatność w procesie wyjaśniania i tworzenia koncepcji oraz rekomendacji dla praktyki.

Słowa kluczowe: metodologia, teoria, łańcuchy dostaw

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ORIGINAL PAPER

STRIVING FOR EXCELLENCE IN AI IMPLEMENTATION: AI MATURITY MODEL FRAMEWORK AND PRELIMINARY RESEARCH RESULTS

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ABSTRACT. **Background:** In hereby article authors try to summarize how AI can be use by companies within production and warehousing. On the basis of previously developed Logistics 4.0 maturity model authors also propose Artificial intelligence maturity levels and on its basis a survey has been conducted in selected Polish and Norwegian companies and actual AI state of development and maturity levels has been recognized. However authors present preliminary stage of research as a multi case study which will be further developed and extended in order to identify branches and areas with a hugest potential to enhance AI utilization.

Furthermore paper presents potential directions of Artificial intelligence implementation as well as tools that can be useful to deal with big data and optimization problems predicted not only for big companies but also SMEs. Authors propose term Artificial Intelligence 4.0 to point out the actual trends in the scope of Industry 4.0 and Logistics 4.0 and revolution with respect to AI. Without doubt AI is a big challenge for manufacturing companies as well as Transport and Logistics Industry and its application should be increased and extended in solving practical problems.

Methods: Methodology applied by authors of hereby paper can be divided on following stages: literature analysis, enlargement of AI maturity model, development of a questionnaire, multi-case studies in Norway and Poland.

Results: The literature search showed a cognitive gap due to fact there is a little of literature dealing with problem of Artificial intelligence maturity models as well as Logistics 4.0 and Artificial Intelligence. Artificial intelligence maturity levels can be combined with Logistics 4.0 maturity models thus relations between actual level of logistics maturity and AI readiness in companies will be recognized. Due to such analysis it will be possible to develop complex roadmap with the organization's strategic guidelines how to deal with Logistics 4.0 and AI. All the companies investigated in this preliminary study could be classified as AI Novices: Companies that have not taken proactive steps on the AI journey and are at best in assessment mode. Even the bigger companies with more automated solutions cannot visualize the benefits AI can bring.

Conclusions: Authors see potential to apply aforementioned model to investigate AI maturity levels in logistics companies and combine obtained results with previously developed Logistics 4.0 maturity model. Authors propose to introduce term Artificial Intelligence 4.0 to emphasize the importance of artificial intelligence with respect to Logistics 4.0 and Industry 4.0.

Key words: Industry 4.0, Logistics 4.0, Artificial intelligence 4.0, Artificial intelligence, maturity levels.

INTRODUCTION

Motivation

Artificial intelligence (AI) is important because it enables dealing with difficult problems, and the solutions to those problems can be applied to sectors important to human wellbeing—ranging from health, education and commerce to transport, utilities and entertainment. Today, as software is present in every aspect of human life and business activity, primary source of value creation is the

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processing of information. To make the process more intelligent, machine learning will yield benefits both humble and historic. Artificial intelligence (AI) is becoming one of the promising tools implemented in the scope of Industry 4.0 and Logistics 4.0. However, so far few companies use AI in practice. Main reason of this fact is high cost and difficulty of implementation. Practitioners and researchers who analyze the trends of the current industrial resolution see the need to intensify the utilization of AI in practical applications.

Due to fact that most agree that the explosive growth of AI is an inevitable. The Fourth Industrial Age will burn through massive amounts of data, with potentially hundreds of thousands of analysts employing AI tools to make sense of it all. It has also been stated by Sundar Pichai, CEO of Google that in the next 10 years, we will shift to a world that is AI-first.

In today's business, Industry 4.0 is driven by digital transformation in vertical/horizontal value chains and product/service offerings of the companies. The required key technologies for Industry 4.0 transformation such as artificial intelligence, internet of things, machine learning, cloud systems, cyber security, adaptive robotics cause radical changes in the business processes of organizations [Sarvari et al. 2018, Hofmann and Rüsch 2017, Schmidtke et al. 2018].

Industry 4.0 and Logistics 4.0 are defined in plenty papers editing since 2010. Logistics 4.0 definitions are nebulous and the concept is not homogenous, thus it is already at initial stage of development. Publications on the subject aim to present Logistics 4.0 as a trend important in logistics as well as solutions and technologies indispensable for its evolution [Barreto et al. 2017].

There are also analyzed challenges of contemporary market that logistics has to deal with, such as information exchange, automation, real-time big data analysis and link Logistics 4.0 to contemporary management paradigms such as sustainability. Logistics 4.0 status in terms of operational perspective is presented in the reports by research centers and logistic services providers [Fraunhoffer IFF 2016, DHL 2015, Dussmann Group 2016].

Hence, the list of methods and tools constituting Logistics 4.0 includes sources of data such as smart low battery consuming sensors, GPS, RFID tags, as well as the Internet of Things, drones, and innovative applications, making logistic processes smarter, more connected, automated and robotized, which undoubtedly improves logistic system performance and contributes to improved performance of supply chains.

Paper presents actual review of literature referred to Logistics 4.0, Artificial Intelligence with respect to Logistics 4.0 as well as maturity models and readiness levels (terms will be defined in section 3.1). Based on aforementioned backgrounds the novelty of proposed model is confirmed.

In the literature authors have found numerous examples of maturity models for business processes, as well as Industry 4.0 [Bowersox et al. 2000, Bubner et al. 2014, Caloghirou et al. 2004, Czaja 2016], nevertheless, there is a gap in the field of Artificial Intelligence and Logistics 4.0. Logistics 4.0 maturity models have been developed by [Oleśków-Szłapka, Stachowiak 2018, Gajsek et al. 2018]. Authors' Logistics 4.0 Model was used to define criteria with which companies are classified into five types. This classification is based on the following three aspects of logistics: (1) management, (2) flow of material, (3) flow of information, which becomes naturally three dimensions for Logistics 4.0 solutions. According to authors, the term 'Logistics 4.0 maturity' reflects the level to which a company or a supply chain has implemented Logistics 4.0 concepts. Authors distinguish five maturity levels: Ignoring, Defining, Adopting, Managing and Integrated. The assessment of maturity level has been based on analysis of Logistics 4.0 dimensions. Authors decided that the most important determinant of maturity is management, and if integration level is coherent with at least one form of the flow (either material or information) the maturity level the two represent is assigned to the company, assuming that the latter dimension is soon to be upgraded Methodology.

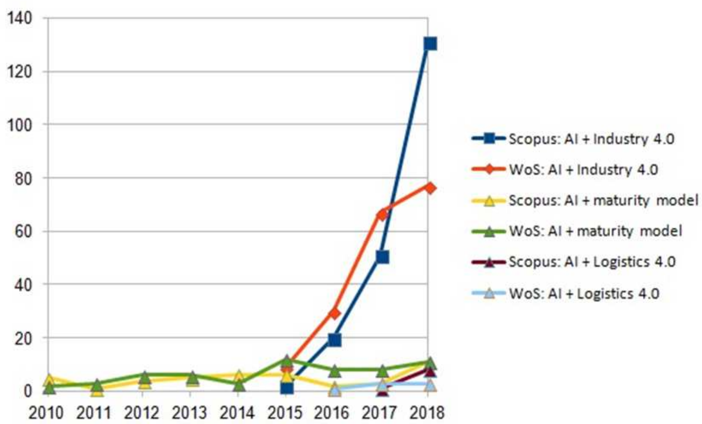
Methodology applied by authors of hereby paper can be divided on following stages: literature analysis, enlargement of AI maturity model, development of a questionnaire, multi-case studies in Norway and Poland.

The first preliminary action was the search for the literature on Logistics 4.0, artificial intelligence and maturity models. The search showed a cognitive gap due to fact there is a little of literature dealing with problem of Artificial intelligence maturity models as well as Logistics 4.0 and Artificial Intelligence. The numbers of papers found in Scopus and WoS databases is presented in Table 1. The quantity of papers referring to Artificial intelligence and Industry 4.0 is extending. From other side Artificial intelligence and maturity model is elaborated in a small number of papers either in Scopus or WoS databases. There are also still few articles discussing the subject matter of Artificial intelligence and Logistics 4.0 (see table 1 and Fig. 1).

Table 1. Numbers of papers about Artificial Intelligence, Industry 4.0, Logistics 4.0 and maturity models in Scopus and WoS databases in years 2010-2018

	Scopus: AI + Industry 4.0	WoS: AI + Industry 4.0	Scopus: AI + maturity model	WoS: AI + maturity model	Scopus: AI + Logistics 4.0	WoS: AI + Logistics 4.0
2010			5	2		
2011			1	3		
2012			4	6		
2013			5	6		
2014			6	3		
2015	2	9	6	12		
2016	20	30	2	8		1
2017	51	67	3	8	1	3
2018	131	77	11	11	8	3

Source: Own elaboration based on Scopus and WoS



Source: Own elaboration based on Scopus and WoS

Fig. 1. Number of papers in Scopus and WoS regarding Artificial Intelligence, Industry 4.0, Logistics 4.0 and maturity models

According to authors' opinion, it is the rationale for realisation of the research as recognizing new term in logistics management is interesting and promising field of research as well as potential of artificial intelligence in discussed domain could be expanded.

The second preliminary action was the survey elaborated in order to recognize and analyze actual situation of development solutions being part of Logistics 4.0 as well as applying Artificial intelligence in practice in logistics companies.

Multi-case studies have been done in Norwegian and Polish logistics companies. Authors have analyzed two big Norwegian companies (one big global clothing company and one medium sized logistics company) and two big Polish logistics companies (3PLs). The survey aimed to find out whether the companies know the term Logistics 4.0 and/or use solutions usually referred to as Logistics 4.0 solutions (identified basing on the preliminary literature review).

The survey was direct interview (CAWI - Computer-Assisted Web Interview) distributed among selected companies supported by a conversation with employees from the company. The survey questions were divided on particular parts: basic information, management area, physical process flow, information process flow, additional information. In total it consisted of 49 questions.

To identify the level of knowledge on Logistics 4.0, Industry 4.0 and the solutions within it including among other things Artificial intelligence the respondents were asked whether:

- they know the terms Logistics 4.0 and Industry 4.0?
- their warehouse is automated?
- their handling processes are automated (fully or partly)?
- their data flow and access to information is integrated in real time?
- they analyse, store and process data with contemporary technologies (i.e. Big Data, Cloud Computing)?
- they introduce innovations (when, what type of innovations)?
- they use robots to perform inventory optimization processes, location of goods in the warehouse processes, internal transport processes, shipping processes, picking processes?
- they use intelligent storage slots in your warehouse
- they use control of location by means of Internet of things (GSM, RFID, NFC, Bluetooth, ZigBee, 6LoWPAN, WirelessHART, ISA100, WiFi)
- their devices are able to collect and process data?
- their devices are able to make autonomous decisions (employees are not involved in decision making processes)?
- they use automatic monitoring in terms of intelligent environment in your company i.e. sensor networks that can make accurate measurements of environmental parameters (temperature, humidity, light etc.) in buildings

Research questions formulated by authors are as follows: (1) Are logistics companies ready to go digital? (2) Are logistics companies ready to become smart and intelligent?. Authors plan to answer these questions by applying maturity assessment method to measure the digital readiness of logistics companies. The model will include causal loop with determinants and consequences of Logistics 4.0 solutions implementation, hence it will be reflecting system dynamics as it strives for logistic excellence.

AI IN INDUSTRY 4.0 AND LOGISTICS 4.0 – CHALLENGES, ACTUAL STATE AND TRENDS

The assumption of the Industry 4.0 revolution is the participation of artificial intelligence at all stages of the product's life, from its design and manufacture, through transport and storage, distribution and sale, its repeated use up to the utilization or recycling [Kusek 2018, Hofmann and Rüsch 2017].

Nowadays, most of the production processes are partly or entirely based on automation and robotics devices equipped with selected mechanisms of AI. Dedicated manufacturing processes based on CAM (Computer-Aided Manufacturing) aimed at the implementation of specialized orders (Smart Factory), are supported by control devices that have the ability to recognize the very complex and individual features of items. Such quality control will be based on machine learning algorithms, gaining experience and looking for potential defects in the entire product class [Inside 2018, Lee at al. 2018, Witkowski 2017].

Another domain in the production where artificial intelligence algorithms are already applied is solving complex optimization problems concerning planning and management [McKinsey&Company 2017]. The data from the integrated enterprise resources management system will be soon supplemented with a wide spectrum of additional data from the Industrial Internet of Things (IIoT) sensors giving detailed information about the overall production process and each element of the process separately.

Huge information resources collected in databases will be used to build complex statistical models, their analysis supported by the AI heuristic approach, resulting in optimal strategies in decision-making processes. It will also enable quick change of production as well as better allocation of resources and workforce [Inside 2018].

The use of AI in logistics will consist in an extended use of data on each element in the supply chain [McKinsey&Company 2017]. For this purpose, it is necessary to identify and locate the product in real time. The current RFID system will be supported by IIoT elements using the 5G network with high operational requirements (an order of magnitude in micrometers) [Kizza 2017, Schneider 2013, Nagy et al. 2018].

An example of the use of such techniques in transport may be intelligent containers that scan their contents and provide such data real time to external databases [Kizza 2017, Lee at al. 2018]. It will enable not only automatic preparation of reloading of goods at subsequent stages of the supply chain, including automatic sorting but elimination of gaps identified during transport (negative verification of the parameters of goods) [European Commission - Information Society and Media DG 2009].

At the level of transport management, AI will support decisions regarding the valuation and profitability of orders, and plan their implementation through the optimization of freights. It will also support dispatchers' decisions regarding the selection of the contractor [Inside 2018].

At the stage of storage, the AI system support will be the automatic identification of goods through the new generation of intelligent storage slots, monitoring its content on an ongoing basis, both for solid and liquid materials (quantitative, weight, volume, chemical analysis). Through automatic detection, the storage conditions of the product in the selected warehouse segment will also be adjusted, which will contribute to energy savings. Thanks to AI it will also be possible to optimize the distribution of goods on a current basis using variable storage methods based e.g. on genetic algorithms [Kudelska and Pawłowski 2019].

Continuous recording of parameters, both at the stage of production as well as transport and storage in complex databases will create a full history covering every moment of product life. This will allow automatic reading of the current (or past) status, full verification in real time, e.g. due to the requirements regarding the suitability of the product for use [European Commission - Information Society and Media DG 2009]. It will also be possible to forecast the product's behavior in any perspective.

The distributor of the product will have a smart marketing environment (AI Marketing Cloud), insight into current sales trends through commodity exchanges, automatic "follow-up" for business contacts and sales support tips [Inside 2018]. Linking this information with the current demand of retail recipients (among other things by monitoring the goods on store shelves or orders via online stores) will allow adjusting the entire supply chain to the current market needs [Kusek 2018] .

The intention of the Industry 4.0 concept is also to record the history of the use of the product at the recipient, the ability to automatically set up maintenance intervals, inspections or to determine the end of acceptable use of the product. However, these are issues subject to additional legal regulations that are hard to be predicted now.

We know, however, that the waste product will be subject to recycling or recycling already planned at the design stage but taking into account its specific history recorded in the database [European Commission - Information Society and Media DG 2009].

In order for a given vision of Industry 4.0 to be implemented, appropriate conditions must be created in the ICT infrastructure that provides high-speed, super-fast and delay-free connections enabling real-time monitoring. The information will be collected through fully identifiable (IPv6) IIoT nodes, enabling fully autonomous contacts at all possible levels of IIoT network architecture (D2D, D2S, S2S), [Kizza 2017, Schneider 2013, IoT Standards & Protocols Guide 2018, Ashraf and Habaebi 2015, Hofmann and Rüsch 2017].

The presence of fiber-optic networks guarantees fast access to database centers anywhere and from anywhere in the world. Now the challenge is to build mobile networks. The 5GPPP is a joint initiative between the European Commission and European ICT industry (ICT manufacturers, telecommunications operators, service providers, SMEs and researcher Institutions) and they are dedicated to deliver solutions, architectures, technologies and standards for the ubiquitous next generation communication infrastructures of the coming decade [5G PPP 2019]. Many initiatives from 5GPPP and other related groups present industrial applications for 5G. The plans of most EU countries are the expansion of the 5G network (the Metis 2020 project) [European Commission - Information Society and Media DG 2009, European Commission 2015].

According to 5GACIA, the Alliance for Connected Industries and Automation, the wireless communication, and in particular 5G, is an important means of achieving the required flexibility of production, supporting new advanced mobile applications for workers, and allowing mobile robots and autonomous vehicles to collaborate on the shop floor. [5GACIA 2018] . In this context, 5G is expected to be the industrial internet that will support the full potential of Industry 4.0. It is also extremely important for Logistic 4.0 especially regarding the communication solutions that goes beyond the limits of the factory.

The networks will guarantee the transmission of information at the level of 10Gb/s (uplink) and 20Gb/s (downlink), creating the so-called "Internet superfluity" enabling the placement of any services anywhere. Of particular interest is the mMTC standard (massive Machine Type Communication) defining the network traffic conditions in the IoT area [European Commission 2015].

One of the biggest problems will be to ensure the full security of such communication. Reports that appeared in recent years warn against the possibility of attacks on unsecured IoT networks and taking control over them, which may have unpredictable consequences. Therefore, it will be necessary to define very strict rules and regulations both in relation to the IoT itself [European Commission 2015] and more broadly in relation to the entire AI [IEC 2012].

AI MATURITY MODEL

Organizational maturity

Maturity can be defined as “the state of being complete, perfect or ready” [Fraser et al. 2002, Mettler 2009, Karkkainen et al. 2014, Maier et al. 2012]. Maturity is referred to the state of growth, level of excellence, as in [Maier et al. 2012], where the process of bringing something to maturity means bringing it to a state of full growth, and to improvement and excellence. Crosby was among the first to propose, in 1979, a quality management model with fives levels of maturity [Kwak and Ibbs 2002, Mazur and Stachowiak 2014].

Technological readiness can be defined as how ready or mature a technology that can be applied. Definition of "readiness" is indicating a possible difference between "ready" and "not ready" of a technology or a difference "technology readiness levels" to be used or applied according to its usefulness [Febriani and Djatna 2016].

The term readiness is associated with maturity and in this paper its interpretation is as in [32], meaning that the difference between readiness and maturity is that readiness assessment takes place before engaging in the maturing process whereas maturity assessment aims for capturing the as-it-is state whilst the maturing process.

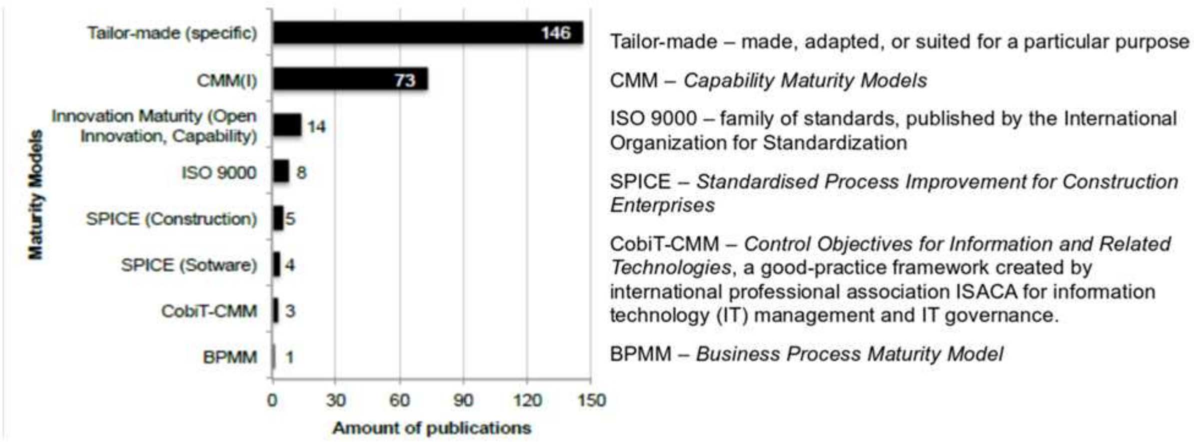
There are numerous maturity and readiness models published, including the ones by [Schumacher et al. 2016], referred to Industry 4.0 readiness, but also technology Readiness Level (TRL) by US DOD and developed by NASA [Heder 2017] and Manufacturing Readiness Level (MRL) also by DOD [Wheeler and Ulsh 2010].

Technology readiness levels (TRLs) are based on maturity scale that consists of nine levels, each one requiring the technology to be demonstrated in incrementally higher levels of fidelity in terms of its form, the level of integration with other parts of the system, and its operating environment than the previous, until at the final level the technology is described in terms of actual system performance in an operational environment [GAO 2016].

Most of maturity and readiness models are tailor made, referring to specific aspects and management areas (See Fig. 2).

Maturity models in literature have different characteristics: they can be of moderate or high complexity, maturity levels can be described in simple or complex manner. The enterprises need to follow new innovations and new technologies to preserve the competitive advantages therefore maturity models and readiness models without doubt can be useful and powerful tools to complete technology, innovation and product roadmaps.

Authors in their research use Logistics 4.0 maturity model developed by [Oleśków-Szłapka and Stachowiak 2019] as well as AI maturity model to assess actual level of maturity in these domains (Logistics 4.0 and Artificial Intelligence 4.0).



Source: Batz et al. 2018

Fig. 2. Published maturity models by area

AI maturity model – framework

Literature analysis shows that level of AI is assessed by means of AI readiness models. Majority of them have been developed by research centers and commercial entities i.e. Accenture, Capgemini, Intel, IBM, and McKinsey.

Authors found model describing Artificial Intelligence maturity which is based on five core pillars that form the critical foundations for AI-driven communication service providers

(CSP): strategy, organization, data, technology, and operations. In this model four core phased where identified: AI Novice, AI Ready, AI Proficient, AI Advanced (see table 2) [Pringle and Zoller 2018].

Table 2. AI maturity models in T.Pringle and E.Zoller model

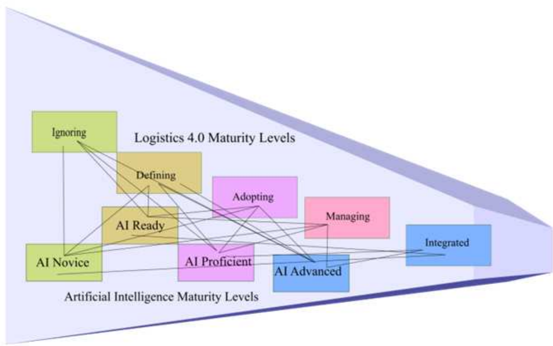
AI Novice	AI Ready	AI Proficient	AI Advanced
Has not taken a proactive steps on the AI journey and at best is in assessment mode	Sufficiently prepared in terms of strategy, organizational setup and data availability to implement AI	A reasonable degree of practical experience and understanding of how to move forward with AI but there are still gaps and limitations	A good level of AI expertise and experience with a proven track record across a range of use cases

Source: Pringle and Zoller 2018

Authors see potential to apply aforementioned model to investigate AI maturity levels in logistics companies and combine obtained results with previously developed Logistics 4.0 maturity model. Authors propose to introduce term Artificial Intelligence 4.0 to emphasize the importance of artificial intelligence with respect to Logistics 4.0 and Industry 4.0. Current trends among manufacturing and logistics companies if they are wishing to implement Logistics 4.0 solutions.

Artificial intelligence maturity levels can be combined with Logistics 4.0 maturity models (see Fig. 3.) thus relations between actual level of logistics maturity and AI readiness in companies will be recognized. Due to such analysis it will be possible to develop complex roadmap with the organization's strategic guidelines how to deal with Logistics 4.0 and AI.

Combinations of AI and Logistics 4.0 maturity levels will also enable to evaluate actual state of digitalization, automation, robotization, autonomy, intelligence and self-awareness in particular companies. Authors want to justify or fail hypothesis that Logistics companies are long away from Artificial intelligence and Logistics 4.0 solutions applied effectively in practice.



Source: own elaboration

Fig. 3. Logistics 4.0 Maturity Levels and Artificial Intelligence Maturity Levels

Authors aim to investigate what features are indispensable to take benefit from Artificial intelligence and how it AI maturity is correlated with Logistics maturity. Based on research AI readiness levels will be defined (1-5). Logistics 4.0 maturity levels has already been assessed within selected Polish companies. Due to small numbers of respondents in preliminary research authors apply grey systems to select appropriate maturity level for surveyed companies. The article discussing these issues will be published in the second quarter of 2019 and presented on 25th ICPR conference in Chicago.

Further increasing the group of respondents will allow the use of statistical quantitative analysis methods. Logistics 4.0 maturity of Polish companies providing logistic services will be compared with the correspondent data on companies representing the same industry but operating on Norwegian market. At this stage authors plan to apply statistical analysis: multidimensional comparative analysis using basics statistics and multiple correspondence analysis (MCA) to detect and represent similarity and diversity across countries.

Next phases comprise statistical analysis: (1) chi-square independence test to verify the relation between the level of maturity and factors indicated (competitive position, size, development dynamics, number of services offered, presence of foreign capital, level of internationalization of operations, number of innovations) and assumption of selected measures of association adjusted to nominal and ordinal data with testing correlation significance using the data from published reports ranking the companies providing logistic services; (2) Multi-criteria decision analysis (MCDA) to analyze the importance and the relations among the main determinants of Logistic 4.0 solutions and rank data; using the technique based on the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to build the structural model with position and relations among the determinants showed at the Impact-Digraph-Map.

AI maturity – preliminary research in Norway and Poland

After the literature review and the elaboration of the survey as presented in Chapter 1.2, a multi-case study was conducted to validate the methodology and get more insights for a future extended quantitative study in Norway and Poland.

The research was focused on the use of technologies in warehouse facilities and consisted of questionnaires answered by middle management professionals. They were asked about how often the company introduces innovative projects and the barriers for that. It was possible to observe that bigger companies are more committed to innovative projects. They can see more benefits from such projects than professionals in smaller companies. Both small and large companies answered that the warehouse processes and process management areas receive more attention than human resource management or transport processes. All of them pointed to budget constraints as the reason for not implementing more innovation projects.

Regarding physical process flow, the picking process, shipping process, internal transport processes, localization of goods in the warehouse and inventory optimization were investigated. At the biggest company investigated in Norway, all these processes were considered partly automated, expect for inventory optimization. This is not yet automated but is intended to be so in the future. None of the respondents apply robots in the physical process flow, but there are interests in the use of robots in the future in areas such as shipping and internal transportation. The small companies do not have automation in their process and no plans for introducing this in future projects. The situation in Poland is quite similar. Bigger companies are investing in modernization of their warehouses and automating selected processes. More innovations are introducing companies with international capital.

The situation is similar in the information process flow. The companies were asked about the use of real-time identification technologies, electronic document flow, real-time data access and their data analysis process. Only bigger companies were enthusiastic about real-time data solutions and data analysis.

The respondents were asked whether their company's devices are able to make autonomous decisions, to learn during processes and to communicate to each other and with employees, but they were not able to answer that. Those questions are crucial to understand the level of AI maturity and how the company is prepared to grow towards AI. The respondents did not know about this topic or could not give concrete examples of AI applications.

All the companies investigated in this preliminary study could be classified as AI Novices: Companies that have not taken proactive steps on the AI journey and are at best in assessment mode. Even the bigger companies with more automated solutions cannot visualize the benefits AI can bring. Despite the amount of research showing the benefits of the use of smart sensors, data analysis tools, tracking systems, and machine learning, the industry is still in a novice stage regarding AI applications.

For further investigations, authors intend to increase the number of respondents, extending the study to different company locations and innovation ecosystems. It will be necessary to access more companies as well as different employees in the same company. It will be important to see the different perspectives of the employees regarding innovation and AI solutions.

CONCLUSION AND FUTURE RESEARCH

Both companies and drivers will benefit from the technology. Autonomous technology will make their jobs easier and safer, which may keep many on the job longer. Authors predict that companies' maturity levels in terms of Logistics 4.0 and AI should be improved. Managers are responsible for introducing innovations, undertaking appropriate decisions to facilitate human jobs, to make job easier and safer. On the one hand, artificial intelligence could form the basis for huge productivity gains and improved quality of life. On the other hand it could lead to a radical change in the world of work. That is to say nothing of the ethical and societal issues that we must consider if machines acquire greater and greater intellectual capacity.

Multi-case studies revealed that companies are not familiar with Logistics 4.0 solutions as well as they do not take advantage from AI potential. Despite of barriers related with budget, technology, resources an undeniable challenge it to prepare for the technological challenges of future employees.

Authors' actual research is focused on surveying bigger target group from Norway and Poland. Companies surveyed are logistics companies as well as production companies. Identification of AI 4.0 and Logistics 4.0 maturity of companies will enable assessment of the industry condition in Poland and Norway and will provide data for analysing correlations between the Logistics 4.0 and AI 4.0 maturity levels in the company as well as between its competitive position, size, development dynamics, number of services offered, structure of capital and level of internationalization of operations.

Finally authors want to develop the causal loop with feedbacks between the determinants and consequences of Logistics 4.0 solutions implementation and AI maturity levels and combine Logistics 4.0 Maturity Model and AI Maturity model with dynamic model of behavior of a company providing logistic services based on feedbacks between the levels of maturity and competitive position, size, development dynamics, number of services offered, structure of capital, level of internationalization of operations and number of innovations. There is also potential to search correlations with additional parameters collected through surveys.

Organizations should first understand their own readiness for taking advantage of Artificial intelligence which is the ability and intend to develop, establish and implement a set of processes for the efficient use of Artificial intelligence. Maturity levels and readiness levels help decision makers understand where to prioritize efforts. Many companies are still unfamiliar with deploying AI applications as well as other Logistics 4.0 tools. Progress to the next stage of maturity is dependent on having the right elements in terms of skills, resources, technology processes and management methods.

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DĄŻENIE DO PERFEKCJI WE WDRAŻANIU SZTUCZNEJ INTELIGENCJI: RAMY MODELU DOJRZAŁOŚCI SZTUCZNEJ INTELIGENCJI ORAZ WYNIKI BADAŃ WSTĘPNYCH

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Słowa kluczowe: Industry 4.0, Logistics 4.0, sztuczna inteligencja 4.0, sztuczna inteligencja, poziomy dojrzałości

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ORIGINAL PAPER

ASSESSING THE PROFITABILITY OF INVESTMENT PROJECTS USING ORDERED FUZZY NUMBERS

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ABSTRACT. **Background:** This article is motivated by the fact that most approaches to capital budgeting are deterministic. In reality, the capital budgeting problem is accompanied by the uncertainty and risk associated with dealing with imprecise data. Taking this uncertainty into account when performing analyses and calculations not only helps to better measure the profitability of investment projects, but also to expand the applicability of capital budgeting methods under real-life or uncertain conditions. The major contribution of this paper is the development of a novel approach to assessing the profitability of an investment project in the presence of uncertainty.

Methods: We present a novel approach for incorporating uncertainty into how the profitability of investment projects is assessed, which we term Ordered Fuzzy Net Present Value (OFNPV). The proposed method measures the level of investment project effectiveness using a model based on ordered fuzzy numbers (OFNs). In addition, ordered fuzzy numbers are used to describe changes to the investment parameters in the assumed time horizon. This paper illustrates an implementation of the proposed technique using a numerical example of an investment process in the logistics department of a company.

Results: The use of the proposed method based on OFNs allows experts to gauge the real-life accuracy of the considered phenomenon, and to express their assessment of its dynamic changes. This is vital to the problem of profitability assessment in investment projects.

Conclusions: Our approach offers a new perspective on the problem of investment in projects and constitutes an effective tool for assessing the profitability of investment projects. This tool could constitute a valuable source of knowledge for investors involved in decision-making processes.

Key words: project, investment project, capital budgeting, NPV, fuzzy number, ordered fuzzy number.

INTRODUCTION

We consider the following problem: there is a company and/or supply chain which has to decide whether or not to execute a potential investment in the area of logistics in a specified time horizon. It is assumed that the initial conditions needed to execute the investment project, including the initial costs, are known. The duration of execution of the investment is also known. What is not known, however, is the complete and unambiguous information about the market capitalization rate or the future inflows and outflows related to the execution of the logistics project in the considered time horizon. These quantities are determined by experts, including logisticians, based on their knowledge and experience. The analyzed problem comes down to finding out whether the given investment project is profitable for the entrepreneur under the specified conditions, taking into account the associated uncertainty and risk. Our aim is to numerically evaluate the considered investment project, which will allow the given company to decide whether to accept or reject it.

The above problem belongs to the class of complex problems, which involve imprecise data and whose solution requires the use of

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nonstandard mathematical methods. The need for a mathematical framework for describing imprecise phenomena that accompany the profitability assessment of investment projects (including estimating future money flows and market capitalization rate) was the reason for introducing the concept of ordered fuzzy numbers.

Due to their specific nature, investment projects undertaken in logistics are burdened with a degree of uncertainty and risk. The main reason for this is their long execution period (often several years). Deciding whether a given investment project should be carried out requires careful planning (either short- or long-range, depending on the planning horizon). It also requires foreseeing situations that could have a positive or negative impact on a particular investment. The issue of capital budgeting is inextricably linked with uncertainty and risk, which generally stem from the unavailability of certain data (i.e. dealing with data that is imprecise). Therefore, the conditions under which an investment project will be executed are hard to predict and define in a clear-cut manner. It must be emphasized that investment projects are already characterized by a high level of uncertainty at the outset. This is due to a key feature of projects, and long-term projects in particular, viz. their innovativeness. The level of knowledge associated with a project thus starts at virtually zero and increases as the project progresses. Only when all the effects, benefits, and costs are established, i.e. towards the end of the project, can the stipulated level of 100% certainty be reached.

Taking this uncertainty into account when performing analyses and calculations not only helps to better measure the profitability of investment projects, but also to expand the applicability of capital budgeting methods under real-life or uncertain conditions. The major contribution of this paper is the development of a novel approach to assessing the profitability of an investment project in the presence of uncertainty. This paper is organized as follows. The first section is devoted to a brief literature review. The third section outlines the employed research methodology, and Principal Component Analysis in particular. The subsequent section describes the resulting measures, discusses their validity and reliability, and presents our key findings. Section 5 contains conclusions and recommendations.

LITERATURE REVIEW

Assessing an investment project before it commences is a tedious task that requires the use of appropriate knowledge, modelling and forecasting methods, in addition to suitable mathematical techniques. The scope and the level of detail of such assessments can be varied, and they can be less or more formalized. Assessing project effectiveness is a crucial step in the decision-making process, during which investment projects are selected for execution. The results of such an assessment determine the subsequent stages of the investment, the analysis and allocation of resources, scheduling, budgeting and the control system. In practice, this involves the unpredictable behavior of the market in the project execution timeframe, including weather conditions, prices and costs, availability of resources, exchange rates, interest rates, behavior of the competition, changes in the level of supply and demand for a given product or service, etc. Traditionally, investment parameters (cash inflows and outflows, available investment capital) are presented in the form of crisp values. In the literature, one can find a variety of methods used for capital budgeting (see e.g. [Chansa-ngavej, Mount-Campbell 1991, Nosratpour et al. 2012]). The most commonly used methods include Payback Period (PP), Net Present Value (NPV), Profitability Index (PI), and the Internal Rate of Return (IRR). The classical forms of these methods do not take into account the uncertainty and risk which may be inherent in the information that they use as input. This information includes: future cash inflows, cash outflows and available investment capital, the required rate of return of an investment or the cost of capital, and the project duration [Kuchta 2000].

These shortcomings need to be addressed using novel and effective computing methods. Attempts to take into account both certain and uncertain data when considering the fuzzy environment of investments have been reported in the literature. We observe an increasing interest in the theory of fuzzy sets, which lays the foundations for describing uncertain events. Several authors already employ fuzzy set theory to help solve the capital budgeting problem in a fuzzy environment. The introduction of the concepts of fuzzy sets and fuzzy numbers was propelled by the need to mathematically describe imprecise and ambiguous phenomena. The above concepts were developed by Zadeh and described in [Zadeh 1965] as a generalization of the classical set theory. Motivated and inspired by this, several authors, such as Buckley [1987], Chiu, Park [1994, 1998], Chen [1991], Chansa-ngavej, Mount-Campbell [1991], Kuchta [2000], Li Calzi [1990], Huang [2007, 2008], Zhang et al. [2011], Tsao [2010], Kahraman and Kaya [2010], and Appadoo [2014] have investigated fuzzy set theory in the context of capital budgeting. In general, they used fuzzy numbers instead of crisp numbers in established formulas. Further works take uncertainty into consideration using fuzzy modelling to assess investment projects. Several authors reported the problems that arise when the capital budgeting problem is solved using fuzzy numbers [Buckley 1987, Calzi 1990; Kuchta 2000].

Recent papers have discussed the drawbacks of convex fuzzy numbers (CFNs) [Kosiński et al. 2009, 2013]. To overcome these issues, Kosiński developed the concept of ordered fuzzy numbers (OFNs). Interestingly, new interpretations offered by the ordered fuzzy numbers approach can be viewed as an extension of classical proposals. Methods for capital budgeting based on ordered fuzzy numbers remain relatively unexplored. Ordered fuzzy numbers were first used by Kosiński [2006] as a tool for a decision support system for evaluating financial projects. Kosiński tackled this problem using discount methods [Kosiński 2006; Chwastyk, Kosiński 2013, Kosiński et al. 2013]. The fuzzy equation determining the fuzzy internal rate of return has already been investigated for a class of OFNs with continuous branches in [Kosiński 2006]. Chwastyk and Kosiński [2013] used a class of Rational Ordered Fuzzy Numbers to model cash flow. The existence of a fuzzy solution for the IRR equation was proved based on the classical algebraic result that the root of a polynomial is a continuous function of the polynomial coefficients. Kosiński and his research team proposed a new tool for a decision support system for evaluating financial projects. It determined the IRR of an investment project in which all the expected expenditures and incomes are vague and are described by OFNs [Kosiński et al. 2013].

This new model of fuzzy numbers was capable of handling fuzzy inputs in the same way as real numbers, i.e. quantitatively. Crucially, the new interpretations provided by the OFN model constituted an extension of the classical proposals, and therefore it was not necessary to abandon established concepts to deal with new ones. In addition to the slightly different interpretation, this new model of fuzzy numbers exhibited many useful mathematical properties, in particular, it eliminated the main difficulty associated with classical fuzzy numbers, i.e. the unbounded loss of accuracy with each subsequent calculation. Moreover, this new approach made it possible to define new methods (based on the arithmetic of OFNs) for processing information in processes dealing with fuzzy control. During standard fuzzy arithmetic operations, certain problems arise during subtraction and division [Kosiński et al. 2013, Prokopowicz et al. 2017]. In recent publications it was demonstrated that the improved precision of operations and the possibility of solving equations in the set of ordered fuzzy numbers could help ameliorate these issues [Kosiński 2013, Chwastyk et al. 2015, Chwastyk, Kosiński 2013, Czerniak 2017, Roszkowska, Kacprzak 2016, Rudnik, Kacprzak 2016, Prokopowicz et al. 2017].

ORDERED FUZZY NUMBERS

A fuzzy set A in X is characterized by a membership function $\mu_A(x)$ which associates each point in $x \in X$ with a real number in the interval [0,1], i.e. the grade of membership of x in A. Thus, we can write $A = \{(x, \mu_A(x)); x \in X\}$, where $\mu_A : X \to [0,1]$ is the membership function of a fuzzy set. For each element $x \in X$ this function assigns its membership degree to fuzzy set A. A fuzzy number is a set that is defined in real numbers; it is convex, normal, it is described by a piecewise continuous membership function, and it has a bounded support [Kosiński et al. 2003]. A fuzzy number, and hence its membership function, can have two basic interpretations. It can be understood as a degree, to which x possesses a certain feature, or as a probability, with which a certain and, at this point, not entirely known value will assume a value x.

An ordered fuzzy number (OFN) A is an ordered pair of continuous functions (f,g), such that $f,g:[0,1]\to R$. The set of OFNs is denoted by $\mathcal{R}$. A small part of ordered fuzzy numbers corresponds to standard fuzzy numbers. A set of pairs of continuous functions, in which one function is increasing and the other is decreasing (while, simultaneously, the increasing function always assumes values lower or equal than the decreasing one) is a subset of a set of OFNs, which represents the class of all convex fuzzy numbers with continuous membership functions. They are termed proper OFNs. Figure 1 shows the construction of a membership function for such proper OFN (f,g).

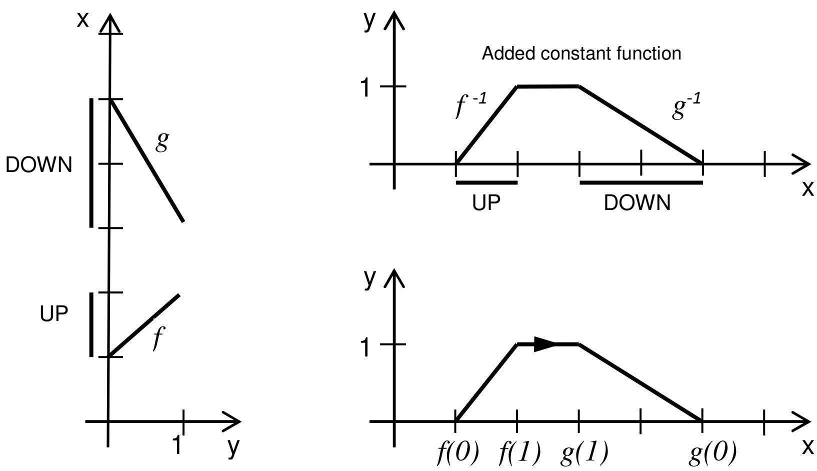

Fig. 1. Construction of a membership function for a proper OFN (f,g), where f is the increasing function

Figure 1 introduces the following notation: UP = f([0,1]) and DOWN = g([0,1]). Graphically, the curves of (f,g) and (g,f) are identical. However, these pairs of functions specify different ordered fuzzy numbers, and they differ in terms of their direction (denoted by an arrow in the diagrams).

OFNs share a significant feature, i.e. direction. OFNs allow us to describe an imprecise value in real-life processes [Kosiński et al. 2009]. The up- and down-branch parts of OFNs can be related to an expert's opinion concerning the dynamic changes of the analyzed value. It is possible to use OFNs without considering their direction, but taking it into account introduces additional information into operations performed with OFNs.

Let $A=(f_A,g_A)$, $B=(f_B,g_B)$, $C=(f_C,g_C)$ be ordered fuzzy numbers. The sum $C=A+B$, the product $C=A\times B$ and the division $C=A\div B$ are defined in the set $\mathcal{R}$ as follows:

$$f_C=f_A*f_B \text{ and } g_C=g_A*g_B \tag{1}$$

where "$*$" denotes "$+$", "$\times$", or "$\div$". Moreover, $A\div B$ is only defined when $f_B(y),g_B(y)\neq 0$ for all $y\in[0,1]$. In the OFN set, subtraction, exponentiation, and taking a root can also be defined in the usual manner, for instance:

$$(f,g)^n=(f^n,g^n) \tag{2}$$

The properties of ordered fuzzy numbers have been precisely described in the paper [Chwastyk, Kosiński 2013] and the monography [Prokowicz et al. 2017].

Each ordered fuzzy number A that is a pair of affine functions is uniquely determined by a 4-D vector composed of real numbers, while addition, subtraction and multiplication by a scalar are consistent with linear operations in the space of 4-D vectors (see Figure1):

$$[f(0), f(1), g(1), g(0)]. \qquad (3)$$

A proper linear ordered fuzzy number will be termed a trapezoidal ordered fuzzy number. If we further assume that $f(1) = g(1)$, we obtain a triangular ordered fuzzy number.

Defuzzification functionals, which map fuzzy numbers into real numbers, play a vital role in the application of ordered fuzzy numbers. The model of constructing a defuzzification functional presented in [Kosiński et al. 2009] allows us to obtain a number of defuzzification functionals, whether linear or non-linear. However, these functionals are not sensitive to direction, i.e. φ (f, g) = φ (g, f), and thus lack an essential feature of ordered fuzzy numbers. Defuzzification functionals sensitive to direction are considered in [Bednarek et al. 2014]. Here, on the other hand, a non-linear center of a gravity defuzzification functional was applied, which is defined by the following equations:

$$\phi_{COG}(\alpha, f, g) = \begin{cases} \dfrac{\int_0^1 [(1-\alpha)f(s) + \alpha g(s)][f(s)-g(s)]ds}{2\int_0^1 [f(s)-g(s)]ds}, & when \quad \int_0^1 [f(s)-g(s)]ds \neq 0 \\ \dfrac{\int_0^1 f(s)ds}{\int_0^1 ds}, & when \quad \int_0^1 [f(s)-g(s)]ds = 0 \end{cases} \qquad (4)$$

APPROACH TO INVESTMENT PROJECT DECISION-MAKING BASED ON ORDERED FUZZY NUMBERS

NPV is the most commonly used discount method. In essence, this method consists of an assessment of the present value of an investment project based on the forecasted streams of net cash flows, which are the measure of an investor's future benefits. NPV is defined as a sum of net cash flows (NCFs) discounted separately for each year and executed over the entire calculation period, with a constant level of interest (discount) rate. This value expresses the updated (on the day of assessment) value of benefits that an undertaking can yield in the future. The general form of NPV is:

$$NPV = \sum_{i=1}^{n} \frac{CF_i}{(1+k)^i} - N_0, \qquad (5)$$

where: n is the number of years, k is the market capitalization rate, CF_i is the cash flow in the i-th year of investment, and N_0 is the initial investment (outlay).

To define the generalization of NPV to ordered fuzzy numbers, let us assume that the initial outlay N_0 and the NPV are real numbers, whereas cash flows CF_i and the capitalization rate K are OFNs. The discounted cash flows in the i-th year of investment are calculated as follows:

$$DCF_i = \phi\left(\frac{CF_i}{((1,1)+K)^i}\right), \qquad (6)$$

where: $(1,1)$ are a pair of constant functions that assume the value of one, and $+, /$ signify, respectively, addition and division in the set of ordered fuzzy numbers defined by equation (2); exponentiation is performed according to equation (3), and ϕ is the defuzzification functional defined by equation (5). Then, equation (6) assumes the following form:

$$NPV = \sum_{i=1}^{n} DCF_i - N_0 . \qquad (7)$$

We propose an alternative to the conventional NPV method and present a new discount method, which we term Ordered Fuzzy Net Present Value (OFNPV). In this cash flow model, uncertain cash flows and the capitalization rate are specified as triangular ordered fuzzy numbers.

ILLUSTRATIVE EXAMPLE

Here, we consider an example of the execution of a potential investment project in the logistics department of a selected company. In order to define the conditions of investment project execution, an expert with appropriate knowledge and experience of planning and executing similar projects, e.g. a logistics manager, is involved in the decision-making process. The use of ordered fuzzy numbers poses a serious problem, namely that an expert is required to give an opinion on individual elements of the investment project in the form of ordered fuzzy numbers (pairs of functions).

It is assumed that the initial outlay N_0 will be 300,000 Arbitrary Monetary Units (AMU). The project is scheduled for 5 years. The remaining project parameters remain uncertain, and therefore, they are determined by an expert in the form of triangular ordered fuzzy numbers. The capitalization rate is $K = [0.11; 0.13; 0.13; 0.15]$. This means that according to the expert, capitalization rates lower than 11% or higher than 15% are not possible, whereas the value of 13% is the most probable one, and other values are probable to a different degree (the closer they are to 13%, the higher the probability). The difference between the proposed approach and the methods using classical fuzzy numbers consists in the incorporation of additional information through the OFN's direction. The direction of an OFN can be used to represent information about dynamic changes in the capitalization rate. Therefore, the ordered fuzzy capitalization rate K contains information about its rising tendency.

In a similar way, the expert determines the ordered fuzzy values of cash flows for subsequent years (cf. Table 1). The direction of OFNs is also used to represent complex information about cash flows. The ordered fuzzy cash flows in the first and third year of investment show a rising tendency, while the remaining ones – a decreasing tendency. This information is very important for the decision-making process.

For calculation purposes, the initial data have to be converted into pairs of functions so as to enable the use of arithmetic operations defined by formula (1). The triangular OFN $A = [a,b,b,c]$ corresponds to:

$$A_{OFN} = \big((b-a)x + a, (b-c)x + c\big), \qquad (8)$$

which is an ordered pair of linear functions.

Using the above formula, OFNs corresponding to values determined by the expert are defined. For instance, the capitalization rate expressed by ordered fuzzy numbers is: $K_{OFN} = (0.02x + 0.11; -0.02x + 0.15)$. The values of cash flows can be expressed analogously (cf. Table 1).

Table 1. Ordered fuzzy input data for the considered investment project

Investment year	Ordered fuzzy cash flows [a.m.u.]	Cash flow expressed as ordered fuzzy numbers
1	[75000,80000,80000,85000]	(5000x+75000, -5000x+85000)
2	[96000,93000,93000,90000]	(-3000x+96000, 3000x+90000)
3	[105000,111000,111000,118000]	(6000x+105000, -7000x+118000)
4	[126000,120000,120000,110000]	(-6000x+126000, 10000x+110000)
5	[130000,123000,123000,115000]	(-7000x+130000, 8000x+115000)

The calculation of discounted cash flows using OFNs will be presented for the first investment. The discounted cash flow in the first year will be:

$$\frac{CF_1}{(1,1)+K_{OFN}} = \frac{(5000x+75000, -5000x+85000)}{(1,1)+(0.02x+0.11; -0.02x+0.15)} =$$
$$= \frac{(5000x+75000, -5000x+85000)}{(0.02x+1.11; -0.02x+1.15)}$$
$$= \left(\frac{5000x+75000}{0.02x+1.11}, \frac{-5000x+85000}{-0.02x+1.15}\right),$$

where: CF_1 is the cash flow in the first year of investment and K_{OFN} is the capitalization rate. The next step in the proposed approach is to move from the discounted cash flow expressed by an ordered fuzzy number to a real value. This is achieved through the defuzzification functional according to equation (4): $\phi = \phi_{COG}\left(\frac{2}{3}, f, g\right)$.

$$DCF_1 = \phi\left(\frac{CF_1}{(1,1)+K_{OFN}}\right) = \phi\left(\frac{5000x+75000}{0.02x+1.11}, \frac{-5000x+85000}{-0.02x+1.15}\right) =$$

$$= \frac{\int_0^1 \left(\frac{1}{3}\cdot\frac{5000x+75000}{0.02x+1.11} + \frac{2}{3}\cdot\frac{-5000x+85000}{-0.02x+1.15}\right)\left(\frac{5000x+75000}{0.02x+1.11} - \frac{-5000x+85000}{-0.02x+1.15}\right)dx}{2\int_0^1 \left(\frac{5000x+75000}{0.02x+1.11} - \frac{-5000x+85000}{-0.02x+1.15}\right)dx}.$$

The discounted cash flows for the remaining periods of the project are determined analogously. The calculations shown here were made using MATLAB. Subsequently, these values undergo defuzzification using functional (4).The values are presented in Table 2 along with the NPV for the subsequent years of investment. In this case, NPV is equal to 56,019.1 AMU, which confirms the expected logistics project profitability.

Table 2. Investment discounted cash flows and NPV obtained using OFNs

Investment year	Discounted cash flows [a.m.u.]	NPV [a.m.u.]
0	300000.00	–300000.00
1	71473.40	–228526.60
2	71812.90	–156713.70
3	77202.70	–79511.00
4	70832.60	–8678.40
5	64697.50	56019.10
NPV		56019.10

The presented example demonstrates that the conclusions drawn from calculations employing OFNs are in agreement with current knowledge and economic analyses. Moreover, owing to the elimination of issues related to using classical fuzzy numbers, the model of ordered fuzzy numbers may prove to be a reliable tool for economic analysis and modelling.

ANALYSIS OF DYNAMICS OF CHANGES USING ORDERED FUZZY NUMBERS

This section considers an example of NPV inference based on the actual values of discounted net cash flows during the execution of a given investment project. In this case, the mathematical apparatus in the form of OFNs is employed to describe the changes in the values of discounted net cash flows and the dynamics of these changes. This approach is based on [Kosiński et al. 2009, Kacprzak 2014].

Investors are interested in how the expected NPV of an investment changes over a time period Δt with respect to the corresponding values for the scheduled period. Information of this kind can be gleaned through the use of triangular ordered fuzzy numbers, which enable the simultaneous presentation of planned and actual values of present cash flows. Triangular ordered fuzzy numbers can be represented by formula (3). We can use the direction of OFNs to represent complex information about the evolution of the planned (expected) discounted cash flows in relation to the actual ones.

The change in the discounted cash flow value in the i-th year of investment can be described by the following triangular OFN:

$$\overline{DCF_i} = [DCF_{0i}, \frac{DCF_{0i}+DCF_{ti}}{2}, \frac{DCF_{0i}+DCF_{ti}}{2}, DCF_{ti}], \quad (9)$$

where DCF_{0i} signifies the predicted discounted cash flow in the i-th year of investment, which is calculated using formula (6), whereas DCF_{ti} is the actual cash flow over the considered period. $\overline{DCF_i}$ allows us to see the graphical description of the change between the expected and real value of the discounted cash flow in the i-th year of investment. The width of the support reveals the magnitude of the change in discounted cash flows.

In addition, the goal is to facilitate an explanation of the change in the value of discounted cash flows by introducing an auxiliary quantity which characterizes this change, i.e. the change dynamics indicator (CDI). The CDI of discounted cash flows in the i-th year of investment can be represented by the following OFN:

$$dynDCF_i = \frac{1}{DCF_{0i}} \cdot \overline{DCF_i} = \left[\frac{DCF_{0i}}{DCF_{0i}}, \frac{DCF_{0i}+DCF_{ti}}{2DCF_{0i}}, \frac{DCF_{0i}+DCF_{ti}}{2DCF_{0i}}, \frac{DCF_{ti}}{DCF_{0i}}\right] =$$

$$\left[1, \frac{DCF_{0i}+DCF_{ti}}{2DCF_{0i}}, \frac{DCF_{0i}+DCF_{ti}}{2DCF_{0i}}, \frac{DCF_{ti}}{DCF_{0i}}\right]$$

Insight into the change dynamics of discounted cash flows is often crucial for evaluating the profitability of a given investment. By expressing the width of the support as a percentage

$$\left(\frac{DCF_{ti}}{DCF_{0i}} - 1\right) \cdot 100\%,$$

we can quantify the change in actual discounted cash flows in relation to the expected ones, with a positive value corresponding to an increase, and a negative value – to a decrease in the value of discounted cash flows. Figure 2 shows how the particularities of the change in the values of discounted cash flows over time can be interpreted through inspection. Growth trends correspond to positive direction, whereas downward trends – to negative direction. If the value of discounted cash flows remains unchanged, both graphs assume the same form, corresponding to a constant.

A graphical illustration of OFNs that mirrors the percentage change in discounted cash flows over time determined by the support width enables the rapid evaluation and ordering of individual periods during the execution of an investment project, e.g. from the change in cash flow that is the most unprofitable for the investor (the largest decrease in the discounted cash flow), to the most profitable one (corresponding to the highest increase). It now becomes possible to illustrate change dynamics in one chart, which facilitates evaluating how individual discounted cash flows change over time. However, a long planning horizon determined by the project execution period, together with the fact that discounted cash flows can either decrease, increase or remain unchanged over subsequent periods, hinder the evaluation of the resultant impact of the changes on the values of discounted cash flows and on their dynamics. OFNs facilitate information mining both for individual discounted cash flows and for the sum of discounted cash flows of a given investment.

The benefits of OFNs can be explained by applying them to the execution of an investment project example. Table 3 presents the expected and actual discounted cash flows expressed in AMU. NPV is assessed after three years of project execution in order to check the reliability of the results obtained during the previous phase (planning). According to Table 3, the discounted cash flow in the first year of project execution decreased from the expected level of 71,473.40 AMU to 65,300.00 AMU, i.e. by 8.64%. During the second and third year, however, an increase in the discounted cash flows was observed in relation to the expected flows, by 12.10% (8,688.10 AMU) and 12.30% (9,497.30 AMU), respectively (cf. Fig. 2).

The present discounted cash flows $\overline{DCF_1}$, $\overline{DCF_2}$, $\overline{DCF_3}$ expressed as OFNs and their change dynamics indices (also OFNs) are shown in Table 4.

Table 3. Expected and actual discounted cash flows for the considered investment project

Investment year	Expected discounted cash flow [a.m.u.]	Actual discounted cash flow [a.m.u.]
1	71473.40	65300.00
2	71812.90	80501.00
3	77202.70	86700.00
4	70832.60	no data
5	64697.50	no data

Table 4. Present discounted cash flows and their change dynamics indices for subsequent investment year

Investment year	Change of value of discounted cash flow [a.m.u.]	Change dynamics index
1	[71473.40;68386.70;68386.70;65300.00]	[1;0.957;0.957;0.914]
2	[71812.90;76159.95; 76156.95;80501.00]	[1; 1.06;1.06;1.121]
3	[77202.70;81951.35;81951.35;86700.00]	[1; 1.062;1.062;1.123]

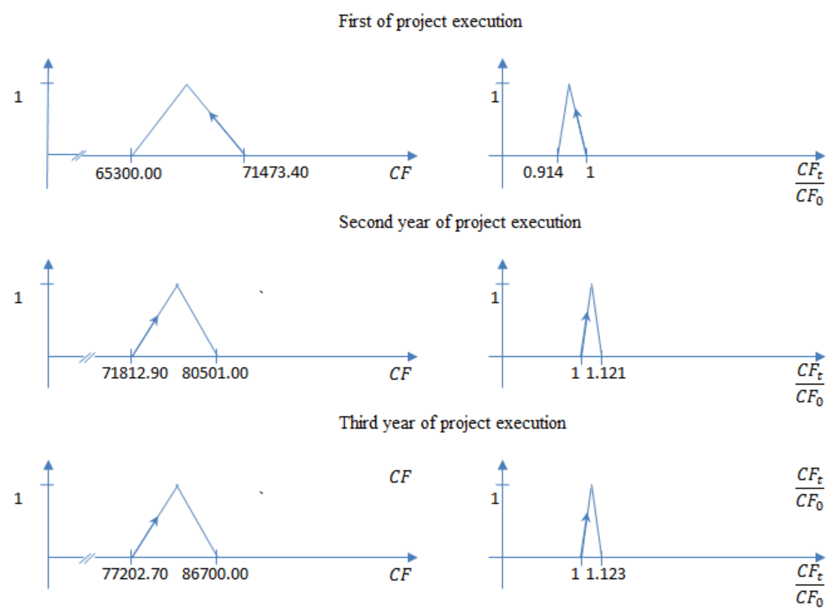

Fig. 2. Present discounted cash flows and their change dynamics for the considered investment

The change dynamics of discounted cash flows over the course of three years is expressed by means of an OFN, as the arithmetic mean of change dynamics over three subsequent years of project execution, yielding [1;1.026;1.026;1.053].

The next step in estimating the present cash flow in the fourth year of investment is to multiply the mean change dynamics by the scalar baseline for the fourth year of investment (70,832.60AMU), which yields [70,832.60;72,674.25;72,674.25;74,586.73]. Using forward inference from the data obtained over the first three years, the present cash flow for the fourth year of investment can be estimated at 74,586.73 AMU, and 68,126.47 AMU for the fifth year.

Examination of the data on the progress of the given investment indicates that the value of discounted cash flows changes. Deviations from expected values are taken into account when estimating the NPV of the investment. For this investment project, the current NPV, determined from the data recorded during project execution and from earlier forecasts, amounts to 75,214.20AMU. Therefore, in this case the increase in the predicted NPV is 34.27% (cf. Table 5). An increase in cash flows observed in the second and third year significantly influences the predicted NPV. The recorded values of cash flows reassure the investor that a correct decision has been made. The recorded values of cash flows reassure the investor that the correct decision has been made. The values predicted for the fourth and fifth years, based on the actual data, allow an updated value of NPV for the project to be inferred.

Table 5. Expected and actual cash flows and NPV for the investment

Investment year	Expected cash flows [a.m.u.]	Expected NPV [a.m.u.]	Present cash flows [a.m.u.]	Current NPV [a.m.u.]
0	300000.00	−300000.00	300000.00	−300000.00
1	71473.40	−228526.60	65300.00	−234700.00
2	71812.90	−156713.70	80501.00	−154199.00
3	77202.70	−79511.00	86700.00	−67499.00
4	70832.60	−8678.40	74586.73	7087.73
5	64697.50	56019.10	68126.47	75214.20
NPV		56019.10	–	75214.20

Actual cash flow values constitute valuable information for the investor. In the presented example, with the exception of the first year of investment, the investor witnesses a significant increase in cash flows. In economic practice, however, there exist investments, whose expected cash flows significantly deviate in minus from the actual values. In such cases it becomes necessary to diligently analyze the underlying causes of decreasing cash flows, and to make correct decisions – such as (as a last resort) halting the execution of the project in order to minimize losses incurred by the investor.

CONCLUSIONS

This article addresses the issue of assessing investment project profitability using OFNs. The main reasons for the complexity of this issue are: operating under conditions of uncertainty and the multi-criteria and multi-level nature of the decisions involved. To handle the uncertainty of net cash flows that stems from a lack of knowledge, this article proposes the use of ordered fuzzy numbers. They present imprecise data by means of a subjective possibility measurement associated with judgmental uncertainty, leading to a new approach for assessing the profitability of investment projects in fuzzy environments. The presented approach sheds new light on this common economic problem. The results of the assessment can be used by decision-makers to decide whether or not a given investment project ought to be carried out or rejected. By taking into account several options, the results of such an assessment can also facilitate selecting the most effective project, one that is deemed the most promising or otherwise favorable. When the investment cost is known, but the expected inflows remain hypothetical, the ability to make rational decisions is crucial.

Ordered fuzzy numbers may be used to illustrate information about cash flows and capitalization rates. They offer a clear, simultaneous representation of several pieces of information, while well-defined arithmetic operations on OFNs allow them to be aggregated. This article presents how to use OFNs to describe the change dynamics for given parameters in the assumed time horizon. Well-defined arithmetic operations and the direction properties of OFNs permit a modelling of the uncertainty associated with financial data and the construction of an entire decision support system in the future. The use of OFNs could eliminate several drawbacks of classical convex fuzzy numbers (CFNs), such as the loss of precision incurred by subsequent operations and the fact that even linear equations cannot be solved in a set of CFNs. In addition, a significant property of OFNs, their direction, is key to solving such problems and thus is valuable for decision-makers. By using OFNs, not only are experts able to assess the degree to which they recognize the considered phenomenon to be accurate and true to life, but also to express their assessment of its dynamics. This is key to assessing the profitability of investment projects. Every investor is interested in how the values of present cash flows and capitalization rates may change compared to their corresponding baseline values (t=0). The proposed approach based on OFNs simultaneously presents the values of present cash flows and capitalization rates over the period under study, and at the baseline.

An illustrative example was presented to emphasize the advantages of the proposed approach. This is an efficient, qualitative-quantitative approach to measurement and evaluation of investment project effectiveness based on OFNs. The proposed approach is easy to interpret by decisions-makers. It offers a considerable advantage when strategic decisions concerning investment projects are made. The authors intend to continue the search for a computationally efficient, qualitative-quantitative approach to capital budgeting under the conditions of uncertainty. Moreover, we intend to develop the approach presented in our previous article by transferring defuzzification to a different stage of calculations. Further discount methods (profitability index and internal rate of return) will be presented for a more precise evaluation of alternative investment projects. Such tools can be perceived as a decision support system based on OFNs. We plan to provide OFN-based commercial software dedicated to the investment process, which we envision will find uses in both practical and academic applications alike.

The presented approach to a profitability analysis of investment projects can be viewed as an early warning system, whose aim is to analyze signals from the environment and to interpret them correctly. It can serve as a tool for detecting potential opportunities and risks in the life cycle of investment projects. This tool could constitute a valuable source of knowledge for investors involved in decision-making processes. The evidence in favor of an ordered fuzzy approach highlights the advantages over the original crisp version of capital budgeting methods. The presented approach provides a formulation that more closely conforms to real situations. The proposed OFNPV method does not imply rejection of other discounted cash formulations but rather compliments existing fuzzy model formulations.

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OCENA OPŁACALNOŚCI PROJEKTÓW Z WYKORZYSTANIEM SKIEROWANYCH LICZB ROZMYTYCH

STRESZCZENIE. **Wstęp:** U podstaw rozważań leży stwierdzenie, że większość podejść do budżetowania kapitałowego ma charakter deterministyczny. W rzeczywistości problemowi budżetowania towarzyszy niepewność i ryzyko związane z przetwarzaniem nieprecyzyjnych danych. Uwzględnienie tej niepewności nie tylko pomaga lepiej zmierzyć efektywność projektów inwestycyjnych, ale także rozszerzyć zastosowanie metod budżetowania kapitałowego w warunkach rzeczywistych lub niepewnych. Głównym celem artykułu jest opracowanie nowatorskiego podejścia do oceny opłacalności projektu inwestycyjnego w warunkach niepewności.

Metody: Prezentujemy nowatorskie podejście uwzględniające niepewność w ocenie opłacalności projektów inwestycyjnych Ordered Fuzzy Net Present Value (OFNPV). Proponowana metoda umożliwia dokonanie oceny efektywności projektu inwestycyjnego za pomocą modelu opartego na skierowanych liczbach rozmytych (OFN). Ponadto skierowane liczby rozmyte służą do opisu zmian parametrów inwestycyjnych w założonym horyzoncie czasowym. Artykuł ilustruje wdrożenie proponowanego podejścia z wykorzystaniem przykładu procesu inwestycyjnego w przedsiębiorstwie w obszarze logistycznym.

Wyniki: Zastosowanie proponowanej metody opartej na OFN pozwala ekspertom ocenić dokładność rozpatrywanego zjawiska, a także wyrazić swoją ocenę na temat dynamiki ich zmian. Ma to kluczowe znaczenie dla problemu oceny opłacalności projektów inwestycyjnych.

Wnioski: Proponowane podejście oferuje nowe spojrzenie na problem inwestycyjny i stanowi skuteczne narzędzie do oceny opłacalności projektów inwestycyjnych. Narzędzie to może stanowić cenne źródło wiedzy dla inwestorów zaangażowanych w procesy decyzyjne.

Słowa kluczowe: projekt, projekt inwestycyjny, budżetowanie kapitałowe, NPV; liczba rozmyta, skierowana liczba rozmyta.

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ORIGINAL PAPER

A COMPREHENSIVE STUDY OF CLASSICAL HEURISTIC ALGORITHMS USED IN THE PROCESS OF SOLVING TRANSPORTATION PROBLEM

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ABSTRACT. **Background:** Transportation Problem (TP) is a special case of integer programming, characterised by indisputable practical significance (in particular in the area of logistics). For this reason, many techniques have been proposed to solve the problem both in optimum and approximate manner. The problem of selecting an effective technique for determining a suboptimal solution for TP was addressed by many researchers, however the implementation of only certain heuristics, 'test bed' applied, as well as non-performance of statistical tests make it impossible to clearly identify the recommended approach to application of heuristics in TP, leaving a research gap which determined the writing of this article. The additional purpose of this paper is to provide a summary of selected approximate methods, taking into consideration the number of iterations necessary to design the optimal solution by means of Modified Distribution (MODI) method and to demonstrate potential correlations between the parameters describing a problem instance and the efficiency of the methods.

Methods: This paper presents a comparative study of four classic techniques (NWC, LCM, VAM and RAM). The tests were performed on three sets of 2,500 pseudo-randomly generated tasks and the observations were also checked by means of the Wilcoxon Signed-Rank Test and Pearson correlation coefficient.

Results: The results confirms that VAM is characterised by a significant quality of the determined results, whereas NWC develops solutions of low efficiency. However, contrary to the observations made for small TP instances, RAM was characterised by a higher error value than LCM for huge set, demonstrating the impossibility to generalise results obtained for small problems (presented e.g. in literature), in order to determine their efficiency for higher instances.

Conclusions: It is recommended to apply VAM both for the determination of initial solution in MODI method and for performing allocation of resources, using only heuristics. However, taking into consideration the utilitarian approach and possible occurrence of the necessity to solve TP instances without using the appropriate software, it is recommended to use LCM for solving large instances of TP. The presence of strong correlation between the number of nodes describing the TP instance and the number of iterations necessary to determine the optimal solution by MODI method has been identified.

Key words: Transportation Problem, Best Initial Feasible Solution, MODI, VAM , RAM, LCM.

INTRODUCTION

Transportation Problem (TP) is a special case of integer programming [Reeb and Leavengood, 2002], formulated by Hitchcock [1941] and solved by Dantzig [1951]. The indisputable practical significance of the problem (Sharma et al. [2012] relied on TP when optimising transport processes at Albert David Company, Liu and Trung [2013] used them for physical flow management in flower delivery process, whereas Salami [2014] applied them at Nigeria Soft Drinks Industry) resulted in development of many techniques intended for solving the problem both in

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optimum and approximate manner. The methods belonging to the first of the listed groups are especially characterised by different time and memory complexity, while heuristics should also be assessed in terms of value of objective function of the obtained results.

The problem of selecting an effective technique for determining a suboptimal solution for TP was addressed e.g. by Ali and Mustapha [2013], Deshpande [2009], Khan et al. [2016], Liu and Trung [2013], Soomro et al. [2014]; however, the implementation of only certain heuristics (in some of the listed papers), 'test bed' applied (characterised by appearance of few test cases, additionally described by a small number of suppliers and customers), as well as non-performance of statistical tests make it impossible to clearly identify the recommended approach to application of heuristics in the process of designating the assignment of load transported between suppliers and customers, leaving a research gap which determined the writing of this article. The additional purpose of this paper is to provide a summary of selected approximate methods, taking into consideration the number of iterations necessary to design the optimal solution by means of Modified Distribution (MODI) method, which uses specific techniques in order to determine the basic results, with the effect of formulating the recommended approach to application of MODI algorithm in business practice. It has been assumed that the article is also intended to demonstrate potential correlations between the parameters describing a problem instance and the error determined by the methods, as well as the number of iterations necessary to define the optimal result.

While analyzing the selected problems occurring in business practice, a significantly higher number of participants can be noticed than the size of TP, which was discussed and verified empirically in the source literature (e.g. [Ali and Mustapha 2013, Deshpande 2009, Khan et al. 2016, Liu and Trung 2013, Soomro et al. 2014]), indicating also utilitarian need of research containing the larger instances of TP. Typical reliance on heuristic methods, connected with conclusions presented in works containing 'test bed', consisting of problems of other sizes than required, may cause application of faulty algorithms during optimization of flows and consequently lead to decreased efficiency of the entire network, hence authors of this work focused on the analysis of three collections of tasks of various sizes, which are to allow the choice of adequate methods, subject to the problem size and make it possible to formulate general conclusions, which justify exclusion of application of inefficient algorithms.

The article was divided into six parts. Following the introduction to the raised topics, the Transportation Problem was formulated, the algorithms used in the process of its solution were presented, the methodology of empirical research was described and the results of conducted research were discussed. The paper ends with discussion, conclusions and further work planned.

FORMULATION OF TRANSPORTATION PROBLEM

This article is based on the formulation of Transportation Problem which was presented in the paper by Shenoy et al. [1986]. It assumes the occurrence of homogeneous goods which are to be transported from a specific number of suppliers m to customers n. Each of the distributors is characterised by a set supply (its volume for supplier i is determined with variable a_i), whereas the customers are characterised by demand (represented by variable b_j for customer j). A model in which the total demand volume is equal to the supply is referred to as Balanced Transportation Problem (BTP), whereas a variant which does not fulfil the described condition is referred to as Unbalanced Transportation Problem - it requires introduction of a fictitious supplier or customer in order to adjust the problem to BTP. The cost of transporting a product unit between the source of origin i and the target destination j is represented by c_{ij} (where matrix c is referred to as the cost matrix). The problem assumes determination of variable values x_{ij} $(\forall i, j)$, representing the volume of load transported between the supplier i and customer j in such manner as to enable minimisation of the total transport cost while meeting customers' needs at the same time.

The mathematical problem formulation assumes the occurrence of the following objective function:

$$\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}\, x_{ij} \rightarrow min. \quad (1)$$

The constraints were determined as:

$$\sum_{j=1}^{n} x_{ij} = a_i, \quad i = 1, \dots, m, \quad (2)$$

$$\sum_{i=1}^{m} x_{ij} = b_j, \quad j = 1, \dots, n, \quad (3)$$

$$x_{ij} \geq 0, \quad (4)$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij} = \sum_{j=1}^{n}\sum_{i=1}^{m} x_{ij} = \sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j . (5)$$

The visualisation of example of BTP instance (for *m*=3 and *n*=3) was presented in Table 1.

Table 1. Visualisation of BTP instance solution

	b_1	b_2	b_3
a_1	x_{11}	x_{12}	x_{13}
a_2	x_{21}	x_{22}	x_{23}
a_3	x_{31}	x_{32}	x_{33}

Source: own work

ALGORITHMS USED IN THE PROCESS OF SOLVING AN INSTANCE OF TRANSPORTATION PROBLEM

North-West Corner Method

North-West Corner Method (NWC) implies iterative assignment of permitted transport value, beginning with element x_{11} (based on the representation of problem solution that was presented in Table 1). The technique pseudocode was presented in Figure 1.

NWC pseudocode

```
i = 0
j = 0
while i < m and j < n do
    if supply[i] < demand[j] then
        allocation[i, j] = supply[i]
        demand[j] = demand[j] − supply[i]
        supply[i] = 0
        i + +
    else if supply[i] > demand[j] then
        allocation[i, j] = demand[j]
        supply[i] = supply[i] − demand[j]
        demand[j] = 0
        j + +
    else
        allocation[i, j] = supply[i]
        supply[i] = 0
        demand[j] = 0
        i + +
        j + +
    end if
end while
return allocation
```

Source: own work

Fig. 1. NWC pseudocode

Least Cost Method

Least Cost Method (LCM) is based on the greedy approach and implies assigning the maximum permitted transport value to subsequent elements, choosing iteratively subsequent cost matrix cells, characterised by the lowest value.

Vogel Approximation Method

Vogel Approximation Method (VAM) was presented by Reinfeld and Vogel [1958]. The results determined by this method are usually characterised by the value of objective function similar to optimal or optimal [Gujjula et al. 2011]. It implies iterative performance of the following four steps until the entire transport has been planned:

1. Determine the cost difference between two lowest available values for each available row and column (not present in the tabu list).
2. Choose the column or row with the largest cost difference.
3. Assign the maximum available transport volume for the cell with the lowest cost, located in the indicated column or row.
4. Add the column and/or row for which the required needs have been met to the *tabu* list.

Russell Approximation Method

The Russell Approximation Method (RAM) proposed by Russell [1969] is based on iterative fulfilment of the following five steps until the entire transport has been planned:

1. For each available row i (not belonging to the *tabu* list) determine u_i, representing the largest unit cost cij present in the cost matrix in row i.
2. For each available column j (not belonging to the *tabu* list) determine v_j, representing the largest unit cost c_{ij} present in the cost matrix in column j.
3. For each available variable x_{ij} determine $\Delta_{ij}=c_{ij}-u_i-v_j$.
4. Assign the maximum available transport volume for the cell represented by the lowest value Δ.
5. Add the column and/or row for which the required needs have been met to the *tabu* list.

Modified Distribution Method

MODI (also known under the name of U-V Method [Tiwari and Shandilya 2006]). Method enables to determine the optimal solution of TP instance [Shenoy et al. 1986]. It uses an initial solution which was determined by the selected heuristics, whereas its procedure assumes iterative performance of the following steps:

1. Determine the initial solution using any heuristics.
2. If the number of occupied cells in the solution is lower than $m+n-1$, there is degeneracy, which must be removed (e.g. using the ε-perturbation method).
3. Solve the equation $u_i+v_j=c_{ij}$ for each occupied cell in the result, beginning from $u_i=0$ or $v_j=0$, determining the subsequent values iteratively.
4. Calculate $Z_{ij}=c_{ij}-(u_i+v_j)$ for each unoccupied cell.
5. If each unoccupied cell contains value Z_{ij} higher or equal to 0, the solution is optimal - finish executing the algorithm. Otherwise, go to step 6.
6. Choose the cell with the lowest value Z_{ij} (largest negative value) and assign an unknown value θ to it.
7. Identify the closed loop which begins and ends in the cell determined in step 6, connecting the occupied cells. Next, add and subtract the value θ alternately from the value of cells.
8. Determine the value θ in such manner that all cells should contain the value ≥0 as a result of performing the operation from step 7. If more than one cell is zeroed, mark only one cell as unoccupied.
9. Perform step 3.

MODI pseudocode

```
Generate the initial solution allocation
if number of occupied cells in allocation is lower than (m + n − 1) then
    Execute ε−perturbation method based on solution allocation
end if
do
    cellsList = prepare a list of occupied cells in allocation
    i = cellsList[0].supplierIndex
    j = cellsList[0].customerIndex
    potentialsU[i] = 0
    potentialsV[j] = costMatrix[i, j]
    Calculate the values in the potentialsU and potentialsV tables, according to potentialsU[i] + potentialsV[j] = costMatrix[i, j]
    For each unoccupied cell occurring in allocation calculate Z[i, j] = costMatrix[i, j] − (potentialsU[i] + potentialsV[j])
    if every calculated elements Z ⩾ 0 then
        optimal = true
    else
        optimal = false
        cell = select the cell with the smallest determined value Z[i, j] (∀i, j)
        Create a closed loop that starts and ends in cell, combining occupied cells that occurred in allocation
        θ = determine the minimum value in cells that belong to a loop with even position (second, fourth, ... element of the list)
        Interchangeably add and subtract value θ from cell values in allocation belonging to the created loop
    end if
while optimal = false
return allocation
```

Source: own work

Fig. 2. MODI pseudocode

The ε -perturbation method quoted in step 2 is based on three steps:

1. Add for each customer a negligibly small number ε.
2. Add for the last supplier the value ε multiplied by the number of customers.
3. Solve the TP instance using any method.

The MODI method pseudocode (based on Shenoy et al. [1986] and Tiwari and Shandilya [2006]), using the ε-perturbation method, was presented in Figure 2.

METHODOLOGY OF RESEARCH

The algorithms were implemented in C# language, whereas the research was conducted on laptop Lenovo Y520 whose parameters were presented in Table 2. In MODI Method, the ε-perturbation method, using heuristics applied in order to create the initial solution, was employed.

Table 2. Parameters of laptop Lenovo Y520 which was used for conducting research

No.	Parameter	Value
1	Processor	Intel Core i7-7700HQ (4 cores, from 2.8 GHz to 3.8 GHz, 6 MB cache)
2	RAM	32 GB (SO-DIMM DDR4, 2400MHz)
3	HDD	1000 GB SATA 7200 RPM, 240 GB SSD M.2 PCIe
4	OS	Windows 10 Home 64-bit

Source: own work

The quality assessment of results determined by particular algorithms was performed on the 'test bed' consisting of three sets described with the appearance of 2,500 pseudo-randomly generated instances of BTP, whose characteristics is similar to the features of the problems occurring in business practice (generally set S1 represents the issues faced by small enterprises, S2 is intended for middle-sized companies, whereas S3 is intended for the largest entities). The parameter values for the original generator of tasks (which are independent from the analysed set) were presented in Table 3. The specific parameter values for S1, S2 and S3 were presented in Table 4. Demand and supply are represented by integers.

Table 3. Parameter values for generator BTP instances, describing all sets of tasks

Parameter	Value
Number of instances	2,500
Minimum demand at point	1
Maximum demand at point	300
Minimum supply at point	1
Maximum supply at point	300
Minimum cost for unit	0.2
Maximum cost for unit	20.2

Source: own work

Table 4. Parameter values for generator BTP instances, with division into sets of tasks

Parameter	Value		
	S1	S2	S3
Minimal number of customers	5	50	150
Maximal number of customers	25	100	250
Minimal number of suppliers	5	50	150
Maximal number of suppliers	25	100	250

Source: own work

As a result, the generated sets of tasks were characterised by the values shown in Tables 5, 6 and 7. The actual maximum demand and supply exceed the assumed values (shown in Table 3), because the balancing of issues was performed in the last step, which determined the difference between the accumulated demand and supply, and divided it evenly between all suppliers/customers (in a situation preventing equal division, the surplus was assigned to the last supplier or customer).

Table 5. Characteristics of tasks from the set S1

Measure\Parameter	Total demand	No. of suppliers	No. of customers	Supply at point	Demand at point	Unit cost
Minimum	622	5	5	1	1	0.2
Maximum	5147	25	25	988	977	20.2
Average	2802.7	14.87	15.02	188.46	186.54	10.2
Standard deviation	828.19	6.08	6.07	116.75	114.54	5.78
Coefficient of variation	29.55%	40.89%	40.42%	61.95%	61.4%	56.64%

Source: own work

Table 6. Characteristics of tasks from the set S2

Measure\Parameter	Total demand	No. of suppliers	No. of customers	Supply at point	Demand at point	Unit cost
Minimum	6618	50	50	1	1	0.2
Maximum	17804	100	100	507	479	20.2
Average	12574.82	74.83	75.09	168.03	167.47	10.2
Standard deviation	1954.62	14.76	14.74	91.19	90.72	5.77
Coefficient of variation	15.54%	19.73%	19.63%	54.28%	54.32%	56.57%

Source: own work

Table 7. Characteristics of tasks from the set S3

Measure\Parameter	Total demand	No. of suppliers	No. of customers	Supply at point	Demand at point	Unit cost
Minimum	22420	150	150	1	1	0.2
Maximum	41598	250	250	532	523	20.2
Average	32463.63	199.45	198.8	162.77	163.29	10.2
Standard deviation	3776.63	28.97	29.09	88.7	88.83	5.77
Coefficient of variation	11.63%	14.53%	14.63%	54.49%	54.4%	56.6%

Source: own work

The following were used as meters for quality assessment of algorithm results: number of iterations after which MODI determined the optimal solution *it* (their average number was marked as $\overline{it}$, whereas the standard deviation was marked as σ_{it}), percentage surplus of the value of objective function in comparison with optimum *e* (their average value was determined as $\bar{e}$, whereas the standard deviation was determined as σ_e) and number of optimal results b. The value of the second meter was determined using the following formula:

$$e=(result\text{-}optimum)\ /optimum\cdot 100\%.$$

The values e and it were subject to Wilcoxon Signed-Rank Test, using R. The following pairs of methods (marked as M1 and M2) were involved in the process, whereas the value of 0.05 was adapted as the level of test significance (the obtained p-values which were characterised by lower results were distinguished and they indicate that an alternative hypothesis was accepted, according to which M1 obtained lower results than M2).

RESULTS OF CONDUCTED RESEARCH

Results for set S1

Table 8 presents the summary of results for tasks in set S1, obtained by particular heuristics. NWC did not determine any optimal solution from the set 2,500 of problem instances, whereas LCM created four best allocations, and techniques based on approximation obtained 11 and 20 optimal solutions (for RAM and VAM respectively). The above-mentioned correlations were also maintained for other values describing the results, implying that the best quality of assignment was obtained by VAM method, whereas the worst quality was achieved by NWC. The results of Wilcoxon Signed-Rank Test (presented in Table 9) made it impossible to deny the above-mentioned observations.

Table 8. Results of heuristic methods for set S1

Indicator\Method	NWC	LCM	VAM	RAM
Minimum *e*	13.35%	0%	0%	0%
Maximum *e*	866.65%	133.62%	106.69%	106.26%
$\bar{e}$	272.26%	31.03%	15.76%	26.59%
σ_e	117.86%	17.88%	12.25%	16.24%
b	0	4	20	11

Source: own work

Table 9. Results of Wilcoxon Signed-Rank Test for *e* determined by heuristic methods for set S1

M1\M2	NWC	LCM	VAM	RAM
NWC	N/A	1	1	1
LCM	**0**	N/A	1	1
VAM	**0**	**2E-285**	N/A	**4.2E-189**
RAM	**0**	**1.61E-43**	1	N/A

Source: own work

Table 10 presents the summary of obtained results, taking into consideration their impact on MODI method operation. On their basis, the observations resulting from the analysis of heuristic methods were confirmed, with the conclusion that it is advantageous to apply VAM for determination of basic solution, whereas the use of NWC causes extension of the procedure of generating the optimal result. Particular attention should be drawn to the higher value of σ_{it} for MODI with RAM in comparison with MODI using LCM, which indicates a lower predictability of the number of iterations necessary in order to determine the optimal result by MODI with RAM. The results of Wilcoxon Signed-Rank Test (presented in Table 11) made it impossible to deny the above-mentioned observations.

Table 10. Results of MODI method for set S1

Indicator\Method	MODI + NWC	MODI + LCM	MODI + VAM	MODI + RAM
Minimum *it*	4	1	1	1
Maximum *it*	122	45	39	44
$\overline{it}$	42.88	14.82	10.54	14.73
σ_{it}	20.43	7.07	5.88	7.36

Source: own work

Table 11. Results of Wilcoxon Signed-Rank Test for the results of MODI method for set S1

M1\M2	MODI + NWC	MODI + LCM	MODI + VAM	MODI + RAM
MODI + NWC	N/A	1	1	1
MODI + LCM	**0**	N/A	1	0.950109
MODI + VAM	**0**	**6E-276**	N/A	**1.5E-264**
MODI + RAM	**0**	**0.049891**	1	N/A

Source: own work

Results for set S2

The obtained results for heuristic methods and average set of tasks (S2) were presented in Table 12. None of the analysed techniques determined an optimal solution, whereas the average error exceeded 1,200% for NWC. Among the other methods, the results created by VAM were characterised by the notably lowest value $\overline{e}$ (and its standard deviation). The results of Wilcoxon Signed-Rank Test (presented in Table 13) confirmed the above-mentioned observations, which are consistent with the theses formulated for S1.

Table 12. Results of heuristic methods for set S2

Indicator\Method	NWC	LCM	VAM	RAM
Minimum *e*	670.51%	30.34%	8.78%	29.1%
Maximum *e*	1762%	115.15%	88.29%	120.5%
$\overline{e}$	1225.22%	69.67%	39.18%	67.72%
σ_e	177.04%	14.04%	11.85%	14.02%
b	0	0	0	0

Source: own work

Table 13. Results of Wilcoxon Signed-Rank Test for *e* determined by heuristic methods for set S2

M1\M2	NWC	LCM	VAM	RAM
NWC	N/A	1	1	1
LCM	**0**	N/A	1	1
VAM	**0**	**0**	N/A	**0**
RAM	**0**	**3.17E-09**	1	N/A

Source: own work

The summary of the number of iterations after which MODI method determined the optimal solution for S2 was presented in Table 14. According to it, the best technique was again VAM, whereas the worst technique was NWC. However, particular attention should be drawn to the observation according to which, contrary to set S1, LCM determined more advantageous results than RAM. The thesis was confirmed by the results of Wilcoxon Signed-Rank Test, which were presented in Table 15.

Table 14. Results of MODI methods for set S2

Indicator\Method	MODI + NWC	MODI + LCM	MODI + VAM	MODI + RAM
Minimum *it*	261	60	34	65
Maximum *it*	790	242	215	258
$\overline{it}$	498.25	137.61	107.39	145.79
σ_{it}	103.58	30.48	26.56	32.19

Source: own work

Table 15. Results of Wilcoxon Signed-Rank Test for the results of MODI methods for set S2

M1\M2	MODI + NWC	MODI + LCM	MODI + VAM	MODI + RAM
MODI + NWC	N/A	1	1	1
MODI + LCM	**0**	N/A	1	**2.48E-82**
MODI + VAM	**0**	**0**	N/A	**0**
MODI + RAM	**0**	1	1	N/A

Source: own work

Results for set S3

The summary of the results determined by heuristic methods for a large set of tasks (S3) was presented in Table 16. Once again, none of the analysed techniques determined an optimal solution, whereas the average error exceeded 2,300% for NWC. Particular attention should be drawn to the observation, according to which $\overline{e}$ for LCM, VAM and RAM did not change significantly in comparison with the results obtained for S2. Once again, the results created by VAM were characterised by the notably lowest value $\overline{e}$ (and its standard deviation). Contrary to the previous analyses, the results of RAM for S3 were described by a worse value $\overline{e}$ than the results of LCM (however, the standard error deviation was lower for RAM). The results of Wilcoxon Signed-Rank Test presented in Table 17 confirmed the above-mentioned observations.

Table 16. Results of heuristic methods for set S3

Indicator\Method	NWC	LCM	VAM	RAM
Minimum *e*	1775.7%	40.24%	15.5%	40.56%
Maximum *e*	2900.96%	111.81%	75.78%	113.18%
$\overline{e}$	2332.95%	69.45%	38.76%	69.63%
σ_e	174.85%	10.35%	8.76%	9.75%
b	0	0	0	0

Source: own work

Table 17. Results of Wilcoxon Signed-Rank Test for *e* determined by heuristic methods for set S3

M1\M2	NWC	LCM	VAM	RAM
NWC	N/A	1	1	1
LCM	**0**	N/A	1	0.193256
VAM	**0**	**0**	N/A	**0**
RAM	**0**	0.806744	1	N/A

Source: own work

The obtained number of iterations after which MODI method determined the optimal solution for set S3 was presented in Table 18. On this basis, it was confirmed that the best technique was again VAM, whereas the worst technique was NWC. As in the case of set S2, LCM determined more advantageous results than RAM. The thesis was confirmed by the results of Wilcoxon Signed-Rank Test, which were presented in Table 19.

Table 18. Results of MODI method for set S3

Indicator\Method	MODI + NWC	MODI + LCM	MODI + VAM	MODI + RAM
Minimum *it*	1258	309	216	340
Maximum *it*	2871	802	662	832
$\overline{it}$	2020.97	513.55	407.36	549.96
σ_{it}	300.5	82.1	69.91	87.43

Source: own work

Table 19. Results of Wilcoxon Signed-Rank Test for the results of MODI method for set S3

M1\M2	MODI + NWC	MODI + LCM	MODI + VAM	MODI + RAM
MODI + NWC	N/A	1	1	1
MODI + LCM	**0**	N/A	1	**4.095E-218**
MODI + VAM	**0**	**0**	N/A	**0**
MODI + RAM	**0**	1	1	N/A

Source: own work

Correlation analysis

The values of the Pearson correlation coefficient *p* were determined to identify the existence of a correlation between *e* and the number of nodes ($n+m$). The obtained results were presented in Table 20 and, in accordance with the interpretation presented by Ratner [2009], they indicate the occurrence of strong positive linear connection between the data for NWC, whereas for the other methods its value is moderate (taking into consideration the results of analysis of scatter diagrams, it was assumed that no significant correlation occurred in them).

Table 20. Value of the Pearson linear correlation between the number of nodes and the average error

Method	*p*
NWC	0.97784511
LCM	0.582538311
VAM	0.517584878
RAM	0.638177185

Source: own work

The correlation between the number of iterations of MODI method *it* and the number of nodes that describe TP instance, was subject to similar analysis. On the basis of the Pearson linear correlation value (Table 21), the possibility of presence of strong positive correlation between the examined data for all methods was identified.

Table 21. Value of the Pearson linear correlation coefficient between the number of nodes and the *it*

Method	*p*
MODI + NWC	0.992342
MODI + LCM	0.988593
MODI + VAM	0.984694
MODI + RAM	0.989044

Source: own work

DISCUSSION AND CONCLUSIONS

In this article, the assumed goals have been achieved and the observations made by Ali and Mustapha [2013], Deshpande [2009], Khan et al. [2016], Liu and Trung [2013], according to which VAM is characterised by a significant quality of the determined results, whereas NWC develops solutions of low efficiency, have been confirmed (through statistical analysis including the Wilcoxon Signed-Rank Test). This correlation has also been maintained for the number of iterations after which the MODI method created optimal allocation, applying the above-mentioned techniques for determination of the initial solution. However, contrary to the observations made for small TP instances, RAM was characterised by a higher value $\overline{e}$ than LCM for set S3, demonstrating the impossibility to generalise results obtained for small problems (presented e.g. by Deshpande [2009]), in order to determine their efficiency for higher instances.

When analysing only the quality of the determined results, it is recommended to apply VAM both for the determination of initial solution in MODI method and for performing allocation of resources, using only heuristics. However, taking into consideration the utilitarian approach and possible occurrence of the necessity to solve TP instances without using the appropriate software, it is recommended to use LCM for solving large instances of TP due to the fact that technique offers solutions better than NWC and comparable with RAM; furthermore, it is characterised by the simplicity of application.

In contrast to other identified works containing the comparison of heuristics applied in the process of TP solving [Ali and Mustapha 2013, Deshpande 2009, Khan et al. 2016, Liu and Trung 2013, Soomro et al. 2014], we also performed the analysis of dependability between efficiency of particular methods and parameters describing the tasks, which is a novel solution of a kind. The presence of strong correlation between the number of nodes describing the TP instance and the number of iterations necessary to determine the optimal solution by MODI method has been identified.

Further work covering the analysis of heuristics applied for solving TP may include examination of new and simultaneously less popular heuristics (e.g. Extremum Difference Method described by Kasana and Kumar [2013], Inverse Coefficient of Variation Method by Jude et al. [2017], Logical Development of Vogel's Approximation Method developed by Das et al. [2014] or Karagul-Sahin Approximation Method by Karagul and Sahin [2019]).

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PORÓWNANIE KLASYCZNYCH ALGORYTMÓW HEURYSTYCZNYCH STOSOWANYCH W PROCESIE ROZWIĄZYWANIA PROBLEMÓW TRANSPORTOWYCH

STRESZCZENIE. Wstęp: Zagadnienie transportowe (ZT) jest specjalnym przypadkiem programowania całkowitoliczbowego, charakteryzującym się niekwestionowanym znaczeniem praktycznym (w szczególności w obszarze logistyki). Z tego powodu powstało wiele technik przeznaczonych do rozwiązywania problemu zarówno w sposób optymalny, jak i przybliżony. Problem wyboru efektywnej metody konstruowania suboptymalnego rozwiązania dla ZT został poruszony przez wielu badaczy, jednakże zastosowanie przez nich tylko niektórych heurystyk, użyte "łoże testowe", a także brak przeprowadzenia testów statystycznych uniemożliwiają jednoznaczne określenie odpowiedniego podejścia do stosowania heurystyki w ZT, pozostawiając lukę badawczą, która stała się inspiracją do napisania niniejszego artykułu. Dodatkowym celem artykułu jest porównanie wybranych metod przybliżonych, z uwzględnieniem liczby iteracji niezbędnych do zaprojektowania optymalnego rozwiązania za pomocą metody Modified Distribution (MODI) oraz wykazanie potencjalnych korelacji pomiędzy parametrami opisującymi instancję problemu a skutecznością technik.

Metody: W pracy przedstawiono badania porównawcze czterech klasycznych heurystyk (NWC, LCM, VAM i RAM). Testy przeprowadzono na trzech zestawach zadań, składających się z 2500 pseudolosowo wygenerowanych instatacji problemu. Obserwacje potwierdzono za pomocą testu Wilcoxon Signed-Rank i współczynnika korelacji liniowej Pearsona.

Wyniki: Badania potwierdzają, że VAM charakteryzuje się znaczącą jakością wyznaczonych wyników, podczas gdy NWC konstruuje rezultaty o niskiej jakości. W przeciwieństwie do wyników sformułowanych dla niewielkich instatacji ZT, wyniki metody RAM dla dużego zbioru charakteryzowały się wyższą wartością błędu niż rezultaty LCM, wykazując brak możliwości uogólnienia wniosków prawdziwych dla małych problemów (przedstawionych np. w literaturze przedmiotu).

Wnioski: Zaleca się stosowanie VAM zarówno do określania bazowego rozwiązania w metodzie MODI, jak i do przygotowania alokacji zasobów, w przypadku korzystania wyłącznie z heurystyk. Biorąc jednak pod uwagę podejście utylitarne i możliwość wystąpienia konieczności rozwiązywania instancji ZT bez użycia odpowiedniego oprogramowania, zaleca się stosowanie LCM do rozwiązywania dużych instancji problemu. Zidentyfikowano także silną korelację pomiędzy liczbą węzłów opisujących instancję ZT a liczbą iteracji niezbędnych do określenia optymalnego rozwiązania za pomocą metody MODI.

Słowa kluczowe: zagadnienie transportowe, Best Initial Feasible Solution, MODI, VAM , RAM, LCM

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ORIGINAL PAPER

MOBILE TECHNOLOGIES IN LOGISTIC CUSTOMER SERVICE AS A TOOL FOR WINNING CUSTOMERS' SATISFACTION

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ABSTRACT. **Background:** The extremely demanding and dynamic situation on the 21st-century market along with market trends such as globalization, product unification or the development of e-commerce and m-commerce make it harder for businesses to compete and lead to greater deployment of technologies. As customers' expectations rise to an unbelievable level, all firms are searching for new means to succeed. Therefore, the aim of this paper is to present the importance of mobile technologies in logistics customer service and boosting customers' satisfaction in the form of a two-perspective judgement concerning both the supplier and the end client.

Methods: In order to acquire the dual perspective, the research includes two interviews with different companies from one supply chain and a survey. Both interviews were structured so as to compare each business's comprehension of the importance of mobile technologies in the logistics supply chain. The survey was conducted among randomly chosen customers aged 20-30, who mostly use mobile technologies while shopping (gived their share in the number of m-commerce customers). This approach made the survey results realistic.

Results: The results show an undoubtable synergy effect of the conscious use of mobile technologies in each linkin the supply chain. Moreover, the study confirms the growing popularity of this solution, as well as its contribution to constantly improving logistics customer service in terms of time, reliability, communication and comfort.

Conclusions: Based on the study, the high level of general customers' satisfaction of mobile technologies is incontestable proof of their overall benefits. Therefore, mobile technologies can be the key to gaining or keeping customers in the 21st-century marketplace.

Key words: Mobile technologies, logistics customer service, satisfaction, omnichanneling.

INTRODUCTION

There is no doubt that 21st-century customers are accustomed to finding any product they need on the market in a very short time, and that firms make huge efforts to live up to their expectations. The problem is that making the product accessible is no longer the issue, nor is the time or place of delivery. Now, the key is to make it possible and easy for the customer to decide how they want to choose the product, pay for it, collect it (and return if needed) and for firms to be able to carry out the whole process relatively easily. This was one of the main reasons for the development of omnichanneling, which has now become a standard, so much so that clients may be unpleasantly surprised when they are left with only a few options for delivery or for returning a product.

The relevance of omnichanneling is also a consequence of the fast development of e-commerce and m-commerce around the world. In the year 2000 the number of Internet users was 415 million, while by 2017 the number had risen to 3.7 billion people [Mobirank 2017], so compared to 7% of people having access to the Internet in 2000, it is now half of the world population and this figure is still increasing. Therefore, new human resources and processes are necessary in order to deal with the huge number of customers who not

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only buy via Internet, but also search for information and need assistance.

What is more, it always depends on the kind of the product. If it is not designed or produced to a special order, the product usually does not really differ from a competitor's, because there is no problem for the rivals to imitate them [Grant 2010]. There are two main reasons for this: globalisation and product unification. Hence, if there is no possibility to compete by modifying the product or by manipulating the price, competitors should resort to other elements of the marketing mix, such as distribution or customer service. The most fascinating aspect of perfect customer service is that each customer wants to be served in a different way, and all these ways must be perfect. That is why all members of the supply chain must cooperate to ensure the customer's needs are met. However the market is dealing with a very high level of competition – supply chain vs. supply chain competition. What is even more problematic about this fact is that many companies are members of more than one supply chain, so this competition takes on the form of web vs. web competition.

All these observations lead to one significant challenge for the supply chains: they must improve their customer service in order to make it enough flexible and reactive to each situation. However high the costs may be, it is now the only possible way to keep up with the markets' expectations. That is why new solutions appear on the market, and mobile technologies are a perfect example of this. Their universal character makes them an excellent tool for each sector and they unquestionably let firms gain a competitive advantage, which is worth the investment. Unfortunately, the literature does not describe this problem sufficiently, usually demonstrating only one perspective. Therefore, in this article the dual perspective of one supply chain is described.

LOGISTICS CUSTOMER SERVICE – DEFINITION AND AIM

In order to understand the role of logistics customer service, customer service in general has to be explained. What definitely needs to be highlighted is the complex character of customer service. It consists of many small elements which have an effect on each other and are divided into three groups: pre-transactional, transactional and post-transactional [Melović et al. 2015]. This fact indicates that customer service not only concerns the act of buying and selling itself, but also the preparation for this transaction and all the activities which take place after it, including returns or after-sales service.

Then, there is the clue to customer service: it concerns delivering the product physically to a final customer, which is the aim of logistics, but also about proceeding with this in a way that awes the customer, which is rather the issue of marketing. This means understanding customer service as starting with the customer's real needs and finishing with their satisfaction: first, clients' needs must be understood, then interpreted and fulfilled in the best possible way.

This leads to an observation that customer service includes many factors which are extremely difficult to measure, such as consumers' needs and desires, which may be voiced out loud, but are not necessarily truly and fully matched with consumers' real and exact feelings. Concerning the definition and the understanding of logistics customer service, its aim may be described as delivering a specified quality level of all its elements and added value in the most effective way, reaching the highest possible level of customer satisfaction at the same time.

So, taking into consideration the fact that logistics customer service is a sequence of activities with an aim to be measured, it is time to call it a process and invent measures which will fully describe whether the aim is achieved or not. But when satisfaction is one of the most difficult notions to be defined, the only way to measure it is either to monitor the general level of satisfaction on a scale or to distinguish some components of it which may be easier to present. A good solution to this is to reach for a definition of logistics reduced to a 9R rule which, as described by different authors, differs slightly in some details, but generally focuses on the adjective "right" and refers to the place and time and way of delivery [Wilson et al., 2013]. This rule indicates certain areas which must be perfected, such as time, reliability, communication and comfort and which are far easier to measure. Therefore, these four areas are used in a satisfaction measurement in research described by this paper.

MOBILE TECHNOLOGIES IN LOGISTICS CUSTOMER SERVICE

Mobile technologies are becoming more and more popular in customers' everyday shopping experiences. Whenever an Internet connection is available and the customer has their mobile device turned on, the whole shopping process and even all what happens before and after the purchase can be carried out using mobile technologies. Having this in mind, a complete revolution in the shopping decision process is no longer in any doubt. Now, when the technology affects every step of it, the process is no longer a linear sequence of activities but rather continuous than discrete [Faulds et al., 2017] which means that customers jump from online to offline and the steps of the process are inverted, appearing in a different sequence and more than once.

There are many different types of mobile technologies available to customers. However, they exist for different reasons and fulfil various needs. They supply the user with information, they act as a kind of an advertisement for a brand or they simply make the purchase more customer-friendly. What is more, some of these technologies are used in companies in order to improve the processes, while others are designed for customers and are more even fun than useful.

For the purposes of this paper and this research, four different mobile technologies have been chosen - RFID, QR codes, geolocation and BLIK. The reason for choosing these particular mobile technologies is that they all contribute to the improvement of four areas of logistics customer service (time, reliability, communication and comfort) and three main flows in supply chains: materials, money and information.

QR codes have already been known for more than two decades, but their popularity grew incredibly when this technology became available not only to companies, but also the customers. Initially, they were used usually in warehouses in order to simplify the way the product flow is organized, but they are now widely used by detail retailers. QR codes are the successors of barcodes, because they can carry much more information.

A QR code is a matrix (a white square with black shapes) which can be read by a QR scanner or a camera in a smartphone [Ashford 2010].

Source: https://www.qrstuff.com/, 11/30/2018

Fig. 1. QR code

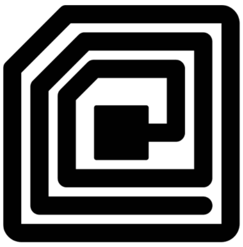
Although the QR code is a two-dimensional code, its area is limited by three squares at the corners, which help the scanner put the code in a specific position and read the information correctly and what is more, thanks to a special algorithm, the code can be read even when slightly damaged [Cheremkhin et al. 2017].

One of the biggest advantages of QR codes is their utility regardless of the branch. Among information hidden in QR codes such data as website addresses, contact information or product details is found [Cheremkhin et al. 2017], which make it easier to find the information needed at every point of the purchase process. However, QR codes are also a good advertising solution, a good example of which being the HBO campaign in which a special QR code was created to advert a new TV series "True Blood".

Source: https://www.ashworthcreative.com/wp-content/uploads/2011/07/hbotruebloodqr.png, 11/30/2018

Fig. 2. "True blood" QR code – advertising campaign of and HBO TV series

However, as technology progresses further, improvements appear very quickly. Therefore, there is another type of code which also enables the user to obtain a great deal of information of the object tagged with the code – the RFID technology. RFID is a short form of Radio Frequency Identification and is used for automatic object identification based on reading or writing the data in RFID tags using radio signals in RFID scanners [Lanko et al., 2018].



Source: https://png.icons8.com/metro/540/rfid-tag.png (12/29/2018)

Fig. 3. 3 RFID tag

The advantages of using RFID are similar to those for QR codes. This technology can be used in almost every sector and not only in retail, but for example, in new car parking solutions, which simplifies the process for the client (in this case, drivers). Furthermore, the aim is to make the process more reliable. Moreover, RFID technology allows the retailer to supply clients with personalised information the minute they enter the store, making it similar to online shopping, where multiple additional links and information are available [Landmark, Sjøbakk, 2017]. This may be extremely important in the times of today's shopping process, which is based on online to offline hopping.

What is more, there is no doubt that consumers live in a constant buzz and they pay little attention to the information they find in their environment. What makes things even worse is the fact that being surrounded by so much information, the client demands real value in it, otherwise they skip it as soon as possible and easily forget. That is why companies have to make a huge effort to get straight to the right customer. Therefore, they use geolocation, a technology basing on a GPS signal which allows for sending information about a promotion to a client's smartphone just when he or she appears nearby the shop. The aim isto influence the client's behaviour and emotions and persuade them to buy. What differentiates this information is that a client interested in it has to agree to receive messages. The best advantage of geolocation is that it makes it possible to reach the client at the right time and place (either the district or area near a specific building, depending on the kind of geolocation), so that just after receiving the information, the client can enter the shop and spend money. Even though geolocation does not work in closed areas like shopping malls, other technologies have also appeared, like iBeacon, which is no longer based on the GPS signal, and therefore may also be used inside a building [Rezazadeh et al. 2018].

Last but not least, there are mobile technologies which simplify the process of payment for shopping. Although paying with the use of debit and credit payment cards is definitely customer-friendly, in 2015 it became even easier, as the customer does not need anything more but their mobile device (usually a mobile phone) with a BLIK system installed. By the end of 2017, 9 banks had already begun participating in this project [Folwarski, 2018]. Payments through the BLIK system are based on a mobile banking application, which has to be installed on the mobile device. However, the number of customers using mobile banking is increasing (from 3.14 million people in 2015 up to more than 3.5 million in 2017).

BLIK is a relatively easy tool. When choosing BLIK as a method of payment for shopping, the customer needs to generate a disposable 6-digit code and write it on the payment terminal in the shop. What is more, BLIK may also be used to withdraw money from the ATM, to transfer an amount of money to another person, or to purchase tickets in ticket machines in buses.

RESEARCH METHODOLOGY

The study has been divided into two parts in order to obtain the most appropriate data possible and a dual perspective. The aim of each part was to obtain information about the respondents' level of knowledge concerning mobile technologies, the point up to which they use any of them, as well as their opinions about each technology concerning time, reliability, communication and comfort compared to their general satisfaction.

Firstly, qualitative research has been conducted in companies which have specific mobile technologies. As assumed, the form of research (being individual structured interviews) allows a detailed picture to be created of the impact of mobile technologies on supply chain processes (especially the logistics customer service process). Therefore, two companies (which cooperate closely) from one supply chain have been chosen in order to produce a description from two points of view. Moreover, such an action enables the researcher to make a comparative analysis.

The research focuses on companies which know and use RFID technology, although a few other technologies were also mentioned during interviews. During spring 2018, two individual interviews took place, one of them with the Director of the Decathlon Warehouse in Lodz and the second with the Director of the Decathlon retail shop in Lodz.

Decathlon is a French network of sports shops which operates globally and, on average, its turnover rises by 0.5 million euro each year. I product range includes over 20 brands, which are differentiated by the sports discipline they are dedicated for. In 2018 in Lodz, there are 3 retail shops and 1 newly build warehouse of this company.

Both interviews were structured in the same way. First, the respondent was asked about his understanding of logistics customer service and about the kinds of mobile technologies used in his company. Detailed questions followed. The researcher asked for the respondents' feelings about the technologies mentioned with regard to four areas: time, reliability, communication and comfort. Also, respondents were asked about other mobile technologies that are a part of their systems.

For the second part of the research, a survey, it was decided that a web poll would produce the most reliable data. Therefore, a web questionnaire was created and distributed among students' groups via the Internet. The number of questions depended on the respondents' familiarity with mobile technologies: detailed questions about each technology appeared only if the respondent answered "yes" to the previous ones, the larger amount being 4 for each technology.

In this case, 3 mobile technologies were selected: QR codes, geolocation and BLIK. First, the clients were asked if they know any of the technologies mentioned. If not, the survey was ended. If they were familiar with some of the technologies, they were asked to answer several more questions in which they graded technologies in four areas, as was done by Decathlon workers with RFID in the interviews.

When it comes to the web survey respondents themselves, there were no strict regulations regarding the ideal client. In fact, the questionnaire could be completed by every person who does shopping, because only those could be users of these specific mobile technologies. Even the questionnaires from clients who didn't know any of the technologies were taken into consideration, because one of the detailed aims of the survey was to check whether each technology is known or not. The survey resulted in 10.16% questionnaires being returned.

RESEARCH RESULTS - INTERVIEWS

As supposed, the interview results made it possible to perform a comparative analysis. The most striking fact for both comments was that each company treats logistics customer service rather comprehensively. What makes the process so crucial is that the supply chain has to service the client in the best possible way, regardless of who the client really is. For the shop, the clients are distinguished by their needs, but for the warehouse, it is also a question of whether it is an individual web customer or a retail shop, as both need to be served well, even though the service is completely different. For both companies, the aim of the process is for it to be run smoothly and quickly, so as to let the clients receive their orders as and when they want. Additionally, the warehouse tries to reduce the time the shop loses on working with the product in order to let the shop workers focus on customers, which is a question of seeing greater value in people rather than in products.

When asked about mobile technologies used in their logistics customer service, both directors mention RFID as a core technology in their companies, and even if in the shop it is part of each activity in the process, in the warehouse it is still an auxiliary tool. The logistics customer service in the warehouse uses it mainly for stocktaking or quality check, but in the near future Decathlon is to launch a project called "100% RFID", which will be based on this technology. The important point here is that RFID is present in every single link of this supply chain, beginning with production up to returns. This leads to the whole Decathlon chain's aim of having non-stop control over the product flow.

When it comes to effectiveness, the warehouse admits that RFID helps in measuring the time needed for each order to be completed. As for the shop, this technology is more of a help in validating data in the system with what is actually in the store. However, the shop's director agrees that the time spent at the checkout is incomparable when the goods are scanned with RFID and not manually. Moreover, it has some added value for the client, who hardly ever underestimates how little time the cashier needs to complete the shopping. Therefore, both the warehouse and the shop benefit from the time reduction gained with RFID.

As was said before, the aim of Decathlon's supply chain is to have control over where each product is at every moment. Therefore, the use of RFID technology makes an extreme rise in the certainty of delivering the right product to the right customer (whether it is a final consumer or the retail shop). What is more, the shop's director indicates that it is usually the human who is the source of errors, not the technology itself.

When it comes to the area of communication, some differences appear. In the warehouse, communication with the suppliers doesn't really exist because Decathlon produces and sells its own products. However, there is a kind of communication between the warehouse and the shop being planned in the "100% RFID" project: RFID is going to be responsible for changes in product status (from: "in a warehouse" into "in a shop"). Furthermore, RFID is present in the process of managing returns in which all information about the mistakes appears automatically in the warehouse right after being discovered in the shop. More cooperation in this area is predicted in future.

In the shop, the communication is on another level, as it takes the form of human-to-human dialogue. Workers use RFID to find any information needed for the client in very little time ("fast shop"). The RFID tag contains not only information about the price, but also technical information or even other users' opinions. In addition, in the future, shops will use RFID in fitting rooms so as to help customers who shop alone. RFID will create a possibility for them to get another size of a T-shirt they are trying on by sending a message to a worker and letting him bring a desired piece of clothing. As an interesting fact, the shop director mentioned the size of RFID tags, which are not relatively big by accident or by technical constraints. Decathlon customers are supposed to see the technology being used and to understand that it is user-friendly, and, ultimately, to use it.

Summing up all the above, both directors agreed that RFID technology makes managing a company far more convenient, mostly by reducing unnecessary actions such as manual scanning at the checkout, making the data a lot more reliable and minimizing the stress of making a mistake, which would be difficult to rectify. What is more, all the ways of using

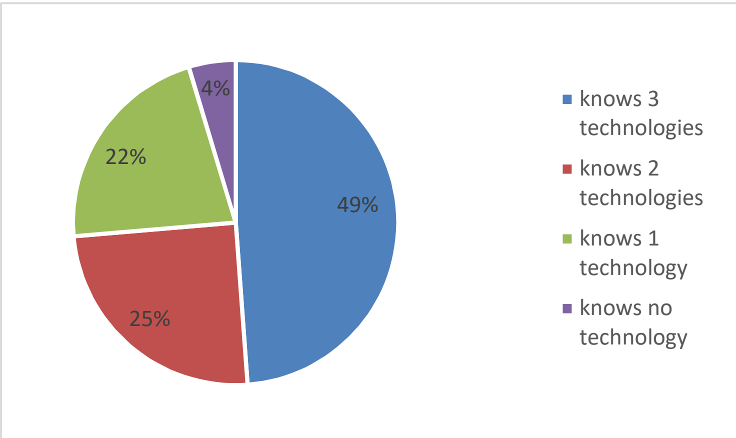
RFID described here seem relatively uncomplicated for staff and customers alike.

Among the other mobile technologies mentioned by respondents are the mobile version of SAP (applicable for tablets), BLIK (used for paying by clients rather than cash) and even mobile versions of the Decathlon website. However, they did not seem significant enough for the Directors in relation to RFID, which can definitely be described as the heart of the Decathlon supply chain.

Nevertheless, both directors noticed the huge power of mobile shopping. They admit that their Polish supply chain is not sufficiently prepared for it, but in other countries, the Decathlon mobile platform manages the number of orders with a high level of consumer satisfaction. Therefore, steps are being taken to live up to other countries and make the Polish supply chain develop by following the market trends.

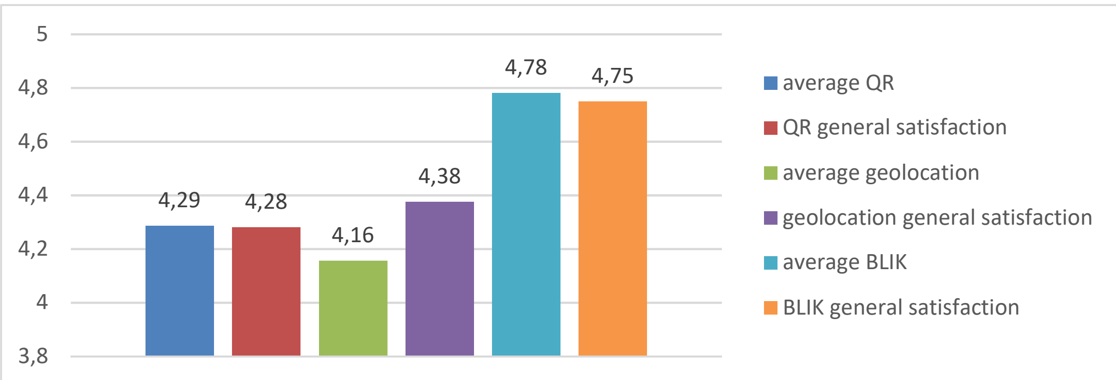
RESEARCH RESULTS – SURVEY

The aim of the second part of this research was to obtain a detailed picture of mobile technology users' satisfaction concerning their use of this solution. As was mentioned before, the group of respondents consisted mostly of customers aged 20-30 (75%), who (thanks to their age, financial abilities and good knowledge of mobile solutions) are believed to know and use mobile technologies most often of all consumers on the market. The survey questions were concentrated on the use of mobile technologies during shopping. In order to make the results comparable with those of the first part, these questions also concerned time, reliability, communication and comfort.



Source: own study

Fig. 4. Consumers' knowledge of mobile technologies



Source: own study

Fig. 5. Mobile technologies estimation

Judging by the results, it may be stated that mobile technologies are quite popular. It appears that almost three quarters of the respondents (74%) know at least two of the technologies chosen for the poll. What is more, only 5% of the respondents do not know any of the technologies they were asked about. A more detailed analysis shows that most respondents know BLIK (almost 90%), which is a rise comparing to previous years.

In the poll, respondents were asked to describe their satisfaction with using each mobile technology, where 1 meant "not satisfactory at all" and 5 stood for "extremely satisfactory". What is important to note is that they were first supposed to give the notes considering each area (including time, reliability, communication and comfort) and then, a second independent note which described their general feelings about each mobile technology. The average results of the poll are presented in Figure 5.

It may be said that, in general, customers have a positive attitude towards mobile technologies and rate them highly. What is more, even though they tend to be tougher when estimating specific areas, their overall satisfaction is rather on the same level or even higher. This means that despite having some points to be upgraded, mobile technologies still serve their purpose. This leads to the conclusion that the question is not whether mobile technologies should be widely implemented or not, it is rather about improving them according to specific consumers' needs and expectations.

CONCLUSIONS

All the observations should make it clear to managers that logistics customer service is about creating a most suitable mix of logistics activities and marketing secrets. Undoubtedly, in the market conditions of the 21st century it is logistics customer service that can either bring new customers or keep old ones from changing the supplier. However, when the whole market goes mobile, it is crucial not to be left behind and that is the reason for implementing mobile technologies. Judging by the research results, these technologies are becoming more and more popular and generate at least satisfactory effects.

Last but not least, it is important to note that human resources, even if in some cases irreplaceable, are also limited and very likely to be a source of mistakes. At this point, technology appears with its 'super power' of being infallible (or at least almost perfect), which makes it possible to obtain more specific data and thus more insightful information about the customers.

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TECHNOLOGIE MOBILNE W OBSŁUDZE LOGISTYCZNEJ KLIENTA JAKO NARZĘDZIE ZWIĘKSZAJĄCE SATYSFAKCJĘ KLIENTÓW

STRESZCZENIE. **Wstęp:** Niezwykle wymagająca i dynamiczna sytuacja na rynku XXI w., podobnie jak pojawiające się trendy takie jak globalizacja, unifikacja produktów czy rozwój e-commerce i m-commerce sprawiają, że przedsiębiorstwom jest trudno konkurować i tym samym prowadzą do wyższego wykorzystania technologii. Podczas gdy oczekiwania konsumentów są znaczne, wszystkie firmy szukają nowych sposobów na odniesienie sukcesu. Dlatego też celem tego artykułu jest prezentacja istotności technologii mobilnych w logistycznej obsłudze klienta i zyskaniu satysfakcji konsumenta, dokonana z perspektywy zarówno dostawcy jak i finalnego klienta.

Metody: W celu uzyskaniu podwójnej perspektywy, badanie obejmowało dwa wywiady z różnymi ogniwami jednego łańcucha dostaw oraz badanie ankietowe. Co ważne, obydwa wywiady miały określoną strukturę, która umożliwiła porównanie sposobu pojmowania istotności technologii mobilnych w logistycznej obsłudze klienta przez każdą z firm. Ankieta została natomiast przeprowadzona pośród przypadkowo wybranych konsumentów w wieku 20-30 lat, których uznano za najczęstszych (ze względu na ich udział w grupie m-konsumentów) użytkowników technologii mobilnych podczas zakupów, co pozwoliło na urealnienie wyników badania.

Wyniki: Otrzymane rezultaty ukazują niezaprzeczalnie efekt synergii uzyskany dzięki świadomemu wykorzystywaniu technologii mobilnych przez każde z ogniw łańcucha dostaw. Co więcej, badanie potwierdziło rosnącą popularność takiego rozwiązania oraz jego wpływ na doskonalenie logistycznej obsługi klienta w obszarze czasu, niezawodności, komunikacji i wygody.

Wnioski: Na podstawie badania można stwierdzić, że wysoki poziom satysfakcji ogólnej konsumentów z technologii mobilnych jest niepodważalnym dowodem ogólnych korzyści z nich płynących. Dlatego też technologie mobilne mogą być kluczem do zyskania lub zatrzymania konsumentów rynku XXI w.

Słowa kluczowe: technologie mobilne, logistyczna obsługa klienta, satysfakcja, omnichanneling

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ORIGINAL PAPER

REMANUFACTURING SUSTAINABILITY INDICATORS: A STUDY ON DIESEL PARTICULATE FILTER

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ABSTRACT. **Background:** Remanufacturing transforms end-of-life products into new products, which brings cost savings for the usage of energy and materials and environmental protection. Sustainability is a significant issue for remanufacturing SMEs trying to stay competitive in the marketplace, while remanufacturing seems to be a promising strategy to explore for increasing the environmental and economic burdens on society. Despite sustainability being a known concept, it very often becomes a purely strategic goal which is not defined at the operational level of business. The major objective of this paper is to determine a set of sustainability indicators for an evaluation of the remanufacturing process, integrating economic, social and environmental aspects of business.

Methods: The literature review method was used to verify current knowledge on remanufacturing sustainability indicators, while the observation method was used to determine the specifics of the remanufacturing process. The brainstorming method aimed to verify the usefulness of existing indicator frameworks and define a set of indicators developed for the assessment of remanufacturing sustainability.

Results: In the presented paper, a set of 11 remanufacturing sustainability indicators was prepared, which were tested on a company in Poland that was remanufacturing a diesel particulate filter.

Conclusions: Although the proposed set of remanufacturing sustainability indicators was defined for a specific company, it may be used as a guideline for comprehensive indicator framework development, regardless of the product type or the size of the company. The main challenge in introducing sustainability at the operational level of remanufacturing in business is enabling multilevel assessments while considering particular sustainability aspects and the company as a whole. This outlines directions for future research.

Key words: remanufacturing, sustainability; indicators, measurement, diesel particulate filter.

INTRODUCTION

This paper draws attention to remanufacturing as a considerable interest in remanufacturing as a research topic has been observed . The above may be confirmed, for example, by an analysis of documents collected in scientific databases including Web of Science or Scopus, where the term remanufacturing has been used as a keyword searched in the publication on many occasions (Fig. 1).

Although the first papers on remanufacturing appeared in the late ‘70s, the vast majority of works were prepared after 2003 and, as a consequence, Fig.1 contains data from 2003-2018. According to Fig. 1, the distribution of papers in both WoS and Scopus databases rose significantly over the period from 2003 to 2018, achieving the maximum value of 201 papers in WoS in 2017, and 205 papers in Scopus in 2018. This may be the result of a sustainable way of thinking, where remanufacturing becomes one of the preferred

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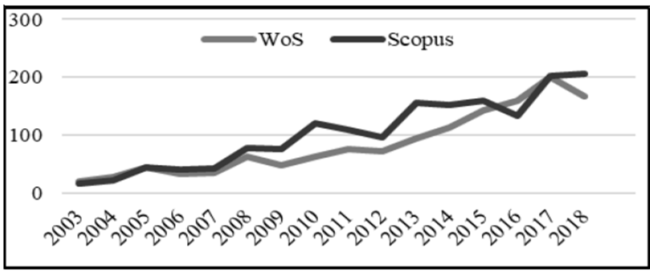
things to do with used products. Despite an overall increase, the number of papers on remanufacturing peaked and troughed several times over the 15 years. Considering the percentage share of papers developed in the last 5 years (around 50%), a linear trend analysis was created for each database, which confirms that the interest rate on the topic of remanufacturing has gone up. In the authors' opinion, this provides the necessary justification for research into remanufacturing, in particular because it has been a relevant issue for Business and Academia.



	WoS	Scopus
Total number of papers	1535	1821
% share of papers (2003-2018)	88,27%	90,72%
First paper publication	1995	1979
% share of papers (last 5 years)	51%	47%
Trend line (last 5 years)	y=16,4x+107,2	y=15,2x+124,8

Source: own work

Fig. 1. Distribution of papers on remanufacturing in WoS and Scopus

Owing to the fact that remanufacturing includes a series of manufacturing steps applied to end-of-life products in order to return them to an as-new condition or at least one of better performance with a warranty [Golińska, Kuebler 2014], it is thought of as a key element of a circular economy [Butzer et al. 2016, Kurilova-Palisaitiene et al. 2018, Jensen et al. 2019], where resource input and output are minimized by closing material loops.

In the literature, there are many examples of remanufacturing benefits, which may be considered in a sustainability context, in particular, economic benefits from material and energy savings, which are related to environmental advantage from emissions and waste avoidance, and social benefits resulting from the creation of jobs and ensuring an accessibility of goods for low-income countries [Fatimah, Aman 2018]. Remanufacturing has often been considered better than manufacturing based on economic and environmental evaluations of these processes (e.g. alternators in [Kim et.al., 2009], turbochargers [Li et al. 2017] and diesel engines [Dias et al. 2013]. In short, following Golińska-Dawson, it was assumed without any further investigation that remanufacturing is sustainable [Golinska-Dawson 2018]. Consequently, the focus of this paper lies in the sustainability of remanufacturing.

Sustainability has not been precisely defined in the literature, thus some problems with sustainability transfer at the operational level of business have been identified [Golinska-Dawson 2018]. Following Golińska and Kuebler, it was claimed that sustainability requirements at the company level may be characterized as a utilization of resources that is economically justified (profitable) and environmentally friendly, while also considering employees' social lives and the surrounding communities (to minimize the influence on them) [Golińska, Kuebler 2014]. Moreover, in order to operationalize the concept of sustainability, it should be measured. Based on the previous experience of researchers of sustainability measurement, it was recommended that several indicators be used. Firstly, these were identified in Agenda 21 as a guideline to measure progress towards achieving sustainability targets to inform decision-makers as well as the public about the current sustainability results. Moreover, indicators allow progress to be tracked over time for important phenomena, as this has been a significant issue for management. Additionally, indicators have been considered as practical tools usable by SMEs, particularly because many remanufacturing companies represent SMEs.

However, many global incentives for measuring sustainability performance with indicators have been identified (e.g. GRI, DJSI, OECD Sustainable Manufacturing Toolkit, etc.) [Golinska-Dawson 2018] that may be adopted by large industries, though some problems have also been acknowledged related to (i) adaptation at the SME level (ii) non-complex considerations of sustainability (e.g. a focus on the environment) and (iii) no adjustment to remanufacturing. Thus, the need to develop a sustainability indicator framework that is applicable, understood and relevant to SMEs has been identified. It must also be adjusted to the economic and political conditions of the country in which the remanufacturing business is being run. Consequently, the major objective of this paper is to determine remanufacturing sustainability indicators. Additionally, the proposed indicators were used to measure the remanufacturing sustainability of a diesel particulate filter remanufacturing company, representing SMEs in Poland. The measurement results have been included in the paper, which was based on the master's thesis of an author of the paper.

This paper is organized as follows. In Section 2, the results of a state-of-the-art analysis on remanufacturing sustainability indicators are included. Section 3 presents the company under study, the remanufactured product and the remanufacturing process of the diesel particulate filter. In the next section, the remanufacturing sustainability indicators used in the company's assessment are discussed. Finally, Section 5 summarizes the limitations of the study and gives an outlook for further research.

REMANUFACTURING SUSTAINABILITY INDICATORS – STATE OF ART

Considering the differences between manufacturing and remanufacturing, it has been stated that there is a need for remanufacturing sustainability indicators, so an in-depth literature review was carried out on remanufacturing sustainability indicators. The conducted search combined the following keywords: „remanufacturing" AND "measurement" OR "assessment" OR "indicators" within the publication title, in the Web of Science and Scopus scientific databases. Articles in English were reviewed, without a time limit, excluding papers on computer science, physics and chemical engineering research. Consequently, the process discovered 35 papers in the Scopus database and 38 papers in the WoS repository. In the second stage of the literature research, the duplicated results were eliminated, reducing the total number of articles to 58. In the final stage, those 58 papers were analyzed by authors of the paper in order to find indicators of remanufacturing sustainability. It is noteworthy that, despite an increasing interest in remanufacturing (Fig. 1), remanufacturing assessment in the context of sustainability is still an undiscovered research topic, as less than 2.5% of all papers on remanufacturing have addressed this particular issue. Moreover, only two papers about sustainability remanufacturing indicators were found and have been analyzed in detail, with the results presented in Table 1.

Table 1. Remanufacturing sustainability indicators available in the literature

Reference	Year	Research methodology	Complexity of sustainability	Indicators number	Requirements for indicators
[Fatimah, Aman, 2018]	2018	Literature review, case study, experts judgments brainstorming	YES	31	Understandability, applicability, relevance
[Golinska – Dawson et.al, 2018]	2018	Literature review, case study, experts interviews	YES	15	Availability of data, comparability, reliability, usefulness, simplicity

Source: own work

With reference to Table 1, only two papers were identified in which remanufacturing sustainability indicators were presented considering all three sustainability pillars without testing them in practice [Fatimah et al. 2018, Golinska-Dawson et al. 2018]. Graham et al. [Graham et al. 2015] proposed a set of 25 indicators for remanufacturing, but they did not address sustainability directly, so this work was excluded from further analysis. The presented references (Table 1) were from 2018, so the topic of remanufacturing sustainability indicators is a new issue for researchers. It was also assumed that in terms of the importance of sustainability in the context of increasing government pressure on the issue, in the coming years sustainability assessments may be obligatory, so an appropriate system of indicators should be determined. Considering the results of the literature review, the authors of the paper made the following conclusions:

C1 – Indicators should be determined with the use of various research methods, considering existing solutions and expert knowledge from remanufacturing businesses and Academia;

C2 – Indicators should meet the following requirements: understandability, applicability, relevance, data availability, simplicity, comparability, reliability;

C3 – The number of indicators should be limited (according to the rule: "less is more", no more than 20 indicators [Golinska-Dawson 2018]);

C4 – Indicators should be suitable for particular remanufacturing businesses in the context of national requirements for sustainability reporting, taking into consideration specific socio-economic conditions.

Taking these conclusions into account, a set of 11 remanufacturing sustainability indicators was determined. These are presented in Section 4.

REMANUFACTURING PROCESS OF DIESEL PARTICULATE FILTER – POLISH CASE STUDY

In this paper, a Polish company remanufacturing diesel particulate filters representing SME, is described. In the subsections below, the following are presented: the company under study, the remanufactured product and the remanufacturing process.

The subject of the conducted research is a remanufacturing company representing the SME sector, with its headquarters in the Greater Poland province, in Poland. It has been on the Polish market since 2008. The main field of the company's business is the maintenance and repair of vehicles, including the servicing and remanufacturing of diesel particulate filters (hereafter: DPF), which has become its core business activity. Its customers are individual vehicle owners from all over the country and abroad, but also business customers such as distributors of Pirelli Eco Technology particulate filters for trucks and buses.

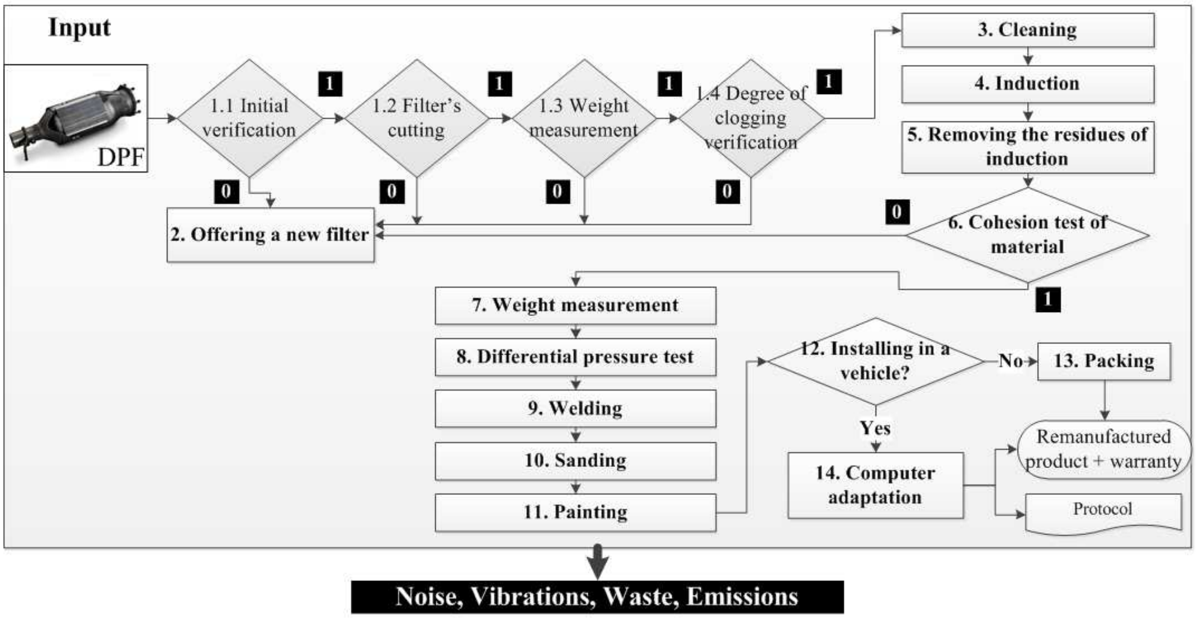
In the company under study, DPFs are remanufactured. In the authors' opinion, this remanufacturing process is particularly relevant considering the environmental context of the product. The DPF is a device that captures and stores exhaust soot to reduce emissions from diesel cars. It should be noticed that DPFs have a finite capacity, so this trapped soot periodically has to be emptied or 'burned off' to bring the filter to an as-new condition. It is noteworthy that only proper remanufacturing in authorized facilities ensures that the correct filters work without polluting the environment. It has been claimed that on the market there have been many companies which do not respect any legal requirements, so they offer products at a low price but only partially remanufactured, not in a sustainable manner.

Remanufacturing is an industrial process in which returned products (cores) are restored to an as-new condition, or at least one of better performance, to be used for at least another lifecycle. This includes the following phases: inspection, cleaning, disassembling, reprocessing, reassembling and testing [Golińska, Kuebler 2014].

It is noteworthy that the steps of the remanufacturing process depend on the product and the company's knowledge and resources, which is related to the company's size. Considering the information from the previous subsections, the remanufacturing process realized by the company under study is mapped and presented in Fig. 2.

The remanufacturing process is started by DFP's delivery (input) as it is a made-to-order process. The customer may deliver a single part or a whole vehicle to have a complex service including the disassembling of parts and the assembling and computer adaptation of remanufactured parts.

In the first stage of the remanufacturing process, the product is verified in a few steps (1.1.-1.4). It is noteworthy that to save resources at particular verification steps, a decision may be made to exclude the product from further stages of the remanufacturing process (where "0" means lack of compliance with requirements and "1", meeting the requirements).



Source: own work

Fig. 2. Remanufacturing process of diesel particulate filter

During the initial verification, cracks and remelting are checked with the use of cameras and light. Secondly, the filter is cut to evaluate the internal product's structure. In the third step, a measurement of the weight of soot and ash is measured. Finally, the degree of clogging in the filter is verified with the use of light and cameras. If during any of the verification steps the requirements are not met, the remanufacturing process ends and the customer is offered a new product.

In the second stage of the remanufacturing process, the filter is cleaned and then an induction process is carried out so the filter is burned in the induction furnace. After that, the residues of induction are removed. In the next step, the final verification of the consistency of the material is done, where post-process cracks are identified. If there is no damage, the remanufacturing process is continued with the following operations: weight measurement, a differential pressure test, welding, sanding and painting. When the customer is interested only in a remanufacturing service, the remanufactured part is packed and given to the customer with a warranty. In the case of a complex service, the DPF is installed in a vehicle with the required computer adaptation, which is done as long as all errors are deleted. A warranty is given on the product and reassembling service.

To sum up, the process output is a remanufactured DPF with a warranty which is as good as a new one. The whole process results in noise, vibration, waste and emissions, which affects people and the planet but also generates a profit for the company's owner and savings for vehicle owners (economic benefit), thus the sustainability context is significant in DPF remanufacturing.

Consequently, it is stated that the remanufacturing sustainability context is essential for this process, thus it should be measured.

REMANUFACTURING SUSTAINABILITY INDICATORS

The objective of this paper was to determine a set of sustainability indicators in the remanufacturing process for SMEs dealing with a diesel particulate filter, to improve the company's competitiveness, as sustainability is perceived to be a critical success factor and a source of competitive advantage.

In order to achieve the major research objective, a brainstorming session was conducted with experts from the company under study and Academia experts (authors of the paper) to verify the usefulness of existing indicator frameworks (Table 1), considering guidelines C1-C4. Finally, a set of 11 remanufacturing sustainability indicators was determined, including all sustainability aspects: economic, social and environmental (Table 2).

Table 2. Remanufacturing sustainability indicators

Class	ID	Name	Description	Type	Range of values	Unit	Reference value	Score	Value
Economic	I1	Remanufacturing quality	Percentage share of products damaged during the remanufacturing process in the total daily sale.	Quan.	0-100	%	100%	100%	5
	I2	Complaints level	Percentage share of complained products in the total monthly sale.	Quan.	0-100	%	≤2,5%	1,4%	5
	I3	Local market share	Percentage market share of remanufactured DPFs in province.	Quan.	0-100	%	≥ 8%	8%	5
	I4	Equipment availability level	The utilization rate of all equipment calculated based on real working time/ available working time.	Quan.	0-100	%	≥ 85%	77%	3
Environment	I5	Energy management	The qualitative indicator describing the approach to energy management in a company on basis of used practices in the assessed company.	Qual.	1-5	-	5	3	3
	I6	Engagement in environmental activity	The qualitative indicator describing engagement in environmental activity on basis of used practices in the assessed company.	Qual.	1-5	-	5	5	4
	I7	Filters recovery rate	Percentage share of filters intended for remanufacturing and remanufactured in the total number of filters delivered to company (per month). Indicator was calculated considering the complex service[1] as well as only remanufacturing[2].	Quan.	0-100	%	≥85%	73,3[1] 78,8[2]	2[1] 3[2]
Social	I8	Engagement in relation with customers	The qualitative indicator describing engagement in relation with customers on basis of used practices in the assessed company.	Qual.	1-10	-	10	10	5
	I9	Employment	The change in employment within two considered periods (e.g. years) considering one of three situations: decrease {-1}, no changes {0} and increase the employment {1}.	Qual..	{-1,0,1}	-	1	1	5
	I10	Engagement in relation with local community	The qualitative indicator describing engagement in relation with local community on basis of used practices in the assessed company.	Qual.	1-5	-	5	5	5
	I11	Safe and healthy	Percentage share of employees' absence days in the total number of working days per month.	Quant.	0-100	%	≤2,5%	7,33%	2

Source: own work

With reference to Table 2, the following were included:

- Four indicators considering the economic aspects of remanufacturing (I1-I4), relating to all economic values associated with the use/utilization/management of resources, energy, labor, technology, methods, waste, and market share of the conducted business;
- Three indicators considering the environmental context of the remanufacturing (I5-I7), which is associated with all environmental consequences caused by the

remanufacturing process, which may both positively and negatively affect people and environmental performance directly and indirectly in different ways. This context of assessment includes all activities undertaken to protect the environment, energy saving and material recovery;

- Four indicators in terms of the social sustainability context (I8-I11). The major social advantages of remanufacturing include jobs creation. However, possible social drawbacks of remanufacturing also need to be considered, including the health and safety of employees and relations with customers, as well as with the local community. Accordingly, the social impact assessment of the proposed indicators considers employees, customers and community.

In the authors' opinion, the indicators proposed in this paper (Table 2) enable a comprehensive assessment of remanufacturing in the context of sustainability, in the company under study. Among the indicators used in the research, 55% were quantitative (hereafter: Quan.) which were calculated with the proper formulas, resulting in a score ranging from 0 to 100%. The reference value defines the aim of a particular phenomenon measured by the indicator. In the research, the reference values were defined by sector experts (e.g. more than 8% was the required value of I3). On the other hand, 45% of the indicators were qualitative (hereafter: Qual.), which were assessed with the use of proper qualitative scales prepared on the basis of brainstorming results, considering the results of the literature review (Table 1) and the experience of the experts. Most of the qualitative indicators were determined with the use of a 5-stage scale with values from 1 to 5, where each level was described with the use of practical solutions adequate for particular indicators. An example of an energy management indicator is presented in Table 3.

Table 3. Energy management indicator

Description of practice	Level of requirements fulfillment	Value
Monitoring the energy costs at the company level.	Very low	1
Taking ad hoc actions for energy consumption reduction (e.g. lighting replacement).	Low	2
Promoting Employees behaviors that are aimed at reducing energy consumption.	Moderate	3
Taking actions for reducing the energy at the equipment level, efforts on renewable energy.	High	4
Using renewable energy sources, implementation of an energy management system.	Very high	5

Source: own work

Considering the information presented in Table 3, it should be noticed that each description of the practice is presented from the perspective of the fulfilment of requirements for a particular indicator, with a value from 1 to 5 or 1 to 10 (for I8). However, most of the qualitative indicators were presented similarly to I5 (Table 3). The I9 indicator was an exception as employment is assessed from the perspective of the situation related to the change in employment rate. Consequently, without changes in employment, the value is "0". If the number of employees decreases, the indicator value is "-1", but if it increases, it is "1", which is the required situation considering the importance of job creation.

Taking into consideration the remanufacturing sustainability indicators, an assessment of the company under study was carried out (Table 2, row: "Score"). Owing to the fact that in the assessment both qualitative and quantitative indicators were used, with various units and values, a relativization was done which resulted in an assessment value within the scale from 1 to 5. The relativized value had to present information about the fulfilment of requirements in the context of particular phenomena measured by the indicator to obtain information about the resulting measurement in the context of requirements for future improvements, according to Table 4.

With reference to Table 4, it was stated that the company under study obtained very positive results in economic and social contexts of sustainability, however, actions to improve the environmental context of company's activity should have been undertaken. Considering all the results, for 55% of indicators it was recommended that their score be monitored as the company got satisfactory results from the assessment. For the following indicators: I4, I5, I6, I7, some actions should have been taken for improvement but only if organizationally and economically possible. The major problem of the company under study was safety and health because the assessment result was unacceptable. Consequently, an immediate requirements were identified for corrective activities to improve indicator values and employees' working conditions. Unfortunately, though the company is able to change the working conditions, unplanned absences e.g. childcare, are out of the company's influence.

Table 4. Assessment of remanufacturing sustainability indicators

Level of requirements fulfilment		Assessment result	Direction for action
descriptive	numeric value		
Very high	5	Satisfactory	Monitoring
High	4	Good	Improvement actions, if possible
Moderate	3	Conditionally acceptable	
Low	2	Unsatisfactory	Corrective actions as soon as possible
Very low	1	Unacceptable	

Source: own work

To sum up, the presented remanufacturing sustainability indicators were considered as a useful tool for decision making in order to verify the sustainability state and to indicate the directions of future actions, and to be more competitive in the marketplace.

CONCLUSIVE REMARKS

In the presented paper, the authors have prepared a set of remanufacturing sustainability indicators which were tested in a company remanufacturing diesel particulate filters in Poland. Consequently, the major research objective was achieved.

As a result of the literature review and the experts' methods, indicators were determined and tested in the company under study, which allowed the indication of directions for future improvement. Two main conclusions were made based on the assessment results. Firstly, the level of complaints from warranty repairs, as very often customers do not follow the guidelines for remanufactured DPF use. Secondly, the low level of recovery rate (I7) is related to a core quality (DPF delivered to the company). It is noteworthy that the company's influence on core quality is limited because it depends on the customer's treatment of the DPF. On the other hand, the company should support customers by planning remanufacturing, starting with regular customers e.g. by sending reminders for DPF remanufacturing, considering the number of miles driven. It was stated that the DPF's quality is essential considering the assessment of the remanufacturing company in the scope of sustainability.

In the presented research, a proposition of indicators was prepared for a specific business in a particular country. In the authors' opinion, it may be used as a guideline for comprehensive indicator framework development, regardless of the product's type or the size of the company. As a consequence, in future research, the authors are going to prepare a set of indicators which will be useful for the sustainability assessment of each remanufacturing process. Moreover, it is also planned to aggregate indicators in order to prepare a procedure enabling multilevel assessment of remanufacturing sustainability, considering a particular sustainability aspect and a company as a whole.

The major direction for the future research is to develop a model for material flow management in the remanufacturing business in order to support decisions at the operational level of business to ensure sustainable remanufacturing.

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WSKAŹNIKI DO OCENY REGENERACJI W KONTEKŚCIE ZRÓWNOWAŻONEGO ROZWOJU NA PRZYKŁADZIE REGENERACJI FILTRA CZĄSTEK STAŁYCH – STUDIUM PRZYPADKU

STRESZCZENIE. Wstęp: Regeneracja pozwala na przywrócenie produktów wycofanych z eksploatacji do ponownego wykorzystania, co bezpośrednio związane jest z oszczędzaniem używanej energii oraz materiałów a także co przyczynia się do ochrony środowiska. Zrównoważony rozwój stanowi kluczowe zagadnienie dla przedsiębiorstw zajmujących się regeneracją, należących do grupy MŚP, gdyż stanowi źródło budowania przewagi konkurencyjnej. Co więcej, regeneracja to scenariusz wtórnego zagospodarowania produktów, który zyskuje na znaczeniu ze względu na wzrost obciążeń środowiskowych oraz ekonomicznych dla ludzi. Pomimo tego, że zrównoważony rozwój to koncepcja powszechnie znana, zazwyczaj jej uwzględnienie ogranicza się do wskazania zrównoważonego rozwoju jako celu strategicznego, pomijając wymiar operacyjny prowadzenia działalności gospodarczej. Celem głównym artykułu było opracowanie zbioru systemu wskaźników służących do ewaluacji procesu regeneracji w kontekście zrównoważonego rozwoju, integrując aspekty: społeczny, ekonomiczny oraz środowiskowy w działalności gospodarczej.
Metody: W pracy wykorzystano metodę analizy literatury celem weryfikacji aktualnego stanu wiedzy w zakresie wskaźników służących do ewaluacji regeneracji w kontekście zrównoważonego rozwoju, podczas gdy metoda obserwacji wykorzystana została do określenia specyfiki procesu regeneracji. Celem weryfikacji użyteczności istniejących rozwiązań w zakresie oceny oraz zdefiniowania systemu wskaźników do oceny regeneracji w aspekcie zrównoważonego rozwoju, wykorzystano metodę burzy mózgów.
Wyniki: W pracy zaprezentowano system 11 wskaźników służących do oceny regeneracji w kontekście zrównoważonego rozwoju, które zostały zweryfikowane w przedsiębiorstwie zajmującym się regeneracją filtrów cząstek stałych w Polsce.
Wnioski: Pomimo tego, że zaproponowany system wskaźników został zdefiniowany dla konkretnego przedsiębiorstwa, to należy go potraktować jako zestaw wytycznych do opracowania kompleksowego systemu pomiaru, niezależnie od wielkości przedsiębiorstwa czy typu regenerowanego produktu. Głównym wyzwaniem w wdrażaniu zrównoważonego rozwoju na poziomie operacyjnym działalności przedsiębiorstwa prowadzącego działalność w zakresie regeneracji, stanowi ocena wielopoziomowa, uwzględniająca poszczególne wymiary oceny zrównoważonego rozwoju oraz przedsiębiorstwo rozpatrywane jako całość, co stanowi kierunek przyszłych badań.

Słowa kluczowe: regeneracja, zrównoważony rozwój, wskaźniki, pomiar, filtr cząstek stałych

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ASSESSING THE EFFECT OF HIGHER EDUCATION SERVICE QUALITY ON JOB SATISFACTION AMONG LECTURERS IN PREMIER POLYTECHNICS USING HEDPERF MODEL

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ABSTRACT. **Background:** Dynamic change has compelled Malaysian Polytechnics to embrace service quality to achieve competitive advantage and sustainability for nation economic development. Current literature in higher education service quality shows that appropriate implementation of HEdPERF in the organization operation will improve the service quality and job satisfaction that subsequently will enhance the organizational performance. Although many studies have explored the relationship between service quality and satisfaction in higher education, the role of service quality as antecedents for employee satisfaction has been poorly discussed in higher education quality management literature.
The aim of this study is to measure the service quality and satisfaction relationship among lecturers at premier Malaysian polytechnics.
Methods: This study employed self-report questionnaires gathered from 187 lecturers at premiere Malaysian polytechnics using HEdPERF (Higher Education Performance) model. Data were analysed using the Statistical Packages for Social Science (SPSS) version 23.
Results: The results revealed that non-academic aspects, academic aspects, programme issue, and access are significant predictors for job satisfaction at Malaysian polytechnics. Conversely, reputation does not play a significant role with satisfaction.
Conclusions: The findings confirm the ability of service provider to correctly execute non-academic, academic, programme issue and access aspects as being important to improve the employee's satisfaction. Only reputation which is insignificant to employee satisfaction is found in the studied organization. Employee and staff should be treated as customers of the organization in view of their criticality for service delivery excellence to achieve organizational vision and mission.

Key words: service quality, job satisfaction, Higher Education Performance (HEdPERF), polytechnics.

INTRODUCTION

Service quality in higher education sector has gained importance due to the social mobility and government agenda for human capital development. Hence, it has attracted attention of scholars and practitioners since the introduction of the concept. Generally, scholars affirm service quality leads to the retention of existing customers and the attraction of new ones, reduced costs, enhanced corporate image, positive word-of-mouth, and ultimately enhanced profitability. Service quality study was dominated by the two western perspectives namely Two-factors Model [Grönroos 1984] and SERVQUAL [Parasuraman, Zeithaml and Berry 1988]. Two-factors Model argue that service quality combines functional, technical and image qualities. On the other hand, Parasuraman et al. [1988] claimed that service quality entails

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responsiveness, assurance, tangibility, empathy and reliability. Both scholars argue that service quality is an elusive concept difficult to evaluate due to its subjective nature, abstract and hard to define because of its complex characteristics.

The conceptualization of service quality is different from goods as the definition of the perceived service quality must be decided by the customers (service recipient) that have always been subjective and kept changing [Parasuraman et al. 1988]. Scholar refer it as comparisons of expectations of service with their perceptions of actual service performance [Grönroos 1984], perception of service performance [Cronin, Taylor 1992], meeting customer's needs and requirements [Lewis and Mitchell 1990]. Service is considered as any activity, benefit or satisfaction that is offered for sale to customer. It is intangible, heterogeneous, inseparable, perishable (cannot be stored) and does not result in the ownership of anything [Parasuraman et al. 1988]. Its production may or may not be tied to a physical product. In short, the main idea of service quality is to focus on meeting the customer's needs and requirements to meet their satisfaction. If the firm can fulfil the customer's needs and requirements, the customer will feel that the service quality is high. Conversely, if the firm fails to fulfil the needs, the service is considered as poor quality. Hence, it becomes necessary to explore the factors that affect service quality and customer's satisfaction as perceived by customers or other stakeholders to satisfy their needs.

Previous studies in service quality have shown that service quality implementation is able to increase the standard of service delivery and customer's satisfaction (internal and external) that subsequently will enhance organization performance [Trivellas, Santouridis 2016] . An in-depth investigation of literature related to organizational management suggests that, an exceptional and well-planned quality agenda is difficult to execute if organization fails to understand customer's requirement effectively in the higher education sector. The needs and wants of customers (internal and external) are critical and they need to be constantly reviewed and integrated into organizational operations processes. Therefore, customers' needs and wants must be given due attention and fulfilled to ensure their satisfaction.

Although the relationship between service quality and customer's satisfaction is a well research area, the role of service quality as antecedents for employee satisfaction is poorly discussed in higher education quality management literature [Trivellas, Santouridis 2016]. Quality management researchers found that this situation has been due to the following reasons: First, previous studies have given more attention regarding the differences of definition, purpose, dimensions and importance of service quality [Gupta, Kaushik 2017]. Secondly, many studies used simple correlation analysis methods to assess the relationship between the perception of customers with service quality and relationship between the service quality and customer's attitude [Mokhtar, Husain 2015]. Thirdly, the practice of measuring higher education service quality by employing generic model (SERVQUAL) has ignored the context specific to the education service environment [Ushantha, Kumara 2016]. Consequently, previous studies only produced general recommendation insufficient for organization to understand the complex nature of service quality to design the systematic continuous improvement plan to achieve customer satisfaction and meet organization goals. Thus, this may be the reasons why clear answer regarding what dimensions form comprehensive model of service quality to achieve satisfaction in higher education is still being disputed.

In Malaysia, higher education is one of critical areas in Malaysia Service Sector Blueprint. Therefore, higher education service quality measurement and management is important for economy sustainability and national targets achievement. This pushes higher education to be more accountable for their service quality and responsive to customer's needs, and subsequently forcing HEIs to find ways for more efficient, effective and customer-centric. However, public HEIs in Malaysia received many complaints from customer showing the incapability of their service performance. In service organization, the service employees play a vital role for service efficiency, effectiveness and deliver service to external customer of the firm. Conversely, majority of the previous studies in higher education quality management has given attention towards student's satisfaction as a customer and ignore the employee's perception as the main driver of service quality excellence in organization. Although the study is important, the role of service quality as a critical determinant of employee's satisfaction especially in Malaysian polytechnics has been neglected. The satisfied employee is a productive employee who is committed to carry out duties and responsibilities to fulfil external customer's needs and wants, that subsequently will help to achieve the organization vision and mission. Therefore, this situation inspires the researcher to fill the gaps in the existing literature by assessing the effect of service quality on employee's attitudes. This study is designed to evaluate the relationship between HEdPERF dimensions and satisfaction. In this article, the scope of the discussion will be touched on six important aspects, namely literature review, methodology, result, discussions and conclusions and recommendations.

LITERATURE REVIEW

Service quality

Parasuraman et al. [1988] proposed SERVQUAL as five factors service quality to measure service quality that is widely accepted in service setting including higher education. However, SERVQUAL received much debate regarding the validity and reliability of the model to measure high contact service setting such as higher education [Silva et al. 2017]. Furthermore, current development in higher education service quality management study suggested the employment of industry specific measurement model to investigate service quality in higher education [Silva et al. 2017] for more understanding and meaningful findings.

Abdullah [2005] proposed HEdPERF (Higher Education Performance), a more complete measurement model [Ushantha, Kumara 2016] to assess the service quality in higher education sector which entails five critical elements namely non-academic aspects, academic aspects, programme issue, reputation and access [Ushantha and Kumara 2016]. Most of the results of the organizational quality management published recently revealed that the ability of higher education organizations to implement HEdPERF accordingly in the course of daily work activities can increase customer's satisfaction towards the organization [Silva et al. 2017]. HEdPERF has been empirically tested for unidimensionality, reliability and validity using both exploratory and confirmatory factor analysis and found to be better model than SERVQUAL and SERVPERF [Brochado 2009]. HEdPERF scale is more comprehensive that is able to capture the authentic determinants of service quality within higher education sector [Ali et al. 2016] and the findings demonstrate an apparent superiority of the factors of HEdPERF scale. HEdPERF encompasses all the aspects of the total service environment [Brochado 2009] in education setting. This element has been used as an important indicator for measuring the achievement of service quality in educational organizations.

Numerous recent studies using HEdPERF to investigate service quality in higher education such as Brochado [2009] that studied 360 students in Portuguese university and found the suitability of the model to measure higher education setting. Ali et al. [2016] investigated service quality among 241 international students at three public Malaysian university campuses in Kuala Lumpur. Their findings displayed that all HEdPERF dimensions influenced student's satisfaction, institutional image and student's loyalty. Mang'unyi and Govender [2017] found that the HEdPERF model can enable higher education managers to identify aspects by which students gauge the quality of the service. Shukla, Gadhavi and Patel [2018] have their finding showing HEdPERF having positive impact on behavioural intentions among customers in higher education in India.

Customer Satisfaction in Higher Education

The concept of which customer group defines quality has still received much debate. It is well understood that customer is the key party interested in higher education that is being served. Often HEIs are confused and face problems in identifying key customer groups and paying close attention to their needs. Firms often use the customer satisfaction index as an indicator for determining the level of quality of services provided [Ali et al. 2016]. Sahney et al. [2004] reported customer in HEIs can be grouped as internal and external customers. According to a well-known quality management scholar in the higher education sector, employees are internal customers and students are external customers [Kanji and Tambi 1999; Sahney et al. 2004]. The quality of service delivered by internal customers (employee) determines the external customer's (student) satisfaction [Hogreve, Iseke, Derfuss and Eller 2017]. Key obstacle relating to service quality performance achievements are mainly related to human resource factors [Abdullah, Abdul Razak, Hanafi and Jaafar 2013]. Employee makes quality happen as well as they can avoid failure to ensure performance sustainability.

In service quality implementation, internal customer focus is critical to service performance and sustainability driven by employee as customer to organization. The implementation of service quality enables organization to fulfil the need and want of the employee as a customer. Management should engage their employees in designing an effective system and shares the achievement. Management can determine the needs and wants of the employee, create role clarity (reduce role conflict and role ambiguity), produce complete materials or knowledge for employee to execute his or her job sufficiently, reduce stress and create procedures for smooth daily operation that sustains improvements. Thus, this may generate conducive working environment for employees that ultimately create employee's satisfaction with their job and organization. In this context, satisfaction is defined as an evaluation of the overall experience with the organization that involves pay, promotion, co-worker, work and supervision [Yee, Yeung, Cheng 2008]. A satisfied employee is productive, committed and pays attention to the efforts of organizational improvement and is willing to jointly achieve the organization's goals [Makhbul, Hasun 2003]. In contrast, a dissatisfied employee tends to sabotage and spread negative stories about the organization to other workers to hate the organization [Talib, Ali 2007]. However, in view of the critical and importance of employee's satisfaction, majority of previous studies have given attention to students and ignored the perspective of employee as internal customer of the organization.

Numerous studies have shown that satisfaction is an important outcome of service quality such as in Weerasinghe and Fernando [2018] with 650 respondents from Sri Lanka, Silvestri, Aquilani and Ruggieri [2017] with 350 tourists of a spa resort as well as Keong, Baharun and Abdul Wahid [2018] involved 329 students from Malaysian public universities. Based on the literature reviewed, Figure 1 shows the theoretical framework for this study.

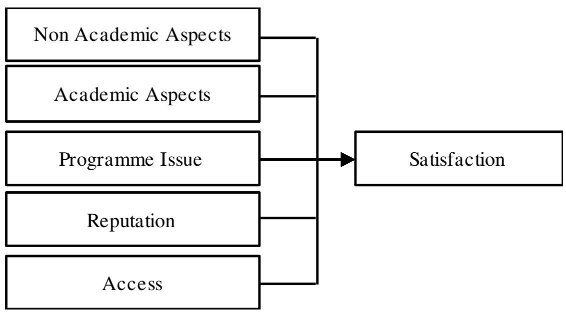

Fig. 1. The theoretical framework for this research

Based on the framework, the hypotheses proposed are as follows:

H1: Non-academic aspects positively affect Satisfaction.
H2: Academic aspect positively affects Satisfaction.
H3: Programme issue positively affects Satisfaction.
H4: Reputation positively affects Satisfaction.
H5: Access positively affects Satisfaction.

METHODOLOGY

This research is a cross-sectional study that has enabled data collection within stipulated time and reduced the dropout and biased data. Data were collected through a set of questionnaires administered by the researcher. The first step in the data collection procedure was to develop a questionnaire from the service quality literature review. This study measures the level of lecturers' satisfaction serving at three premier polytechnics using purposive sampling. The premier polytechnic is a polytechnic that of same level with university in terms of management excellence, administration, student affairs, academic and it is an icon to the entire polytechnic system. Lecturer is an internal customer of the institution. The sample selection strategy at premier polytechnics has at least served for two years to ensure that respondents have sufficient experience and knowledge regarding the polytechnic system so that the responses are accurate and fair, regarding the implementation of the quality programmes in the institution.

Measures

The questionnaire consists of three sections. The first part is the set of questions to measure the service quality construct of higher education services in polytechnics namely non-academic aspects, academic aspects, program issues, reputation, and access. Items questionnaire of non-academic aspects, academic aspects, program issues, access and reputation are adapted from Ali et al. [2016] and Abdullah [2005]. Non-academic factor includes variables that linked to management's ability that relates to duties and responsibilities carried out by non-academic staff. Academic aspects represent the responsibilities of academics, and it highlights key attributes such as having positive attitude, good communication skill, allowing sufficient consultation, and being able to provide regular feedback. Program issue factor emphasizes the importance of offering wide ranging and reputable academic programmes/ specializations with flexible structure and syllabus. Reputation refers to graduate employability, and excellent place to live and study. Finally, access relates to issues such as approachability, ease of contact, availability and convenience including convincing website or on-line services.

The second part measured the satisfaction using Job Descriptive Index by Smith, Kendall, and Hulin [1969] that has been widely used for assessment of all aspects of job satisfaction. Items of satisfaction was adopted from a study by Yee et al. [2008]. It covers five facets namely pay, promotion, co-worker, work and supervision. The third part included the respondent demographic information. Demographic characteristics of respondents were only used as control variables as this study focuses on lecturer's behaviour.

The validity process was carried out and a questionnaire was reviewed by two academic experts in service quality management and four lecturers in the study setting. Question items have been checked face-to-face. This method was in line with the recommendations Hunt, Sparkman and Wilcox [1982]. After the improvement, the number of questions on non-academic aspects were ten, academic aspects were eight questions, program issues were six questions, access had nine items, reputation was four questions, and satisfaction was five questions. All questions were measured using the five-point Likert scale starting from Strongly Disagree (1) to Strongly Agree (5). From 300 questionnaires distributed at the research setting, 187 (62.3%) completed and fit for further analysis. All feedback provided was undisclosed and solely for research purposes.

Data Analysis

The Statistical Software for Social Science (SPSS) version 23 has been used to analyze the research data according to the recommended procedures Hair, Hult, Ringle and Sarstedt [2017]. The data were analyzed using four steps. First, performing the confirmatory factor analysis to assess the validity and reliability of the questionnaire. Second, construct analysis was executed to determine the construct rate according to the respondents' perceptions, and to assess the data collinearity. Third, study hypothesis was tested using linear regression analysis. Significant hypotheses were determined using value of beta (β-Value) and t-statistic (t-Value) at $p < 0.05$, $p < 0.01$, or $p < 0.001$. Fourth, overall strength of the model will be based on R2 Value. The degree of model strength was determined based on the following criteria: 0.02 (weak), 0.13 (simple) and 0.26 (strong) (Cohen, 1988).

RESULT

Table 1 shows the demographic profile of the respondents. As the education area was considered a female dominated sector, it was found that the biggest number of respondents were female (61%) and majority respondents aged between 31 and 40 years (54.0%). With regards to working experience with current polytechnic, more than half of the respondents had 11 to 20 years of experience (54%) and majority of staff hold Master's degree (60.4%). Finally, the respondents from academic department were 93.6% and non-academic were 6.4%.

Table 1. Respondent's background (n=187)

Respondent's characteristics	Category	Frequency	Percentage (%)
Gender	Male	73	39.0
	Female	114	61.0
Age	20 -30	8	4.3
	31- 40	101	54.0
	41- 50	59	31.6
	51 and above	19	10.2
Working experience	Less than 10	64	34.2
	11- 20	101	54.0
	21 - 30	19	10.2
	31 and above	3	1.6
Education	Diploma	5	2.7
	Bachelor Degree	54	28.9
	Masters	113	60.4
	PhD	15	8.0
Department	Academic	175	93.6
	Non-academic	12	6.4

Table 2 shows the results of the reliability and validity analysis of instruments based on the procedure recommended by Hair et al. (2017). Confirmatory factor analysis were conducted on 42 items representing six constructs, namely non-academic aspects (10 items), academic aspects (8 items), programme issue (6 items), access (6 items), reputation (4 items) and satisfaction (5 items). The results from factor analysis found that all items representing each construct had factor loading greater than 0.40, indicating that all items reached the level of item validity (Hair et al., 2017). Furthermore, the Kaiser Mayer-Olkin (KMO) test was conducted to determine the suitability size of the sample study. The results showed that all the constructs had value higher than 0.60 and Bartlett's test of sphericity value was significant, suggesting that the sample of this study was sufficient to be used in the hypothesis testing [Hair et al. 2017]. All constructs have an eigenvalue of more than 1.0 with a percentage of variance explained were more than 45 percent, indicating that all constructs reached the specified level of validity (Hair et al., 2017). The Cronbach alpha value for each construct has a value greater than 0.70, indicating that all constructs reached a high level of reliability (Hair et al., 2017). Overall, the results of this statistical analysis confirmed that this study instrument was valid and highly reliable.

Table 2. Findings on reliability and validity test

Construct	Item	Factor loading	KMO	Bartlett test of sphericity	Eigen value	Variance Explained (%)	Cronbach Alpha
Non-academic aspects	10	0.733-0.841	0.889	χ^2=1484.379, p < 0.001	6.382	63.818	0.936
Academic aspects	8	0.796-0.892	0.916	χ2=1290.720, p < 0.001	5.824	72.802	0.946
Programme Issue	6	0.689-0.928	0.920	χ2=898.152, p < 0.001	4.444	74.060	0.918
Access	9	0.783-0.884	0.939	χ2=1415.241, p < 0.001	6.422	71.356	0.948
Reputation	4	0.838-0.935	0.805	χ2=617.872, p < 0.001	3.256	81.398	0.922
Satisfaction	5	0.829-0.891	0.836	χ2=686.242, p < 0.001	3.739	74.784	0.913

Table 3 shows the results of the descriptive statistics and Pearson correlation analysis. The mean value of each construct ranged from 3.629 to 4.097, meaning non-academic aspects, academic aspects, programme issue, access, reputation and satisfaction levels were between neutral (3) and agree (4) levels. Correlation coefficients for relationships between independent variables (non-academic aspects, academic aspects, programme issue, access, reputation) have a value of less than 0.90, meaning that the constructs of this study were free from serious multicollinearity issues (Hair et al. 2017).

Table 3. Result of descriptive statistics and Pearson correlation analysis

Construct	Mean	Std. Dev.	Pearson correlation analysis					
			Non-academic aspects	Academic aspects	Programme Issue	Access	Reputation	Satisfaction
Non-academic aspects	3.714	0.657	1					
Academic aspects	4.097	0.608	0.680**	1				
Programme Issue	3.884	0.740	0.640**	0.755**	1			
Access	3.910	0.679	0.740**	0.795**	0.828**	1		
Reputation	4.012	0.763	0.530**	0.674**	0.774**	0.740**	1	
Satisfaction	3.629	0.883	0.641**	0.564**	0.701**	0.722**	0.576**	1

**Note: significant at p<0.01 level

Table 4 shows the results of hypothesis testing H1, H2, H3, H4 and H5. Variance inflation factor (VIF) of each independent variable of non-academic aspects (2.350), academic aspects (3.142), programme issue (4.110), access (4.971) and reputation (2.764) were smaller than 10.0 (Hair et al., 2017); meaning that the construct was free from multicollinearity problems. Meanwhile, the input of non-academic aspects, academic aspects, programme issue, access, reputation into the analysis has contributed 58.8% changes in satisfaction. This contribution level illustrates that the model of this study is strong (Cohen 1988). Hence, the results of hypothesis testing produced four important findings. First, academic aspects have a significant relationship with work satisfaction (β= -0.186; p <0.05), hence H1 is supported. Second, the non-academic aspects have a significant relationship with work satisfaction (β= 0.254; p <0.05), hence H2 is supported. Thirdly, programme issue has a significant relationship with work satisfaction (β= 0.359; p <0.05), hence H3 is supported.

However, it was found that reputation does not have a significant relationship with work satisfaction (β = 0.010; p <0.05), hence H4 is rejected. Lastly, findings from regression analysis shows that access has a significant relationship with work satisfaction (β = 0.377; p <0.05), hence H5 is supported. This finding explains that non-academics aspects, academic aspects, programme issue and access have significant impact towards work satisfaction. It was also found that access has the largest contribution among others (β = 0.377).

Table 4. Regression analysis result

Independent variable	Dependent variable (Satisfaction)	
	β value	t-value
Non-academic aspects	0.254**	3.466
Academic aspects	-0.186**	-2.201
Programme Issue	0.359***	3.709
Access	0.377***	3.547
Reputation	0.010	0.131
R square	0.588	
Adjusted R square	0.576	
F	51.617***	

Notes: Significant at **p < 0.05; ***p<0.001

DISCUSSION

The findings confirm that non-academic aspects, academic aspects, programme issue, and access are effective higher education service quality practices to help increase employee's satisfaction. Conversely, reputation is a service quality dimension that is not capable to improve employee's satisfaction.

The result revealed that reputation has no significant relationship with satisfaction among the lecturers in premier Malaysian polytechnic. The results of this study are probably due to Malaysian polytechnic is a public HEIs and employees are considered as government servants. As a government servant, reputation is not important because it did not contribute to any needs and wants related to job benefit, welfare and recognition. The recruitment of employees in polytechnic was conducted under Education Service Commission of Malaysia via on-line system. The recruited employees are then deployed to polytechnics throughout Malaysia. The deployment was based on the lecturer's expertise and polytechnic niche area. This process is assisted by Department of Polytechnics Education and Community Colleges as a centralized coordinating body that governed polytechnic system. The lecturers do not select the polytechnic based on the reputation of the institutions. Likewise, in-service lecturer can be transferred to other polytechnics depending on strategic planning of polytechnics system, institution's needs, and government requirements that affect the polytechnics operation.

Another finding from this study was academic dimension has negative significant relationship with satisfaction. As concurred by some scholars that quality initiatives tend to generate unhealthy working environment such as increase the workload and limit the academic freedom that subsequently increased stress, insecurity and dissatisfaction among lecturer [Van Kemenade, Pupius and Hardjono 2008]. A study among 1,500 teachers in the Netherlands higher education found that quality initiatives create more stress and workload and are always facing employee rejection [Van Kemenade et al. 2008]. Quality is external control that needs lecturer to comply with bureaucratic and documentation procedures. Lecturers are highly-educated people that require continuous improvement, creativity and innovation which are internally driven and prefer autonomy in their work situation [Van Kemenade et al. 2008]. They do not want to be controlled through tight procedure that limits their creativity and innovation in the classroom while delivering their lectures. Thus, quality initiatives implementation is always seen as standard and static measures that limit the academic endeavors, hence, this leads to stress and dissatisfaction among lecturers. To move forwards, organizations should not only improve quality of product or service, but also the quality of employees' work life.

This study is able to show the main characteristics of the higher education system which has to be handled for quality excellence implementation, also provided an insight into the application of quality and the benefits it can bring to employees in terms of satisfaction and welfare. This finding is also in line with the previous study, revealing that implementation of quality with more focus to hard factors such as structure, procedure, documentation; thus, ignoring the soft factors may affect the satisfaction of human in the system [Van Kemenade et al. 2008].

The findings of this study can implicate three important aspects, namely, contribution to theory, contribution to methodology and contribution to management. In terms of contribution to theory, this study has increased our understanding that the implementation of non-academic aspects, academic aspects, programme issue, and access are effective higher education service quality practices to help increase employee's satisfaction. Conversely, reputation cannot increase employee's satisfaction. For the contribution to the methodology, the questionnaires used in this study have reached the level of validity and reliability. Therefore, this situation can help to produce accurate and credible research findings.

Furthermore, this study can help the management to improve the quality management of the organization. To ensure the success of this agenda, the top management should focus on the following aspects; first, management must keep engaging the employees and give attention to fulfil the needs and wants of the employees. It should be done thoroughly covering every layer of workers in the organization. This exercise will get employee buy-in and shape a new way of thinking as well as in the long run that will generate an excellent service quality culture. Secondly, management need to amend the client charter and quality policy to include employee as customer of the organization. Website survey conducted by the researcher on client charter and quality policy shows that none of the premier polytechnics include employee as customer in these important documents. Thirdly, organization needs to conduct survey to collect needs and wants of the employee and integrate it in the organization policy. Employees must be engaged, so that they can provide practical and effective suggestions for improvement and service quality in relation to non-academic aspects, academic aspects, programme issue, reputation and access. Employees are a critical element because quality services in HEIs are determined by the employees who deliver the services. Fourthly, organization must invest in training program and the improvement of workplace competencies that focus on skills, knowledge and attitudes relating to academic quality implementation in polytechnics. Finally, organizations need to conduct employee's satisfaction assessment and consistently improve services in line with the changing needs of work situation and the environment.

CONCLUSION AND RECOMMENDATION

This study examines service quality hypotheses to predict its effect on employee satisfaction. The research utilised HEdPERF instrument that also shows high level of validity and reliability through factor analysis. Furthermore, the findings confirm that non-academic, academic, programme issue, and access are important to improve the employee's satisfaction. Only reputation is insignificant to employee's satisfaction. Factors that do not contribute to dependent variables are given explanation. Accordingly, future studies should look into account non-academic, academic, programme issue, reputation and access as important dimensions in the field of organizational service quality. In conclusion, this study attempts to assist organizations to focus on the critical aspects that need to be addressed by the management and appropriate planning of the organizational level. Employees and staff should be treated as customer of the organization in view of their criticality for service delivery excellence.

This study employed HEdPERF dimension to test the relationship between service quality and satisfaction at premier Malaysian polytechnics. As shown in the findings, non-academic aspects, academic aspects, programme issue, access have significant relationship with satisfaction among lecturers at premier Malaysian polytechnics. Only reputation has no significant relationship with satisfaction. Future research should replicate the study to different contexts to assess the quality satisfaction for more solid results. Future studies also should analyse the relationship of quality programme towards work stress among lecturers in polytechnics. This factor may further explain the low-level satisfaction that may decrease the organizational effectiveness.

This present study is a cross-sectional study and data were collected only at a certain period of time. Meanwhile, the data were collected only in premier polytechnics, which did not involve other types of polytechnics such as conventional polytechnic. Finally, the generalizability of finding must be conducted with care due to sample limitation. Future studies can be further reinforced based on the following recommendations; first, future study is suggested to cover the broader context of education services including community colleges and private HEIs. The broader perspective will increase the understanding of the attitude and behaviour of different employees on the quality of services provided by the organization. Finally, it can be crucial to conduct longitudinal study design to see patent changes and the influence of the relationship between service quality constructs and satisfaction in view of quality programme implementation.

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OKREŚLENIE WPŁYWU JAKOŚCI USŁUG WYŻSZEGO SZKOLNICTWA NA ZADOWOLENIE Z PRACY U WYKŁADOWCÓW UCZELNI PRZY UŻYCIU MODELU HEDPERF

STRESZCZENIE. **Wstęp:** Dynamiczna zmiana wymusiła na Politechnice Malezyjskiej skupienie się na jakości usług w celu osiągnięcia przewagi konkurencyjnej oraz rozwoju zrównoważonego ekonomii kraju. Przegląd literatury naukowej dotyczącej jakości usług w szkolnictwie wyższym wskazuje, że prawidłowego wdrożenie modelu HEdPERF w działaniach operacyjnych zwiększa jakość usług oraz zadowolenie z pracy, co z kolei zwiększa efektywność organizacyjną. Aczkolwiek wiele pracy dotyczy zależności pomiędzy jakością usług a satysfakcją w szkolnictwie wyższym, to rola jakości usług jako czynnik wpływający na satysfakcję pracowników szkolnictwa wyższego nie jest należycie zbadana.
Celem tej pracy jest zmierzenie zależności pomiędzy jakością usług a satysfakcją z pracy wśród wykładowców w najważniejszej Politechnice Malezyjskiej.
Metody: Dane do analizy zebrano poprzez przeprowadzenie ankiety wśród 187 wykładowców w najważniejszej Politechnice Malezyjskiej, przy zastosowaniu modelu HEdPERF (Higher Education Performance). Następnie dane poddano obróbce statystycznej przy pomocy Statistical Packages for Social Science (SPSS) version 23.
Wyniki: Otrzymane wyniki wskazują na istnienie wpływu na zadowolenie z pracy pracowników Politechniki Malezyjskiej takich czynników jak aspekty pozaakademickie, aspekty akademickie, realizowany program oraz istniejący dostęp. Z drugiej strony, reputacja nie ma istotnego wpływu na satysfakcję z pracy.
Wnioski: Otrzymane wyniki potwierdzają istnienie czynników wpływających istotnie na zadowolenie z pracy zatrudnionych, takich jak aspekty pozaakademickie, aspekty akademickie, realizowany program oraz istniejący dostęp. W badanej organizacji tylko jej reputacja nie wpływała na zadowolenie pracowników. Pracownicy oraz pracodawcy powinni traktowani jako klienci organizacji, gdyż mają istotny wpływ na jakość oferowanych usług i związane z tym osiągnięcie wizji i misji organizacji.

Słowa kluczowe: jakość usług, satysfakcja z pracy, Higher Education Performance (HEdPERF), politechnika.

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ORIGINAL PAPER

SELECTED APPLICATIONS OF METAL NANOPARTICLES IN MEDICINE AND PHARMACOLOGY

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ABSTRACT. **Background**: Nanotechnology is a field of science and technology that has been developing rapidly for several decades. It is considered to be one of the major activity areas of the scientific, technological and innovation sectors. The use of innovative technologies enables the modification and production of nanomaterials with new or enhanced properties. Metal nanoparticles are different from their bulk counterparts, and they have become the subject of growing attention due to their unique characteristics caused by their different size as well as their potential applications.
Methods: As a result, they are used in many different areas of life. This work presents the most important examples of metal nanoparticle applications in pharmacology, cancer therapy and stomatology.
Results and conclusion: Nanotechnology makes it possible to quickly transform the results of basic research into successful innovations, and develop leading technologies whose results can be implemented in large international groups of companies and small businesses in all sectors of the economy. As such actions require a properly functioning supply chain, the development and implementation of nanotechnology products will not reach the appropriate level without the proper logistics.

Key words: metal nanoparticles, medicine, pharmacology, cancer therapy.

DEFINITION OF METAL NANOPARTICLES

A nanometer is equal to one billionth of a meter. Nanomaterials are a group of structures in which at least one dimension falls within the range of 1 to 100 nm [Olawoyin 2018]. One of the interesting issues in the field of nanotechnology is metal nanoparticles. Depending on their origin and chemical composition, there are natural nanoparticles, nanoparticles obtained as a result of human activity, as well as unintentional nanoparticles defined as by-products of nanotechnological processes [Kargozar, Mozafari 2018].

In general, nanoparticles are divided into three main groups: one-dimensional, two-dimensional and three-dimensional. Nanoparticle structure can be characterized by a random arrangement of atoms. Nanoparticles with an ordered structure are single crystals or crystal clusters. Some nanoparticles are incorporated in the structure of other metals. A 1D, 2D or 3D nanoparticle has a specific orientation towards the surrounding metal [Kelsall 2009]. The most common 3D nanostructures are nanoparticles whose cross-section does not exceed the length of 100 nm at any point. They may differ in shape but in most cases, they are spherical or oval. 3D structures also include dendritic structures, nanocones, nanoposts and nanoflowers. If the length of all three sides, e.g. of a hexahedron, is several nm, such a system becomes a zero-dimensional system [0D], often called a "quantum dot". The distribution of density of states is no longer continuous and it consists of a number of energy levels [as in the case of atoms or molecules] that correspond to the

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successive quantum numbers and gradually higher energies.

Quantum dots are nanostructural semiconductor systems that consist of atoms 12–16 and 13–15 of the periodic table. Single dots are made of a core that consists of 100–100000 atoms, mainly cadmium telluride or selenide with semiconductor properties. The core is surrounded by a protective layer of zinc sulfide, to which various ligands may be attached, such as nucleic acids, proteins and antibodies that show affinity for specific structures in the organism [Rzeszutek et al. 2014]. The photoluminescence of quantum dots depends on their size, so it is relatively easy to obtain dots that emit electromagnetic radiation with different wavelengths [Dwiecki et al. 2014]. They are also characterized by relatively narrow photoluminescence emission bands, a high quantum capacity, and a long life of fluorescence and stability [Galian and de la Guardia, 2009]. Polymer dots are cross-linked or aggregated with a polymer produced from a monomer or a linear polymer. This kind of dots is created as a result of an aggregation of the carbon core with polymer chains [Zhang et al. 2011; Gao et al., 2013].

Nanoparticles are characterized by a great chemical diversity. The majority of them are metal oxides, metals, silicone compounds, varieties of carbon or ceramic materials. They can also have significantly different shapes. Monometallic nanoparticles have the form of hexahedrons, tetrahedrons, octahedrons, truncated octahedrons, icosahedrons, concave hexahedrons, rods, spheres, whiskers, rice grains and even stars. Their usable forms include powders, suspensions, solutions and gels [colloids].

Due to their size, metal nanoparticles have different properties than larger particles made of the same material. They also show various levels of order throughout the volume of the material they form. They can form ordered crystal structures, amorphous bodies or vitreous bodies composed of unorganized atoms. Nanoparticles with a crystal structure can be single crystals, or they can be composed of randomly arranged crystals or grains, which influence the physical properties of the material [Suwanboon, Chukamnerd 2007].

METAL NANOPARTICLES IN PHARMACOLOGY

As microorganisms quickly become immune to antibiotics, many scientists are looking for new antibacterial substances. It is also more difficult to fight various kinds of viruses. A combination of medicines and nanoparticles has proven to be an effective way to address the most resistant viruses and bacteria. Studies carried out by Shahverdi [2007] showed that the combination of nanosilver with antibiotics intensifies the effects of antibacterial medicines, such as amoxicillin, erythromycin, clindamycin, penicillin G and vancomycin. The results obtained by Suganya et al. [2015] suggest that nanosilver may be the key element in treating AIDS patients. The authors tested the antibacterial effects of biologically synthesized silver nanoparticles against strains obtained from patients infected with HIV. The nanosilver was synthesized with the use of spirulina. The studies showed that silver nanoparticles effectively inhibited the replication of HIV-1. The combination of spirulina and nanosilver turned out to be even more effective against the virus.

Nanosilver is also used as an antibacterial agent in the production of bandages, dressings and surgical masks. A nanosilver coating on prostheses and medical equipment ensures long antibacterial activity due to the slow release of silver ions [Darouiche et al.1990, Leaper 2006].

Copper oxide nanoparticles actively combat hospital-acquired infections as well as the influenza A virus and SARS virus [Ren et al., 2009]. TiO_2 nanoparticles, thanks to their photocatalytic properties, can be found in preparations for disinfecting surgical instruments, catheters or surfaces made of transparent materials. TiO_2 nanoparticles used with nanofillers exhibited bactericidal effects on Escherichia coli and fungicidal effects on Candida albicans [Kosmala and Szymańska 2016] after incubation in visible light for 24 hours. Due to their physico-chemical properties, TiO_2 nanoparticles are applied in dermatology in order to treat such conditions as juvenile acne or atopic dermatitis [Świdwińska-Gajewska, Czerczak 2014].

Nanoparticles are more and more often used as systems that transport various kinds of active substances to specific body tissues. Nanoparticles improve the pharmacodynamic and pharmacokinetic parameters of medicines, such as bioavailability and time of release of the active substance, and they extend the period of pharmacological activity. Their small size allows nanoparticles to efficiently move within the body, and make it more difficult for the immune system to detect the medicines. Over the past few years, more attention has been paid to the nanoscale systems for administering medicines, mainly due to their excellent biocompatibility, the ability to reach a specific place in the body, as well as their nanosize [Zhou et al. 2005]. The large surface facilitates the binding of ligands that recognize the receptors of target cells, which makes it possible to transport medicines to specific cells. Nanoparticles serve as carriers of therapeutic substances that enable a targeted therapy thanks to combination with ligands, which bind with specific receptors on the surface of the affected cells, and are also used in imaging examinations to detect lesions of disease. For this reason, nanoparticles are perfect for diagnosing and treating various diseases, which allows earlier detection of pathological changes and more effective treatment of patients [Wang, Thanou 2010].

The treatment of neurodegenerative diseases can also make use of nanoparticles bound with antioxidant particles, such as cerium oxide. The currently used antioxidants remove only a small part of redundant oxygen forms; unfortunately, also from those places where their quantity is appropriate. Nanotechnology makes it possible to create particles that would control the scavenging of free radicals by themselves on the basis of redox potential, i.e. particles that would act only where necessary [Singh et al. 2007].

METAL NANOPARTICLES IN CANCER TERAPHY

Nanoparticles have an enormous significance and are becoming more and more important in the treatment of cancer. The studies on silver particles, which have been conducted for many years, lead to a conclusion that such particles can be used in cancer treatment [Cryer, Thorley 2019]. Gynecological oncology implements the AgNORs [argyrophylic nucleolar organizer regions] method, which consists of the single-stage colloidal silver coating of nucleolus organizer regions to assess cell ploidy and proliferation [Bańkiewicz et al. 2005].

Nanoparticles used as contrast agents play an enormous role in cancer diagnosis. Imaging with the use of nanoparticles is more effective than imaging with the use of standard contrast agents. This stems from the numerous advantages of nanoparticles, such as their small size, optical properties, and the ability to accumulate in the area of the tumor thanks to the EPR effect [Gao et al. 2004, Gaucher et al. 2005]. Multi-functional nanoparticles are of considerable significance because they can be combined with diagnostic agents and contain therapeutic compounds, making it possible to simultaneously image and treat tumors [Wang et al. 2008]. This is caused mainly by the fact that the functionalization of the nanoparticle surface with the appropriate bioparticles [e.g. antibodies] enables them to circulate within the body even for several days, and selectively accumulate in specific areas of the body (cancer cells).

The recent years have witnessed a considerable progress in the development of nanoparticle systems that improve the imaging and diagnosis of cancer by means of MRI [Sun et al. 2008, Shubayev et al. 2009, Veiseh et al. 2010]. The use of nanoparticles in MRI results in a greater contrast, which improves the discrimination between pathologically changed tissues and healthy tissues. Iron nanoparticles have been subjected to comprehensive examinations concerning the possibility of using them to improve the contrast of MRI [Hao et al. 2010]. As presented by the latest studies on hybrid preparations with a superparamagnetic iron oxide core, modifications with external coatings and functional sensors have been developed in such a way as to enable the increase of contrast in alternative imaging techniques other than MRI.

Gold nanoparticles conjugated with antibodies – antibody epidermal growth factor receptor [EGFR] – seem to be a promising diagnostic tool for cancer cells. The appropriate functionalization with antibodies – EGFR – causes colloidal gold nanoparticles to change SPR peaks, which may be used to differentiate between malignant and benign cells [El-Sayed et al. 2005]. Another way to functionalize gold nanoparticles is to flatten them in order to achieve better internalization and binding with cells. Apart from a polymer, a fluorescent dye can be added. The added dye makes it possible to trace the path of gold nanoparticles to the selected cells [Tiwari et al. 2011].

Targeted cancer therapy is becoming a quickly developing area of both clinical and preclinical studies. The mechanism of operation of targeted medicines involves inhibiting specific signal transmission paths for cancer development processes: infiltration, proliferation, angiogenesis and formation of metastases [Duchnowska 2007]. The specific delivery of medicines to cancer cells with the use of nanoparticles can be affected in two ways: by releasing therapeutics from nanoparticles extracellularly to the micro-environment of the tumor [passive transport], or by releasing medicines inside the cell through endocytosis (active transport) [Xia 2010].

Metal nanoparticles are also used in radiotherapy. One example of this is gold particles. Gold nanoparticles are used to support radiotherapy because of their ability to absorb radiation. Nanogold accumulates in the location of the tumor and absorbs ionizing radiation, making it possible to administer smaller therapeutic doses, thereby protecting healthy tissues. The studies carried out by Hainfeld et al. [2008] showed that gold nanoparticles did not inhibit the growth of cancer lesions, while radiation only slowed down the growth of the tumor. However, radiation performed immediately after the administration of gold nanoparticles resulted in a considerable reduction of the size of the tumor or its total eradication.

Gold nanoparticles are also used in hypothermia, i.e. a non-invasive cancer treatment method. Due to the supply of gold nanoparticles, cancer cells are exposed to temperatures that are higher than usual, which leads to their destruction. Gold nanoparticles make it possible to convert laser light into heat; irradiation with laser increases the temperature around gold nanoparticles, which breaks the cancer cell membrane. Heat is produced as a result of, among other things, electron – phonon and phonon – phonon interactions. In addition, therapy at higher temperatures is related to cytotoxicity in the environment with a low pH and low oxygenation. Such conditions are found in cancer cells, but not in healthy ones, so only cancer cells die [Koperkiewicz 2015].

Under the influence of UV radiation or ultrasound, TiO_2 nanoparticles become able to destroy cancer cells. UV light can damage cancer cells and their surroundings. The in vivo studies on glioma cells carried out by Yamaguchi's scientific group [2010] showed the effectiveness of TiO_2 nanoparticles in photodynamic therapy. A similar effect on glioma cells was exhibited by TiO_2 nanoparticles created by means of ultrasound [Yamaguchi et al. 2011].

METAL NANOPARTICLES IN STOMATOLOGY

Another significant area in which nanotechnology is applied is the production of dental implants. Nanoparticles are widely used mainly for preparing the surface of implants with geometry in the nanometric scale, and for producing coatings with better adhesive properties. They are also applied as fillers in dental materials. The addition of TiO_2 nanoparticles to dental prostheses increases their bactericidal properties. The activation of TiO_2 nanoparticles leads to the formation of reactive oxygen forms; however, this process requires light. Photoactivation of prostheses can be carried out outside the oral cavity, e.g. at night, when the prosthesis is not in use. It is a comfortable, safe and hygienic solution for people who wear prostheses [Kosmala, Szymańska, 2016]

Implantology is constantly looking for solutions to accelerate and improve osseointegration and minimize the risk of infection and implant rejection [Wiatr, Niwakowska 2013]. Sugita et al. [2011]

studied the effects of coating an implant surface with a layer that contains titanium dioxide nanoparticles. The results showed that the application of a very thin coating causes a diametrical change to the biological properties of implants, while the morphology of the implant surface remains unchanged. Dental implants are exposed to damage caused by the accumulation of bacterial biofilm. At present, it is becoming increasingly more common to modify implant surfaces with nanoparticles. The use of a nanoparticle coating on an implant surface protects it against infections over a longer period of time. Flores et al. [2010] observed that the application of iron to titanium coatings had an antibacterial effect on Pseudomonas aeruginosa. Such a reaction positively affects the healing process and minimizes the risk of implant rejection.

The application of a gold nanoparticle coating on titanium implant surfaces led to the regeneration of bones. The studies showed that the presence of gold nanoparticles on titanium surfaces significantly improved the differentiation of osteogenic cells and influenced bone regeneration [Heo et al. 2016].

Abdulkareem's research group [2015] coated titanium surfaces with layers of ZnO nanoparticles, hydroxyapatite and a combination of ZnO with hydroxyapatite. After 96 hours of incubation, the scientists observed that the amounts of anaerobic bacteria and Streptococcus spp. were reduced on all examined surfaces. The best results were obtained for the surface on which a layer of ZnO nanoparticles and hydroxyapatite was applied. The obtained results led to the conclusion that an implant coating covered with a layer of metal nanoparticles provides effective antibacterial protection and reduces the risk of infection. The results proved the benefits associated with the use of composites, which can act synergistically to offer effective antimicrobial protection.

The development of a bacterial biofilm is a process that consists of many stages and starts at the moment of the first contact between the material and body fluids. Macroparticulate ingredients of body fluids quickly adsorb on the surface of biomaterial and create a conditioning layer that changes the nature of the surface of the implant. Such biofilms are often resistant to traditional antibacterial agents. The creation of a bacterial biofilm on the surface of teeth, i.e. dental plaque, plays an important role in the pathogenesis of parodontium diseases. A very promising solution is to develop filling materials that contain antibacterial substances which would hinder the development of bacteria. Wu's research group [2015], using dimethylaminohexadecyl methacrylate [DMAHDM] as the filler along with calcium phosphate nanoparticles, developed self-healing composites that can be widely applied in dentistry. Zhang et al. [2012] developed a binding agent that has a cidal effect on bacterial biofilms by combining quaternary ammonium dimethacrylate [QADM] and silver nanoparticles. The combination of silver nanoparticles and quaternary ammonium dimethacrylate [QADM] also improved the strength of the binding agent.

Li et al. [2014] developed binding agents created by combining [DMADDM] and silver nanoparticles. The developed agents significantly inhibited the growth of a biofilm. Such a combination offers a wide spectrum of possibilities of using it both as an antibacterial and anti-caries agent. The studies carried out by Zhang et al. in 2013 proved that the application of two antibacterial agents, i.e. 12-methacryloyloxydodecylpyridinium bromide [MDPB] and silver nanoparticles, improved the strength properties of dentine and reduced biofilms on the dental plaque. Such a combination can be successfully applied while developing binding agents and sealing materials, as well as composites and cements that hinder the development of biofilms and caries.

CONCLUSIONS

Nanotechnology is a new research approach related to understanding and improving the properties of matter on a nano scale. On that scale, matter exhibits completely different and surprising properties, which blur the traditional boundaries between scientific and technical disciplines. The solutions offered by nanotechnology are widely used in medicine. This work has presented the most important examples of metal nanoparticle applications in pharmacology, cancer therapy and stomatology.

At present, science shows that nanotechnology has become a key to a wider spectrum of technologies and therapeutic methods. Nanotechnology gives rise to new questions and leads to new connections that will have an enormous impact on the future of medicine.

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PRZYKŁADY ZASTOSOWANIA NANOCZĄSTEK METALI W MEDYCYNIE I FARMACJI

STRESZCZENIE. **Wstęp:** Nanotechnologia jest dziedziną nauki i techniki, która rozwija się intensywnie od kilkudziesięciu lat. Zaliczana jest do jednego z głównych działów aktywności sektora nauki, technologii i innowacji. Zastosowanie innowacyjnych technologii umożliwia modyfikowanie i otrzymywanie nanomateriałow charakteryzujących się zupełnie nowymi lub ulepszonymi właściwościami. Nanocząstki metali stały się przedmiotem uwagi ze względu na ich unikalne właściwości spowodowane różnym rozmiarem oraz potencjalnym zastosowaniem. W efekcie nanocząstki metali znalazły zastosowanie w wielu różnych dziedzinach nauki.
Metody: W niniejszej pracy przedstawiono najważniejsze przykłady zastosowań nanocząstek metali w farmakologii, terapii nowotworowej i stomatologii.
Wyniki i wnioski: Nanotechnologia stwarza możliwości szybkiego przekształcenia wyników badań podstawowych w zakończone sukcesem innowacje oraz opracowanie wiodących technologii, których wyniki można wdrażać w wielkich międzynarodowych koncernach, jak i małych przedsiębiorstwach we wszystkich sektorach gospodarki. W celu realizacji takich działań niezbędny jest prawidłowo funkcjonujący łańcuch dostaw. Zatem rozwój i wdrażanie produktów nanotechnologii bez odpowiedniej logistyki nie mógłoby osiągnąć odpowiednio wysokiego poziomu.

Słowa kluczowe: nanocząstki metali, medycyna, farmacja, terapia nowotworowa

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ORIGINAL PAPER

THE USE OF A HYBRID MODEL OF THE EXPERT SYSTEM FOR ASSESSING THE POTENTIALITY OF MANUFACTURING THE ASSUMED QUANTITY OF WIRE HARNESSES

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ABSTRACT. **Background:** Control plays the main role in ensuring the stability of production processes, while digital models of processes and methods of artificial intelligence are used more and more commonly in it. Production of highly diversified items in small lots at low inventory levels is characterised by a much lower stability as compared with large-lot manufacturing. Additionally, innovations created for items or processes result in disturbances to current work. Although this turbulence is usually momentary, it may lead to a loss of function or manufacturing stability, which in turn translates into financial losses, as well as losing customers. This paper presents the potential of using simulation models and artificial neural network models to assess the stability of a reorganized production system.

Methods: The problem analysed in the paper is that of merging a simulation model with an ANN model by designing a hybrid model. A direct connection of both types of models is not possible due to their various structures, specificity, and different purposes, as well as the various types of input and output data. Therefore, the idea of merging these two types of models through an expert knowledge base and fuzzy inference was proposed. The results from the simulation model and the ANN model were used to gather the knowledge on the production system being analysed. It has been proposed that the output from the simulation model provided knowledge of the risk level, while the output from the ANN model provided knowledge of process stability.

Results: The paper presents the idea of projecting a hybrid model of the expert system in order to assess the stability of a reorganized production system. A model of a hybrid expert system was developed to assess the potential of executing the assumed production plans. The level of risk and the level of stability determined by the simulation model and the ANN model are entered into the system. The output from the expert model is the value of the variable determining the potential of achieving the goal. In the construction of the model, fuzzy inference was used, which uses linguistic variables and is characterized by a knowledge system in the form of fuzzy rules "if ... then ...". For both the independent variable and for the dependent variable, a set of membership functions representing accepted linguistic variables was proposed, and then decision rules were determined.

The idea of merging simulation models with ANN models was tested on a practical example in production system that manufactures products for dishwashers.

Conclusions: The potentiality to execute production plans depending on the level of risk and the level of stability of the production system is too complicated to be modelled mathematically, but based on the analysis of data from the simulation and ANN models, it is possible to obtain information concerning the relations between corresponding input and output values.

Key words: production system, risk assessment, artificial neural networks, fuzzy logic, stability, variability.

INTRODUCTION

A modern customer requires that an item should not only be of the proper quality and sold at a low price, but also diversified, i.e. available in various versions and variants. In order to meet these demands, manufacturers are forced to manufacture items in small batches and deliver quickly them to the market.

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Manufacturing planning is a complex engineering problem which requires a combination of theoretical methods, computer-based simulation approaches and artificial neural networks. Unfortunately, contemporary production and manufacturing systems are marked by dynamic changes. This is a result of the amount and type of item produced, and varying cycle times of executing inflictions [Zwolińska, Grzybowska, Kubica, 2017]. Variation is an integral part of every system, it is also inevitable in any process [Deming 1993, Cyplik, Hadaś, Fertsch 2009, Grzybowska, Gajdzik 2012, Johnston 2016, Sitek, Wikarek 2016, Kiedrowicz, Nowicki, Waszkowski, et al. 2016]. However, a problem with ensuring the stability of production appears here. Production in small batches with highly diversified items and low inventory levels is indicated by a much lower stability as compared with large-lots manufacturing. Although these disturbances are usually momentary, they may lead to a loss of function or production stability, which in turn translates into financial losses, as well as losing customers. For these reasons eliminating variety and factors leading to uncertainty, as well as assuring stability of the production systems is a key matter [Zwolińska, Grzybowska, Kubica 2017]. In order to ensure the smooth functioning of a production system, the stability of its processes must be ensured and, on the other hand, fast decisions, which would be encumbered with the lowest possible risk and uncertainty, should be made [Antosz, Stadnicka 2017]. The concept of stability is derived from systems theory and means the ability of a system to return to a stable state after the disturbances have ceased.

Ensuring the stability of the production process is a prerequisite for achieving the planned production level. Control plays the main role in ensuring the stability of production processes, while digital models of processes and methods of artificial intelligence are used more and more commonly in it [Gola, Klosowski 2019].

Considering the new manufacturing paradigm – Industry 4.0 – future factories are indicated by a more flexible structure to produce highly customized items in smaller quantities, at a lower cost, of an advanced quality within the required time window. Against such a sweeping trend, it is only possible when the factories layout and processing flow are correctly designed and modified quickly [Zhang 2019].

Computer modelling and computer simulation have been widely used in the analysis, assay and optimization of production systems by scientists for almost 60 years [Taylor et al. 2009]. Matching an appropriate type of model to the nature and character of the decision is a highly important aspect here (Burduk, Grzybowska, Kovacs, 2018). Artificial neural networks are another very significant group of models more and more commonly used when making decisions concerning the control or management of production processes. Can and Heavey even indicate the advantage of ANN over modelling and computer simulation due to its advanced efficiency and the ease of designing the model [2012]. Artificial neural networks learn to solve global problems in a reasonable amount of time [LeCun et al. 2015].

Most of the previous papers in this field only suggested various algorithms to optimize production planning, which could be very time-consuming in reality. Therefore, this paper will also pay attention to the integration of simulation-based methodology and artificial neural networks to make a trade-off between work performance and planning cost.

Therefore, this study aims to enrich the theoretical foundation of production planning by taking advantage of a simulation-based methodology and artificial neural networks.

The aims of the study are to present the results of a simulation test that has been conducted and to perform an empirical analysis. The publication has the following structure: Section 2 describes the characteristics of the company and the process of manufacturing products. Section 3 presents an assessment of the risk in the production system analysed. In next part, we present assessment of the stability of the production system. Section 5 focuses on the hybrid model, while the final section contains a summary and conclusions.

CHARACTERISTICS OF THE COMPANY AND THE PROCESS OF MANUFACTURING PRODUCTS

The idea of merging simulation models with artificial neural networks models was tested using a practical example. A model of the hybrid expert system was built for this purpose in the Matlab software with Fuzzy Logic Toolbox in order to assess the potential of executing the assumed production plans depending on the level of stability and the level of risk. A production system that manufactures products for Electrolux dishwashers was used as an example.

In the period when the research was conducted and the data were collected, the factory planned to increase its production by 30% over two years in order to handle its growing number of orders. At the same time, a decision was made to reduce the production costs by decreasing the inventory levels. These actions could lead to disturbances in the course of the production process (loss of stability). An agreement entered into with a key customer of the factory means that the order processing times must be very short. In order to expand its production plan, the factory intends to introduce a number of organizational changes involving an increase in the production capacity at stations that are bottlenecks. However, these changes will not be discussed in this paper.

The problem of the potential to execute production plans depending on the level of risk and the level of stability of the production system is too complicated to be modelled mathematically. Data analysis shows that through simulation and artificial neural networks models it is practicable to obtain information about the relations between corresponding input and output values. The major items of the proposed expert system will be a knowledge base and rules of inference. Burduk et al. [2018] proposed the fuzzy inference method, which is characterized by a knowledge system in the form of fuzzy rules "if ... then ...".

The factory analysed produced approximately 700 various types of product. All these items are characterized by high level of similarity in their structure and in the manufacturing process. Each wire harness consists of so-called modules, while a module consists of wires ended with terminals. Both the number of modules and the number of wires may differ depending on the type of wire harness. Some wires are connected with the use of insulating tape. The modules are connected in the enclosure [Burduk, 2013]. Figure 1a shows the structure of the wire harness, while Figure 1b presents a schematic diagram of a sample harness.

The selected types of products are manufactured on the same production floor. Transport between stations is carried out by production employees. Harnesses are transported on so-called hangers. Figure 2 presents the names of stations, their locations, the order of tasks, and the flow of materials.

The work centres at which wires are inserted into electrical connectors, operate in parallel with the assembly centres. After the increase in the production plan and the introduction of organizational changes, it is estimated that the highest load will be on assembly centres (even 75%). The load on remaining stations will be from 26% (packaging, taping) to 60% (cutting of electrical wires). The production system analysed here is controlled in accordance with the principles of the pull system. The process is stimulated by assembly centres. Production takes place at the customer's request in small lots of approx. 250–350 pieces.

The reliability structure of the production system is a combination of series and parallels. Figure 3 schematically presents the tasks performed during the production.

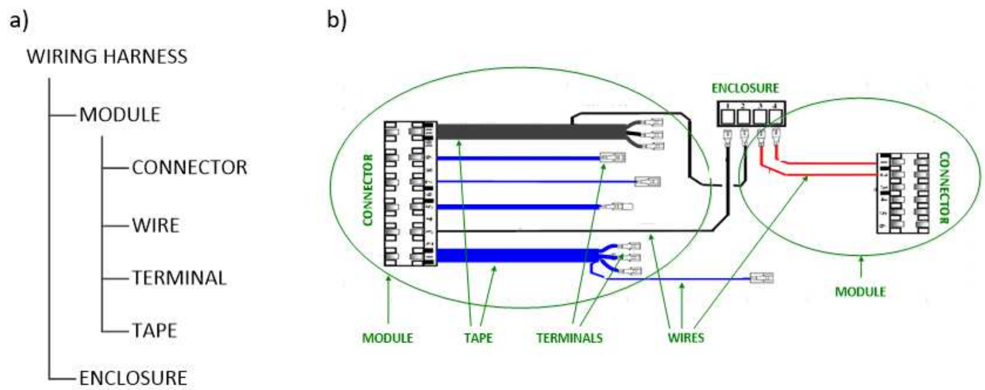

Fig. 1. a) Structure of a wire harness, b) schematic diagram of the selected wire harness

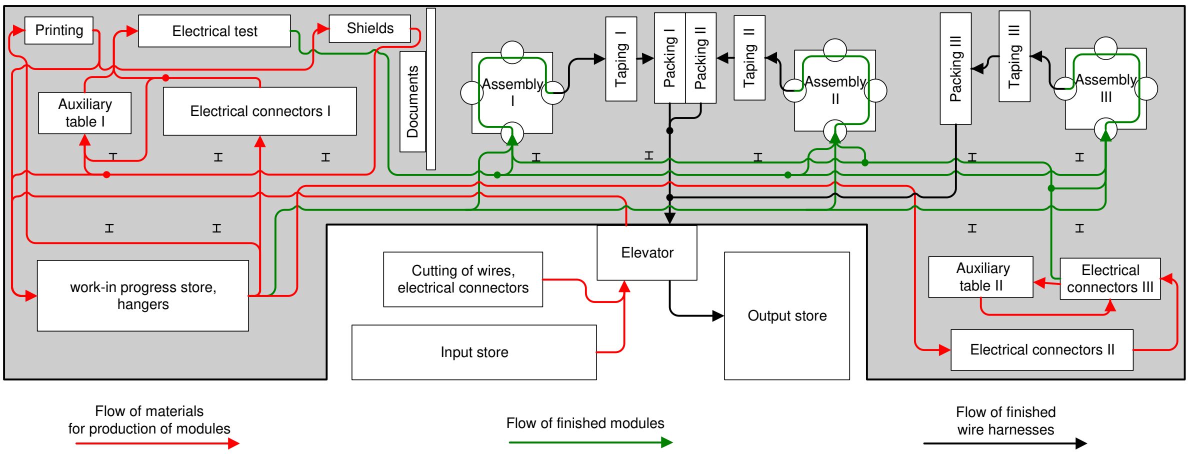

Fig. 2. Layout of the production floor and the flow of components in the process of production of wire harnesses

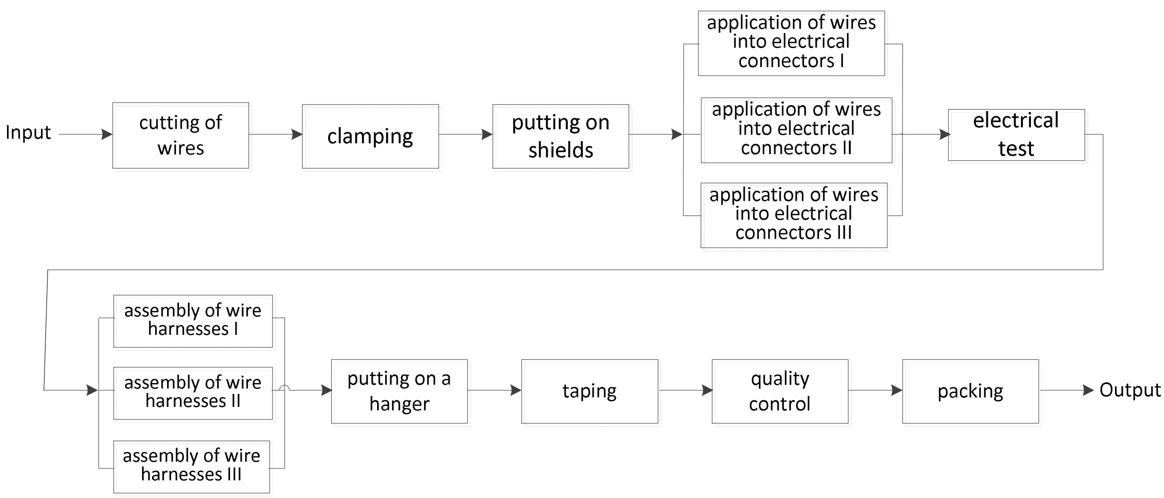

Fig. 3. Flowchart showing the stages of the production of wire harnesses

The assembly takes place on three stations operating in parallel (Assembly I, Assembly II and Assembly III). The time of assembly of products depends primarily on the number of the modules included in it. This is associated with the fact that more components need to be assembled and taped. The material flow in the assembly centre is presented in Figure 4.

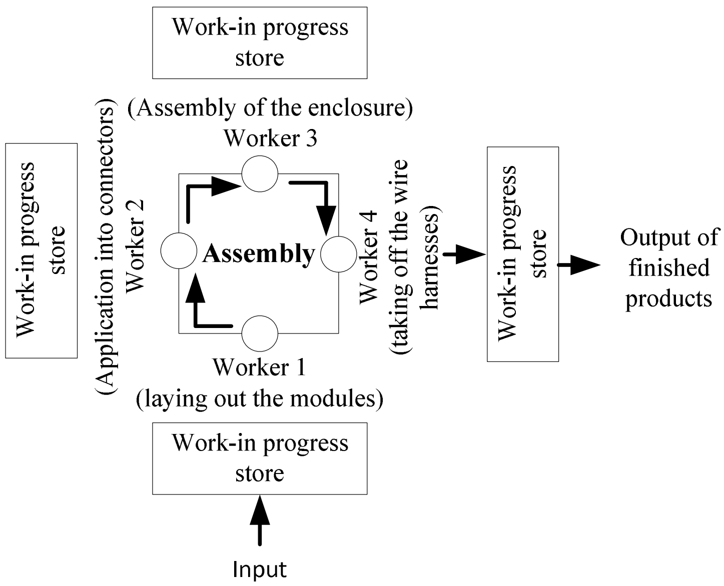

Fig. 4. Material flow in the assembly centre

The assembly stations are bottlenecks as they are the critical place in the process. Assembly tasks are performed on a rotary table by three employees. Employee 1 lays out the prepared modules on the assembly table in accordance with the drawing of the item to be assembled, which is shown on the table. Employee 2 inserts additional wires into connectors, Employee 3 assembles modules in enclosures, while Employee 4 picks up harnesses and places them on a transport hanger. If one of the modules or additional wires has not been installed correctly, the item is considered defective at the final quality control.All assembly tasks require precision and high skills among the employees. An incorrect arrangement of modules causes a significant extension of the time needed for the application of additional wires in the next task. Both the work of laying out the modules and taking off the products must be performed cautiously, because the wires may slip out of the connectors or enclosure. As the final assembly centres operate on the principle of a swivel, the skills of the works are important, as they need to work with the same pace.

In connection with the factory's plans to increase production capacity, a decision was made to assess the level of risk in the production system using the modelling and simulation methods, and then to examine the level of stability with the use of an artificial neural network. Analysis performed with the use of the models will allow the potentiality of achieving an advanced level of production to be assessed.

ASSESSMENT OF THE RISK IN THE PRODUCTION SYSTEM ANALYSED

For the needs of the risk analysis, a standard production plan was adopted, in which the planned increase in the production capacity was taken into account and the limits of the process stability were determined as ± 5% of the plan. Table 1 presents the production plan adopted for further analyses and the assumed limits of the process stability.

Table 1. The production plan and the adopted limits of the process stability depending on the number of modules in a wire harness

Number of modules in a wire harness [pcs]	Production plan [pcs/shift]	Limit of the stability of the production plan [pcs/shift]
2–4	370	352–388
5–6	350	333–367
7–9	330	314–346
9–12	250	238–262

Due to the fact that risk factors occur in the production system at random, a representative period (T) should be adopted for the analysis. It has been assumed that this period should be 3 months, because this is the time that allows the full characteristics of the risk factors to be gathered. The factory operates in a two-shift system, which for the assumed representative period gives a total of 120 production shifts. For this representative period, the production volume should be:

$$W = 1300 \frac{pcs.}{working\ shift} \cdot 120\ working\ shifts = 156000 \frac{pcs.}{12\ weeks}$$

The next step was to identify the risk factors occurring in the production system and to compile their characteristics. It involved observations, an analysis of the specification of previously completed production orders, and measurements of process times, as well as consultations and interviews with employees on various organizational levels. The data collected in this way are presented in Table 2.

Table 2. Identified risk factors and their characteristics

Name and designation of risk factor	Characteristics of the impact on the production system
Risk of absence of employees (r_1)	Caused by an absence which is at the level of 10% of working days a year per employee.
	Resulting from sick leaves, which translates annually into 7% of the working time per 1 employee.
Risk of rotation of employees (r_2)	Rotation concerns 33% of production employees a year. The negative impact of the rotation on the production system results from the fact that a new employee must undergo training and gain experience. In the case of assembly workers, the decrease in the performance is approx. 50% – the workers reach the assumed efficiency only after a period of 1 month of work.
	With respect to other work centres, the decrease in the efficiency is at the level of 30% and lasts about 1 week.
Risk of quality errors (r_3)	Apart from the defects that occurred in the assembly centres, repairing defective elements takes place at separated workstations and does not have a significant influence on the production process.
	In the case of assembly centres: - typical number of elements to be corrected at the level of 5 elements/shift/assembly station. in the case of occurrence of employee rotation, the number of elements to be corrected is 20 elements/shift/assembly station on average; a decrease in quality lasts for approx. 2 weeks.
Risk of downtimes on the production line (r_4)	Failures of the machines, for which the average downtime of the workstation in the period analysed ranged from 0.4 to 1.5 h a week.
	Unplanned changeovers resulting from the need to execute orders with a higher priority; The following data concerning the additional changeovers of workstations were obtained: semi-automatic machines for the applications of wires into electrical connectors – from 8 to 16 min depending on the number of wires in a module.

In order to determine the increases in production times resulting from the occurrence of risk factors, two simulation models were built in ProModel v.4.0 software. The first model did not include any risk factors and the purpose of its construction was to assess the potentiality of executing the production plan and to validate the model. The results of the simulation confirmed that the increased level of the production plan could be achieved the production system. The simulation for the assumed number of 156,000 items ended after 57,208 minutes, which was after 119.2 production shifts.

The objective of building Model 2 was to investigate how the risk factors presented in Table 2 affect the potentiality of execution of production plans. The results from Model 2 showed that the increase in the time caused by the occurrence of the risk factors was at the level of 39.6 (33%) working shifts for the production plan assumed. This means that at the current risk level it is not possible to execute the increased production plan. The results of the simulation showed also that the problem of the occurrence of risk factors concerned only assembly centres — for them the load in Model 2 even reached 89%. Therefore, in the later part of the study, the analysis was limited only to the assembly centres.

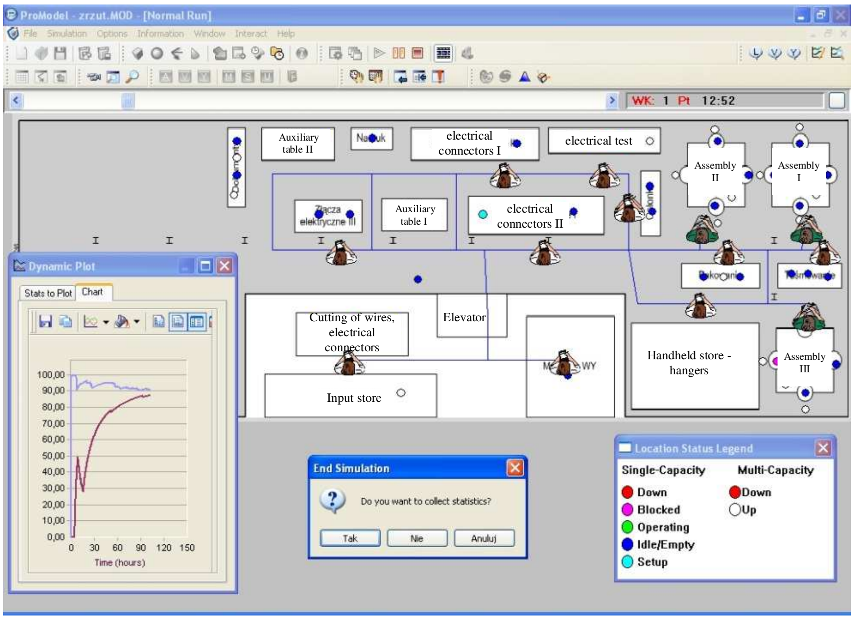

Fig. 5. Screenshot of Model 1

For each assembly centre, the losses (S) (the number of products not manufactured due to the occurrence of risk factors in the system) were calculated according to the formula [Burduk & Chlebus, 2009a, Burduk & Chlebus, 2009b]:

$$S_i = W_i \cdot \frac{\Delta t_i}{T}$$

where:

S_i – loss on the number of the manufactured products caused by the occurrence of risk factors in individual assembly centres (M1, M2 and M3),

W_i – the indicator (here productivity) analysed in the production system, theoretically possible for the production system to obtain,

$$W_i = \frac{156000\,pcs.}{3} = 52000\,pcs.,$$

$$\Delta t_i = 39.6\,working\ shifts,$$

$$T = 120\,production\ shifts$$

Thus, for individual assembly centres, the losses caused by the occurrence of risk factors will be as follows:

$$S_{M1} = S_{M2} = S_{M3} = 52000 \cdot \frac{39.6}{120} = 17160\,pieces$$

The risk of not achieving the production goal for each assembly centre will be [Burduk, 2010]:

$$R_{M1} = R_{M2} = R_{M3} = \frac{S_{Mi}}{W} = \frac{17160}{156000} = 0.11$$

Due to the fact that the assembly centres operate in parallel, while it has been established that the remaining work centres do not have any impact on the risk of this system, the total risk R_C will be [Burduk, 2010, Burduk & Chlebus, 2009a]:

$$R_C = R_{M1} + R_{M2} + R_{M3} = 0.11 + 0.11 + 0.11 = 0.33$$

The value of R_C for the entire production system is 0.33. This means that with a probability of 33% the production system will not achieve the assumed goal, i.e. the production of 1300 pcs of wire harnesses per production shift.

ASSESSMENT OF THE STABILITY OF THE PRODUCTION SYSTEM

The purpose of designing an artificial neural network model was to assess the stability of the wire harness assembly process. The assembly process can be deemed stable if the production volume is consistent with the production plan adopted. Otherwise, corrective actions should be taken that consist in changing the values of input parameters of the production resources used in the process.

In order to predict the quantity of the products manufactured at the given input parameters, a unidirectional neural network (multilayer perceptron) was built. The quantity of assembled products of good quality, i.e. those which passed the electrical test successfully, was to be the dependent variable. The independent variables were selected as follows:

X1 – the number of modules in the wire harness,
X2 – the skills level of Worker 1,
X3 – the skills level of Worker 2,
X4 – the skills level of Worker 3,
X5 – the skills level of Worker 4,
X6 – time of taping,
X7 – the number of defective elements detected at the electrical test station.

In order to evaluate the parameter of workers' skills levels, 4 values have been introduced:

1 – a worker who works less than 1 week,
2 – a worker who works less than 2 week,
3 – a worker who works less than 4 week,
4 – an experienced worker.

The data were collected from observations and measurements of an actual process, as well as from the analysis of the organizational specification and quality control reports. In total, 378 measurements were available for each variable. This set was divided into two parts, one of which served as a training set, while the second part was used for testing the network. The test was performed in the SAS Enterprise Miner 6.2 environment. The first step was to investigate the correlation between independent variables and the dependent variable. The results containing the correlation value are shown in Table 3.

Table 3. Values of the correlation between the analysed variables

Independent attribute (variable)	Correlation value
number of modules in the wire harness	0.16583
skills level of Worker 1	-0.16872
skills level of Worker 2	-0.22465
skills level of Worker 3	-0.14535
skills level of Worker 4	0.03276
time of taping	0.02104
number of defective elements detected at the electrical test station	-0.02957

The results indicate that there is no point in using the linear regression method to solve the problem being analysed here and it is reasonable to use the ANN model that builds non-linear regression models. Further tests were performed with a multilayer perceptron network, with modified values of the number of neurons in the hidden layer

Further investigations involved changing various numbers of independent variables. Their aim was to find such a combination of independent variables that the neural network would provide the best prediction of the number of products manufactured per shift. Selecting the variables depended on the results of previous tests, specifically on the absolute value of the correlation (Tab. 3). In the first test, all input attributes were used, in the second test, the 'taping time' attribute was discarded (the lowest absolute value of the correlation), and in the third test the 'number of defective components found at the electrical test station' attribute was additionally discarded (the next lowest absolute value of the correlation). The results are shown in Table 4, where the values obtained represent the network selection criterion – the mean square error; the results involve an analysis of the input data set, which was also used for the ANN training process [Burduk 2013].

Table 4. The results of the experiments for different variants of the neural ANN built

Neural network model	Mean squared error			
	Experiment No. 1	Experiment No. 2	Experiment No. 3	Experiment No. 4
MPN – NN=4	999.05	2443.71	1056.1	427.08
MPN – NN=8	2537.86	1369.98	1437.86	1019.25
MPN – NN=16	327.08	767.69	375.39	526.14
MPN – NN=32	1219.25	754.22	327.15	2088.12
MPN – NN=48	2375.39	872.49	999.05	368.14
GLM	1851.50	1450.28	1851.50	2569.8

where:
MPN a multilayer perceptron network,
NN number of neurons in the hidden layer,
GLM generalized linear model.

In the case of each test, the worst results (with the advanced mean squared error) were obtained for a neural network built according to the generalized linear model. The best results were obtained for a multilayer perceptron network with 32 neurons in the test no. 3, a schematic diagram of which is presented in Figure 6. This model was then used for further tests, i.e. for the assessment of the stability of the wire harness assembly process for various values of independent variables.

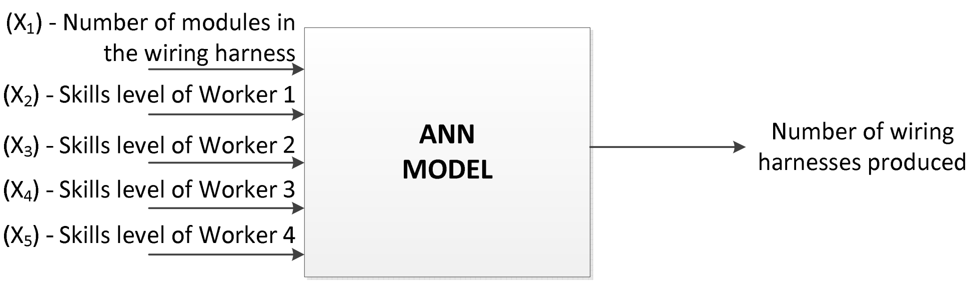

Fig. 6. Independent variables and the dependent variable used to build the ANN model

For the neural network designed in such a way, a series of tests using the test data was carried out in the SAS Enterprise Miner 6.2 environment. The test data contained various variants of changes in input attributes (independent variables). For such data, the neural network model predicts the values for manufactured products, which are interpreted in the context of the stability of the assembly process. The purpose, course and results of one of the tests are described below.

The purpose of the test was to examine how the skills levels of the employees at the assembly centre affect the stability of the process analysed. A wire harness with 7 modules was selected as an example. The production plan for products consisting of 7 modules was assumed at the level of 330 pcs/shift. For the needs of the study it was assumed that the production process is stable if the absolute value of the quantity of the components produced is within the range (314–346 pcs of products per production shift) [Burduk 2013]. Table 5 shows the production volume predicted by the artificial neural network model, which depends on the skills level of Employee 3, assuming that the level of skills of other employees is high.

Table 5. The predicted production volume for different skills levels of Worker 3 and a fixed number of modules to be assembled

Network inputs					Network outputs
Quantity of modules [pcs]	Skills level of Worker 1	Skills level of Worker 2	Skills level of Worker 3	Skills level of Worker 3	Predicted production volume
7	4	4	4	3	340
7	4	4	3	3	328
7	4	4	2	3	308
7	4	4	1	3	269

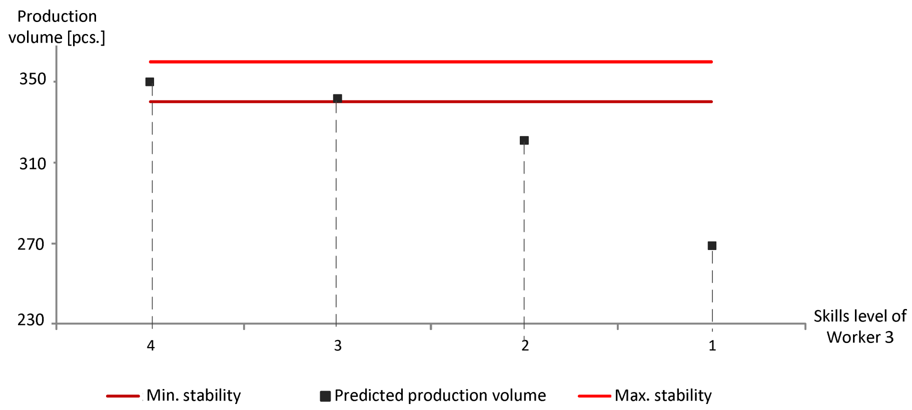

Fig. 7. The predicted production volume of wire harnesses for a fixed number of modules and different skills levels of Worker 3

The data included in Table 5 are also presented in the context of the process stability in Figure 7.

As can be seen from Table 5 and Figure 7, the process loses the steady state if Employee 3 works for a period shorter than two weeks. This result confirms the observations made when collecting the data and analysing the process. It also confirms the opinions of employees and process managers after a month of performing. Assembly works a new employee is able to work in accordance with the pace adopted for the assembly centre and the number of defective items returns to the assumed level.

Subsequently, other tests were conducted which confirmed that this neural network can be used to assess the stability of various variants of independent variables. The results obtained with the use of the neural network and the results obtained with the use of the simulation models for determining the level of risk in the system will be used to build a hybrid model of the expert system.

BUILDING A HYBRID MODEL

For the needs of the project, a fuzzy hybrid model was built and the following linguistic variables were determined:

- risk level = {low, average, high},
- stability level ={below the range, in the range,above the range},
- possibility of executing the plan (achieving the goal) ={low, high}.

For the variables specified above, their membership functions were defined. Figure 8 shows the membership function for the "risk level" linguistic variable.

The membership function proposed for the "risk level" linguistic variable is universal and can be adopted for all the production systems examined. Figure 9 shows the membership function for the "stability level" linguistic variable describing the production plan of products consisting of 9-12 modules.

Figure 10 shows the membership function for the linguistic variable "potentiality of executing the plan (achieving the goal)".

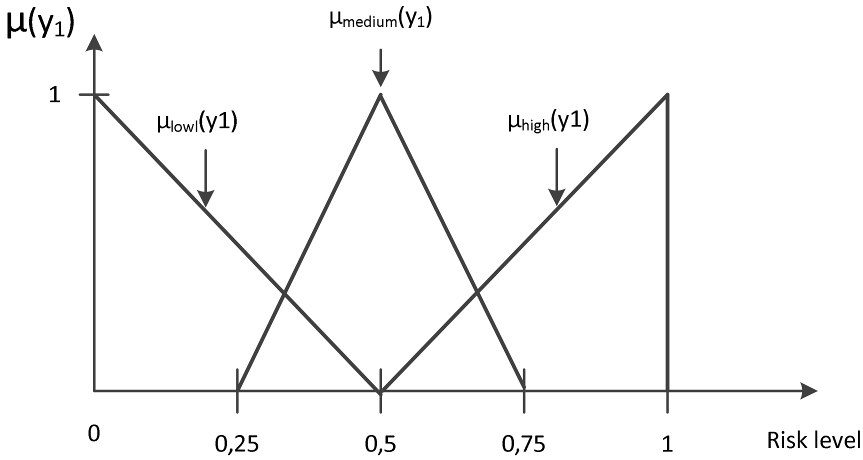

Fig. 8. Membership function for the "risk level" linguistic variable

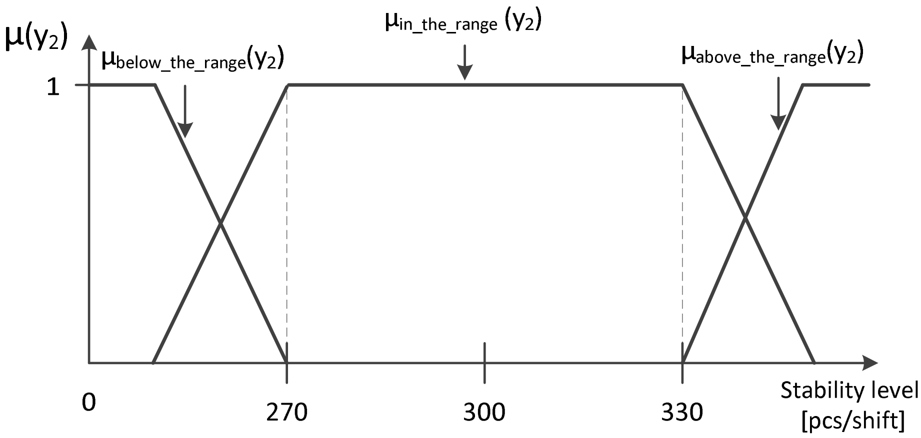

Fig. 9. The membership function for the "stability level" linguistic variable in the production process of wire harnesses consisting of 9-12 modules

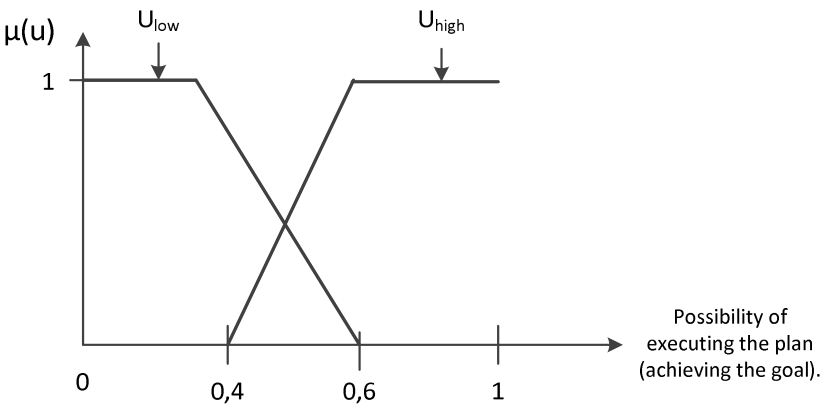

Fig. 8. The membership function for the linguistic variable "possibility of executing the plan (achieving the goal)"

As in the case of the "risk level" linguistic variable, the proposed membership function for the linguistic variable " potentiality of executing the plan (achieving the goal)" is universal and can be adopted for all the production systems tested.

Stage 1. Building a knowledge base

After that, a database was built of rules describing the relationships between individual values of variables, i.e. the rules describing the potentiality of executing the production plan depending on the level of risk in the production system and on the level of its stability.

If WR is low and PS is above range, then RC is high
If WR is low and PS is within the range, then RC is high
If WR is low and PS is below the range, then RC is low
If WR is medium and PS is above the range, then RC is high
If WR is medium and PS is within the range, then RC is low
If WR is medium and PS is below the range, then RC is low
If WR is high and PS is above the range, then RC is low
If WR is high and PS is within the range, then RC is low
If WR is high and PS is below the range, then RC is low

where:
WR – risk value,
PS – stability level,
RC – possibility of achieving the goal.

The database of decision rules can also be presented in the form of a decision table (Table 6).

Table 6. Decision table of the rule base

Y_1 / Y_2	below the range	within the range	above the range
low	low	high	high
medium	low	low	high
high	low	low	low

Stage 2. Operation of the expert system

The first step in the work of the fuzzy model of the expert system will be fuzzification. This step boils down to converting the sharp values of system inputs into fuzzy values. This is done on the basis of membership functions defined earlier (Figure 8, Figure 9, Figure 10). In the next step (b), the inference rule is selected from the knowledge base defined earlier. In the example of production system analysed, the use of Mamdani architecture is proposed. Each rule is fulfilled to some extent, because the inputs had certain degrees of membership in the corresponding fuzzy sets. If the premise of the rule consists of two premises concerning two inputs connected by the conjunction "and", the degree of membership in the entire rule is determined typically as the degree of membership in the entire relationship which is the combination of two fuzzy variables. The resulting fuzzy set is obtained as the sum of conclusions from individual rules. As the final result of the step of inference (b), the value of the output variable is obtained in the form of a fuzzy set. The last step of the stage 2 is sharpening (step c). It allows converting the output fuzzy set to the form of the sharp value. The literature suggests several methods of defuzzification. The most popular of these include the middle of maximum method, the centre of gravity method and the centre of sums method.

A decision was made that the best method for verifying the work of the model of the expert system for assessing the potentiality to achieve the production goals is to use specialized software. Matlab software with Fuzzy Logic Toolbox was selected and its general view is shown in Figure 11.

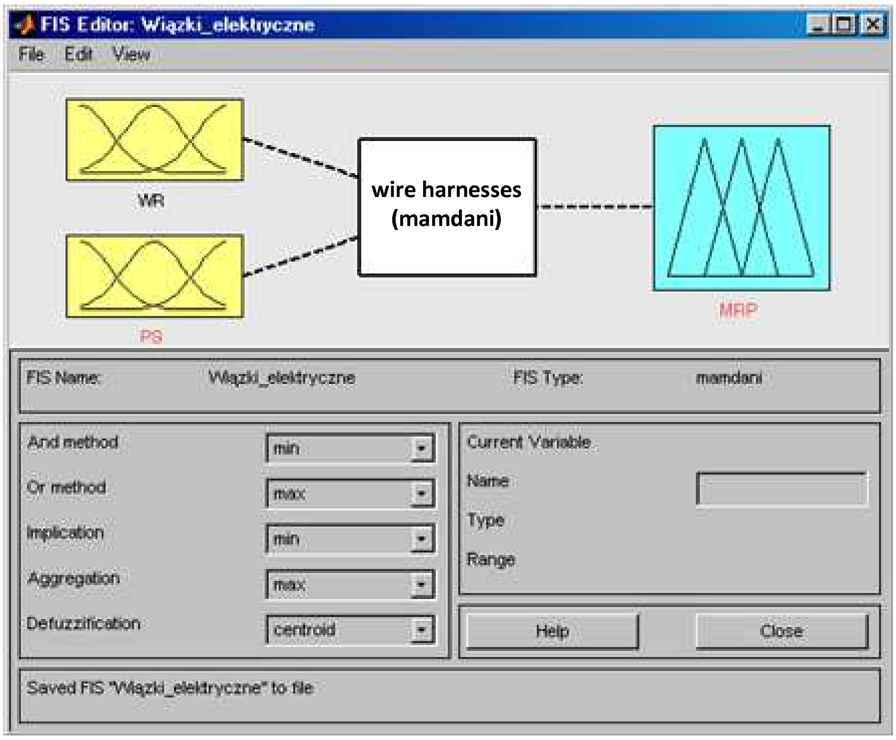

Fig. 11. The expert system designed – view of a screen from Matlab software with Fuzzy Logic Tool

This allowed the use of the fuzzy rule-based system in Mamdani architecture to determine the value of the probability of executing the plan (achieving the goal). For the following input data to this system: Y1=0.2 and Y2=280, the value U=0.95 was obtained. This means that for these values of the independent variables, the probability of executing the plan (achieving the goal), i.e. to produce 300 pcs of products per production shift, is high (95%).

CONCLUSIONS

The paper presents an idea of designing a hybrid model of the expert system in order to assess the stability of the production system, which was verified on a practical example. This model proves that a combination of the simulation modelling method and the ANN method would bring considerable benefits in the analysis of production systems and in ensuring their stability. Such a construction of the expert system model combines the advantages of the simulation models and artificial neural network models and allows assessing the potentiality of achieving the goals set for the production system in the conditions of a randomly occurring risk factor.

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HYBRYDOWY MODEL EKSPERCKIEGO SYSTEMU OCENY STABILNOŚCI SYSTEMU PRODUKCYJNEGO

STRESZCZENIE. **Wstęp:** W artykule przedstawiono koncepcję sterowania systemem produkcyjnym, pozwalającą na zachowanie jego stabilności, a tym samym na realizację założonych planów produkcyjnych. W tym celu zaproponowano połączenia modeli symulacyjnych i modeli sztucznych sieci neuronowych (SSN) systemu produkcyjnego. Połączenie obydwu typów modeli było możliwe dzięki opracowaniu hybrydowego modelu systemu ekspertowego do oceny możliwości realizacji planu produkcji (celu) w zależności od wielkości ryzyka i poziomu stabilności analizowanego systemu produkcyjnego. Analizowany problem – możliwość realizacji planów produkcyjnych w zależności od wielkości ryzyka i poziomu stabilności systemu produkcyjnego – jest trudny do zamodelowania matematycznego. Jednak na podstawie analizy danych, pochodzących z modelu symulacyjnego i modelu ANN, można uzyskać informacje dotyczące zależności odpowiadających sobie wartości wejściowych i wyjściowych.

Metody: Na podstawie przedstawionego sposobu zarządzania procesu produkcyjnego z wykorzystaniem modeli komputerowych, przeanalizowano możliwości zastosowania modeli symulacyjnych i modeli ANN w ocenie stabilności i ryzyka systemów produkcyjnych. Dokonano analizy i porównania obydwu typów modeli ze względu na sposób budowy oraz rodzaj danych wejściowych i wyjściowych.

Wyniki: Na bezpośrednie połączenie modeli symulacyjnych i modeli SSN nie pozwala ich odmienna budowa, specyfika oraz inne rodzaje danych wejściowych i wyjściowych. Dlatego prezentowana w artykule koncepcja fuzji obydwu typów modeli odbywa się poprzez bazę wiedzy eksperckiej i wnioskowanie rozmyte.

Wnioski: Na potrzeby sterowania systemem produkcyjnym, zaproponowano budowę hybrydowego modelu systemu ekspertowego do oceny możliwości realizacji celu w zależności od wielkości ryzyka i poziomu stabilności systemu produkcyjnego.

Słowa kluczowe: system produkcji, ocena ryzyka, sztuczne sieci neuronowe, logika rozmyta, stabilność, zmienność

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ORIGINAL PAPER

INDUSTRY 4.0: STATE OF THE ART AND RESEARCH IMPLICATIONS

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ABSTRACT. **Background:** Over the last few years, the Industry 4.0 concept has attracted attention among both academics and practitioners. Industry 4.0 is a very broad domain including production processes, efficiency, data management, relationship with consumers, competitiveness, and much more. Therefore, the aim of the paper was to analyze the main contributions published on the topic of Industry 4.0.

Methods: The literature review method was used to verify current knowledge on the Industry 4.0 topic, with the use of developed methods for literature review research dedicated to it.

Results: On the basis of the literature review procedure, answers to the research questions were obtained: RQ1: Is the "Industry 4.0" topic still relevant for researchers? RQ2: Does the national policy on Industry 4.0 influence the research interest in Industry 4.0? RQ3: What are the key components of Industry 4.0? RQ4: What are the implications of Industry 4.0 for other research topics?

Conclusions: This paper contributes theoretically to the development of the literature on Industry 4.0. Results obtained from the research not only summarise the current research activities but also indicate existing potential research directions. The findings of this review can be used as the basis for future research on Industry 4.0 and related topics, as well as a guideline for making a literature review.

Key words: Industry 4.0; literature review; state of art.

INTRODUCTION

This paper draws attention to Industry 4.0 as it has been observed to be a considerable interest of the fourth industrial revolution as a research topic, which has concerned Academia, business, and governments, since 2011, when the German term "Industrie 4.0" was announced at the 2011 Hannover Fair. It was stated that Industry 4.0 has been one of the most frequently discussed topics among people, which may be confirmed e.g. by the analysis of trends in the Google Trends browser (Fig. 1).

Google Trends show the interest in terms of region or interest in terms of time for any searched keyword. Interest in terms of time estimates numbers representing individual interest towards the highest point in the chart printed in the browser. A value of 100 indicates the highest popularity of a particular term. In order to verify the worldwide potential in the aspect of Industry 4.0, checking of interest by time was sufficient, considering the English ("Industry 4.0") term and the German one ("Industrie 4.0") as Germany is the place of the concept's origin. Since the beginning, there has been much more interest in this topic in the German language, but the situation changed in 2017, where the total number of searches in English was higher. Moreover, this increasing trend in the number of searches has continued and in the authors' opinion, this situation will take place for the next few years.

Citation: Kosacka-Olejnik M., Pitakaso R., 2019. Industry 4.0: State of the art and research implications. LogForum 15 (4), 475-485, http://doi.org/10.17270/J.LOG.2019.363

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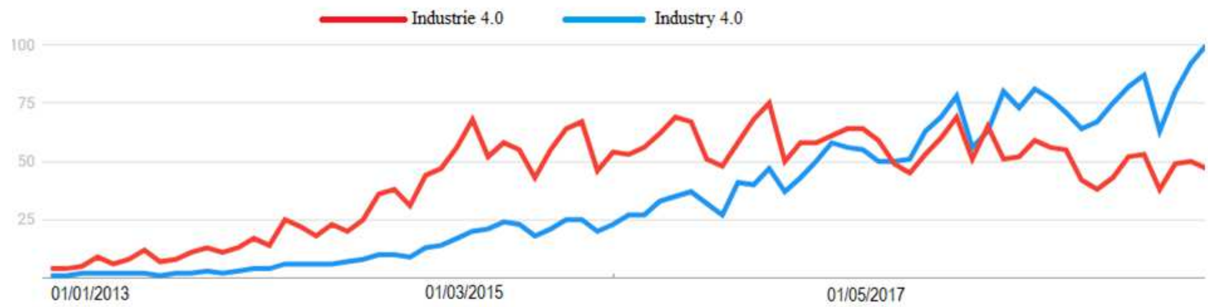


Source: own work

Fig. 1. Interest rate of "Industry 4.0" topic (between 01.01.2013-22.03.2019)

The high importance of Industry 4.0 has been caused by interest from the government. The German federal government has supported the idea by announcing that Industry 4.0 will be an integral part of the "High Technology Strategy for Germany 2020", an initiative aimed at leading the technological innovation. Consequently, Germany was closely followed by other countries which decided on an industrial revolution, including China, France, Japan, South Korea, the United Kingdom, and the United States. National proposals and policies have been created to drive the development of industry in the medium and long term, which was described in detail in [Lu,Weng 2018, Da Silva et al. 2019]. Considering the above, it was claimed that there is pressure to move towards Industry 4.0.

Table 1. Reviews on Industry 4.0 – state of art

Reference	Year	Time window	Database	Scope of the research
Liao et al., 2017	2017	Till 06.2016	WoS, Scopus, Science Direct	1) Journals and conferences including Industry 4.0 topic; 2) Enabling features of Industry 4.0; 3) Existing Industry 4.0 application fields; 4) The most frequently citied references; 5) Research objects and research goals in Industry 4.0; 6) Researchers working on Industry 4.0, countries, and represented institutions; 7) The list of standards, software and hardware appeared in Industry 4.0 implementations.
Lu, 2017	2017	2011-2016	WoS, Google Scholar	Research on Industry 4.0 categorization including following categories: Cyber-Physical Systems (CPS) based Industry 4.0, Interoperability of Industry 4.0, Concept and perspectives, Key technologies, Applications of Industry 4.0.
Oztemel, and Gursev, 2018	2018	Till 2017	CiteSeerX, ACM, AISeL, EBSCO host, Emerald Insight, Taylor Francis, Science Direct, Google Academic	1) National incentives for Industry 4.0 (Germany, USA, Japan, China, Taiwan, South Korea, Turkey); 2) A set of goals to achieve Industry 4.0; 3) Industry 4.0 components description (CPS, Cloud systems, IoT, machine to machine (M2M) communication, Smart factory, Data mining, big data, ERP and business intelligence, augmented reality, simulation, virtual manufacturing, robotics; 4) Description of particular Industry 4.0 research projects.
Kamble et al., 2018	2018	2012-2017	WoS	1) Research on Industry 4.0 categorization including: research categories (conceptual papers on Industry 4.0, human-machine interactions, machine-equipment interactions, technologies of Industry 4.0 and sustainability) research approach (conceptual, case study, simulation, experimental, survey, prototype); 2) Qualitative analysis of number of papers per year; 3) High contributing authors; 4) Contributions by publishers, journals and country; 5) Keywords in publication title statistics; 6) Co-citation map of top contributing authors.
Piccarozzi et al., 2018	2018	Till 06.2018	Scopus, WoS, Google Scholar	1) Qualitative analysis of number of papers per year; 2) Contributions by journals and country; 3) Research on Industry 4.0 categorization based on methodological aspect (conceptual, empirical); 4) Industry 4.0 definition divided by main domain in which they were found (technical components, value chain, smart factory, competitiveness, strategy, IoT); 5) Industry 4.0 domains

Source: own work

Industry 4.0 is a new concept, but it is not a completely new research area, as it has been based on previous research and has tied together recent advances in the areas of automation, artificial intelligence, production technology, information communication technology, and cloud technology [Lu, Weng 2018].

As a result of preliminary research on Industry 4.0, only five papers presenting a literature review of Industry 4.0 were identified (Table 1).

Despite the dynamic nature of the research on Industry 4.0, limited access to a systematic and extensive review of recent research on this topic has been identified. With reference to Table 1, researchers have done literature reviews on Industry 4.0 using various scientific databases. However, the most frequently used repositories were Scopus and Web of Science. Research on Industry 4.0 has been analyzed qualitatively (e.g. definition of Industry 4.0) and quantitatively (e.g. distribution of papers per year, contributions by journals or country, etc.). The most recent review was from the middle of 2018, but it was focused on the managerial context of Industry 4.0. In the authors' opinion, the most comprehensive paper was [Liao et al., 2017], but it presents the state of the industry up to the end of 2016.

Accordingly, this paper conducts a review on Industry 4.0 made up to 03.2019 to give a more recent look at the Industry 4.0 topic, considering aspects presented in research questions RQ1-RQ4, which have not been analyzed in any study so far (Table 2).

Table 2. Research questions

ID	Question	Objective
RQ1	Is the "Industry 4.0" topic is still relevant for researchers?	To justify conducting a research on Industry 4.0 topic
RQ2	Does the national policy on Industry 4.0 influence the research interest in the Industry 4.0?	To verify the relationship between national policy on the Industry 4.0 and research on this topic
RQ3	What are the key components of the Industry 4.0?	Identification the key components of Industry 4.0, considering the human and technological context
RQ4	What are the implications of Industry 4.0 on other research topics?	Identification of the scope and size of Industry 4.0 influence on research apart from manufacturing process

Source: own work

Consequently, the major objective of the paper was to obtain an overview of Industry 4.0 following a list of specified research questions (Table 2), which was required to achieve the following partial objectives:

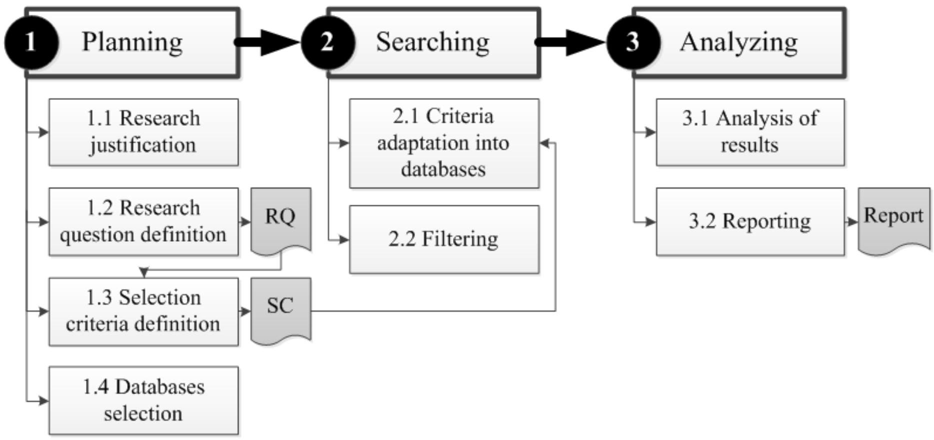
- O1: A procedure for literature review development;
- O2: Carrying out a literature review.

In the paper a few research questions were presented that have taken up the issue of Industry 4.0 considering aspects which have not been discussed so far in the literature or that have not been updated. The presented results of the literature research are preliminary research on the state of Industry 4.0.

The remainder of this paper is structured as follows. The research methodology is introduced in Section 2. Section 3 presents the main findings of the literature analysis on the basis of research questions RQ1-RQ4. Based on the answers to those questions, Section 4 provides final conclusions with research limitations and future perspectives..

RESEARCH METHODOLOGY

A literature review is an essential part of any research work. The aim of this study was to obtain an overview of Industry 4.0 considering the relevance of the topic, the influence of national policies on the interest rate of Industry 4.0, key components of Industry 4.0 and research directions. To achieve the major objective of the paper, approaches developed by Kitchenham [2004] and Denyer and Tranfield [2009] have been used to gain comprehensive insights into Industry 4.0. Owing to the fact that one common approach to the literature review has not been identified, the authors decided to prepare a procedure useful for the literature review on a specific topic which corresponds with the partial objective O1 (Fig. 2).



Source: own work

Fig. 2. Review procedure

With reference to Fig. 2, the review procedure consists of three stages, including planning, searching and analysis of the obtained results. In the authors' opinion, the procedure for literature review should be simple to use and clear on how to analyze the results. The prepared procedure (Fig 2.) was used in the paper to verify this.

Considering the major objective of the paper, the literature research was justified. The research questions RQ1-RQ4, presented in the Introduction, were used in the literature research in order to define the selection criteria described in Table 3.

Table 3. Selection criteria

Criterion	Description
Keywords	"Industry 4.0" OR "4th industrial revolution" OR "fourth industrial revolution"
Search field	Title
Time window	2011 - 03.2019
Language	English
Publication type	Conference paper, book chapter, article
Inclusion criteria	I1: The whole content of the paper is written in English
	I2: The paper explicitly express research focus on Industry 4.0

Source: own work

Considering the efforts of previous research on the literature review of Industry 4.0 (Table 1) the following keywords have been searched among paper titles: "Industry 4.0", "4th industrial revolution", "fourth industrial revolution". Book chapters, articles and conference papers were included in the search to ensure the research originated from academic sources. In the research, papers published after 2011 and written in English were included (as the date of the concept's origin). In order to ensure the high quality of the research, two inclusion criteria were used, regarding the language of the whole content of the paper (I1) and the research focus on Industry 4.0 (I2). At the last step of the planning stage (Fig. 2), scientific databases were chosen, considering the use of repositories to which access is available for authors of the paper, using scientific databases with the highest coverage for the researched topic. For these reasons, the authors referred to papers from the Web of Science (WoS) and Scopus databases, which contain a significant number of renowned publications on the Industry 4.0 topic, which corresponds to the information presented in Table 1.

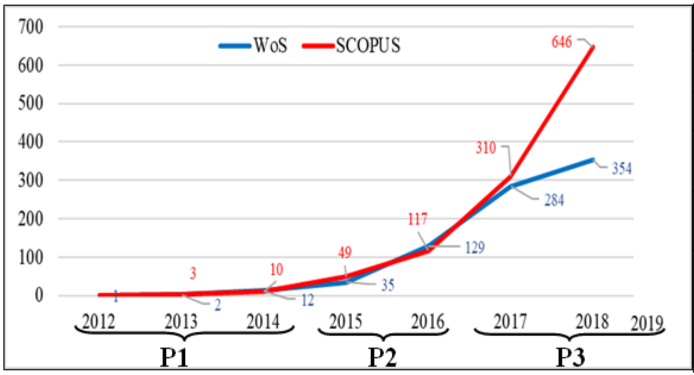
Regarding Fig.2, in the second stage of the review procedure, answers to the research questions were searched by selection criteria adapted into filtering for databases and papers.

The last stage of the conducted research included an analysis of the results and a report of them, which is described in detail in the next section.

RESEARCH FINDINGS

Is the "Industry 4.0" topic still relevant for researchers?

To present the current interest rate in the Industry 4.0 topic among researchers, an analysis of documents collected in scientific databases was carried out, including Web of Science (WoS) and Scopus, where particular selection criteria (Table 3) were adopted into databases. The results of publication filtering are presented in Fig. 3.



	WoS	Scopus
Total number of papers	857	1250
First paper date	2012	2013
Max. number of papers per year	354	646
% share of papers (2017-2018)	74%	76%

Trend lines:
$y = 14{,}429x^2 - 53{,}286x + 41{,}286$ (WoS)
$y = 31{,}583x^2 - 157{,}7x + 161{,}29$ (Scopus)

Source: own work

Fig. 3. Distribution of papers on Industry 4.0 per year (28.03.2019)

Although the term, Industry 4.0, was used for the first time in 2011, the first scientific paper was published in 2012 (WoS) and in SCOPUS it was dated in 2013. With reference to Fig. 3, the authors determined three phases of research on Industry 4.0 (P1-P3):

- P1: 2012-2014, the initial phase, where there was little interest in Industry 4.0 with a high conceptual character;
- P2: 2015-2016, the introduction phase, where there was increasing interest in Industry 4.0 as the concept had begun to be introduced into the national policies of particular countries;
- P3: 2017-2019 (till now), the growth phase, where a high level of interest has been identified in the Industry 4.0 topic, which has been a well-known and recognized concept from a theoretical perspective, resulting in works on the practical applications of Industry 4.0 solutions. Moreover, at this phase, the creation of new concepts based on Industry 4.0 may be observed, which go beyond industrial application e.g. Logistics 4.0.

According to Fig. 3, the distribution of papers in both the WoS and Scopus databases, rose significantly over the period from 2012 to 2018, achieving the maximum value in 2017 of 354 papers in WoS, and 646 papers in Scopus. Although there were differences in the number of papers in the compared databases, the trend was quite similar. It is noteworthy that there has been a rapid growth in the number of publications on Industry 4.0 since 2017, wherein both databases the total number of papers was around 300, while in 2016 it was almost three times less. Considering the percentage share of papers developed between 2017 and 2018 (around 75%), a multinomial trend analysis was carried out for each database, which confirmed that the level of interest in the Industry 4.0 topic is going to go up (Fig. 3). On the basis of trend analysis, it was assumed that in 2019 there may be more than 920 papers in the SCOPUS database and around 540 publications in the WoS database, so the positive trend should continue. It was planned that these forecasts be verified in 2020.

To sum up, there was a clearly defined pattern on the graph (Fig. 3) that confirms a growing interest in research on the Industry 4.0 topic, which will be continued in the future. In the authors' opinion, this provides a justification for research on the fourth industrial revolution, in particular, that it was a relevant issue for Business and Academia in the past and it should be important in the future, too. It was claimed that the challenge is to describe existing Industry 4.0 solutions used in practice, because in the authors' opinion, the practice of Industry 4.0 is ahead of the theory of this concept. Taking the above into consideration, it was stated that the RQ1 was answered.

Does the national policy on Industry 4.0 influence the research interest in the Industry 4.0?

It was assumed that national policies and programs leading to Industry 4.0 should have an impact on the level of interest on this topic among researchers, expressed in number of papers. To verify this assumption, results were analyzed of the distribution of papers by country, presenting the top 5 countries, considering the number of papers (Table 4).

Table 1. Documents per country

Position	WoS			Scopus		
	Country	No of papers	% share	Country	No of papers	% share
1	Germany	167	13,36%	Germany	225	18,00%
2	China	77	6,16%	Italy	124	9,92%
3	Italy	67	5,36%	UK	90	7,20%
4	Spain	51	4,08%	USA	84	6,72%
5	UK	50	4,00%	China	82	6,56%
Total		412	32,96%	Total	605	48,4%

Source: own work

Regarding Table 4, in WoS almost one-third of all papers were written by researchers representing the top 5 countries, while this share was greater by almost 15% in the Scopus database. Despite the database type, Germany was a leader providing almost one-fifth of all papers in Scopus and around 14% of all works in WoS. Considering the above, the authors verified the assumption with respect to these top 5 countries, so information was sought on national policies and programs on Industry 4.0 to assess the level of commitment to Industry 4.0 at the national level according to a scale where:

- 0 - there is no national policy on the Industry 4.0;
- 1 – there is a national policy, there are undertaken some initiatives for Industry 4.0;
- 2 – there is a national policy, there are many valuable in the context of the whole country initiatives for Industry 4.0 promoted by business and government;
- 3– there is a national policy, there is a plenty of initiatives on Industry 4.0 promoted by business and government, and the policy has an influence on other countries initiatives.

With reference to Table 4, it was stated that, according to the number of papers on Industry 4.0, the most influential country has been Germany, and later were identified: China, UK, USA, Spain and Italy. In order to answer the RQ2, an analysis of literature and Internet sources on Industry 4.0 initiatives in selected countries was carried out, which was scored according to the accepted scale (0-3). The results of the analysis are shown in Table 5.

Table 5. Assessment of commitment in Industry 4.0 at national level

Country	Examples of initiatives	Score (0-3)
Germany	Platform Industrie 4.0, BDEW, BDI, Bitkon, VDA, VDMA, ZVEI	3
China	Made in China 2025, Smart Factory 1.0 Initiative, Internet Plus, Internet of Things Center Shanghai	3
Italy	The I4.0 National Plan	2
Spain	Connected Industry 4.0 (CI 4.0)	2
UK	Catapult centres, High Value Manufacturing, Satellite Applications	2
USA	Industrial Internet Consortium (IIC), National Network for Manufacturing Innovation (NNMI), AllSeen Alliance	3

Source: own work based on Kagermann et al. 2016

To sum up, it was stated that in the case of all the countries analyzed in this section, a positive relationship has been identified, confirming that the more initiatives on Industry 4.0 at the national level, the bigger the research interest in the topic. In the authors' opinion, this confirms that research follows practical achievements.

What are the key components of the Industry 4.0?

In the presented paper, the authors' claim that many approaches to the definition of Industry 4.0 have been identified in the literature, considering the following categories: technical components, value chain, smart factory, competitiveness, strategy or The Internet of Things, described in detail in [Piccarozzi et al , 2018, p.11]. One common thing for each definition has been a technological context, as technology plays an essential role as it is required for change. As a consequence, following Burritt and Christ [2016], in this study, Industry 4.0 was considered as "an umbrella term used to describe a group of connected technological advances that provide a foundation for increased digitization of the business". Considering the results of previous literature research on Industry 4.0 (Table 1), a list of key components of Industry 4.0 was prepared and verified by the authors of the paper (Table 6).

Table 6. Key components of the Industry 4.0

Keyword	% share (WoS)	% share (Scopus)
Internet of Things (IoT)	30,22%	47,12%
Big data	15,52%	33,92%
Cyber Physical System (CPS)	11,44%	43,20%
Smart Factory	8,52%	29,84%
Cloud computing	6,18%	15,92%
Data mining	1,05%	6,48%
Virtual reality	1,52%	6,00%
Augmented reality	3,03%	7,92%
Robots	5,60%	16,64%
Additive manufacturing	2,22%	5,60%

Source: own work

With reference to Table 6, it was stated that some of the components are more relevant, e.g. Internet of Things or Big Data, because they appear more often in the paper's topic (title, keywords, abstract), but it is essential that all elements define the meaning of Industry 4.0. In the authors' opinion, Industry 4.0 creates a smart factory which results in smart products being delivered to customers. It is noteworthy that in manufacturing, as well as in the whole value chain, innovative solutions are used combining the physical and virtual world (by CPS), where things and objects are linked through IoT. Moreover, in Industry 4.0, additive manufacturing (e.g. 3D printing), virtual reality, cloud computing, big data, and data mining are used as there is a huge amount of data resulting from the communication between objects.

To sum up, there are many components of Industry 4.0 which should be used in order to introduce Industry 4.0. In the author's opinion, this topic requires empirical research in the industry to verify theoretical data about the key technological components of Industry 4.0.

What are the implications of Industry 4.0 on other research topics?

In order to get the answer for the last research question (RQ4), publications with the term "4.0" in the publication title and published after 2011 were analyzed, excluding papers with the following terms in the title: "Industry 4.0", "Industrie 4.0" and "version 4.0".

It was assumed that the term "4.0" combined with other words had been used by researchers to determine new concepts which were defined by the authors of the paper as "Industry 4.0 secondary documents". As a result, a list of concepts based on Industry 4.0 was identified (Table 7).

Table 7. Concepts based on Industry 4.0

Concept	frequency	% share	cumulative % share	Concept	frequency	% share	cumulative % share
Education	25	12,76%	12,76%	Supply chain	3	1,53%	87,24%
Operator	16	8,16%	20,92%	Machine Tool	2	1,02%	88,27%
Health	16	8,16%	29,08%	Marketing	2	1,02%	89,29%
Logistic	16	8,16%	37,24%	Country (Thailand)	2	1,02%	90,31%
Management	14	7,14%	44,39%	city	2	1,02%	91,33%
Work	12	6,12%	50,51%	Mobility	2	1,02%	92,35%
Factory	9	4,59%	55,10%	Material	2	1,02%	93,37%
Agriculture	7	3,57%	58,67%	Audit	1	0,51%	93,88%
Resources (energy, water)	7	3,57%	62,24%	Engineering	1	0,51%	94,39%
Medicine	7	3,57%	65,82%	Remanufacturing	1	0,51%	94,90%
Leadership	5	2,55%	68,37%	Workforce	1	0,51%	95,41%
Organization	5	2,55%	70,92%	Transport infrastructure	1	0,51%	95,92%
Lean	4	2,04%	72,96%	Productivity	1	0,51%	96,43%
Maintenance	4	2,04%	75,00%	Insurance	1	0,51%	96,94%
Service	4	2,04%	77,04%	Everything	1	0,51%	97,45%
Quality	4	2,04%	79,08%	Cybercrime	1	0,51%	97,96%
Economy	4	2,04%	81,12%	Administration	1	0,51%	98,47%
Enterprise	3	1,53%	82,65%	Software	1	0,51%	98,98%
Safety	3	1,53%	84,18%	Government	1	0,51%	99,49%
Paint Shop	3	1,53%	85,71%	Tools	1	0,51%	100,00%

Source: own work

Based on the filtering scientific databases WoS and Scopus, 40 concepts were identified in the literature within the Industry 4.0 framework which could be categorized as e.g. considering human aspect, level of interest (country, city, enterprise, etc.), business activity (e.g. marketing, logistics, remanufacturing, management, etc.), resources context (including machines, tools, water, energy, etc.) and other unclassified aspects.

Firstly, papers available in the Scopus database (182 papers) were identified, and secondly, papers included in the WoS repository (67 papers). In the next step, all papers were included in the one spreadsheet, eliminating duplicates, which resulted in 196 papers, which were analyzed in detail. Each concept based on Industry 4.0 was examined in the publication title to identify the frequency of occurrence in the literature. It was stated that the identified concepts are not equally important for researchers (% share of use of a particular concept in the paper's title). Considering the Pareto Rule, it was claimed that 50 % of all concepts have been used in 80% of all Industry 4.0 secondary papers. The in-depth analysis resulted in the conclusion that the most relevant concepts (top five) based on Industry 4.0 are: Education 4.0, Operator 4.0, Health 4.0, Logistics 4.0 and Work 4.0. In the authors' opinion, a human context of Industry 4.0 appears very often in the research, considering issues related to working conditions, health and, most relevant of all, an education context. In the authors' opinion, the education aspect has become very relevant, because it is related to people's skills and qualifications who have to deal with revolution 4.0, not only in the Industry, but also in Services, Transport, Administration, etc. (Table 7). It is noteworthy that Logistics 4.0

has been an important issue, too. As a consequence some efforts may be observed on a description of maturity models for Industry 4.0 (in total, 13 papers on that topic have been identified in WoS and Scopus (e.g. [Schumacher et al., 2016; Ganzarain, Errasti, 2016]) and for Logistics 4.0 [e.g. Sternad et al. 2018, Oleśków-Szłapka, Stachowiak 2019]. To sum up, Industry 4.0 is a very influential research topic, which may be confirmed by data in the Table 7. In the authors' opinion, the level of interest in the concepts presented in this paper should increase because a research gap has been identified in the context of the Industry 4.0 topic.

CONCLUSIONS

In this paper, the authors have presented the results of a literature review on the Industry 4.0 topic focusing on a few aspects of the fourth industrial revolution, namely:

- Future potential for research on the Industry 4.0 topic, which corresponds to RQ1;
- The relationship between incentives for Industry 4.0 at the national level and research on Industry 4.0, which corresponds to RQ2;
- Identification of key elements of Industry 4.0, which corresponds to RQ3;
- Identification of new concepts based on Industry 4.0, which corresponds to RQ4.

Taking the above into consideration, it was stated that the partial objective, O2, was achieved, and, as a consequence, the major objective of the paper was achieved.

In this study, knowledge about the existing state of art papers on the Industry 4.0 topic was gathered to provide a guideline for future research on this topic. It should be kept in mind that literature review papers are always active for some period of time. Because the world is changing very fast, researchers have to follow changes and update their work. Consequently, the literature review should consider the results of previous research, to treat them as a guideline. In this paper, the authors have used existing literature review papers on the Industry 4.0 topic in order to obtain answers for specified research questions (RQ1-RQ4). Considering the previous literature on Industry 4.0 (Table 1), the authors have specified a list of questions which have not been included in the literature review so far.

Considering the results of the presented study, several limitations should be noted. Firstly, in the presented research, only a few research questions were included about the actual state of Industry 4.0 (up to March 31, 2019). It should be noted that the list of research questions has not been closed as the paper presents results of preliminary research on Industry 4.0. In the future, the authors are going to prepare a complex literature review that will summarize all information about Industry 4.0 in the scope of various dimensions, including those which have been presented in the papers in Table 1.

Secondly, academic sources (collected from the WoS and Scopus databases) were used in the research, so the future research should be extended to other repositories like Google Scholar or IEEE Xplore Digital Library and should take into account evidence from industry/practitioners. The next issue is the language limitation which has influenced the research, as existing Industry 4.0 research published in other languages (in particular, in German) was excluded.

Despite some limitations, as a result of the literature review, the current status of the research on Industry 4.0 was reported from the perspective of selected research questions. In the future, it is planned to expand this research by adding German language and additional databases in order to build our own database of all the papers on Industry 4.0 and to add to the analysis additional research questions which were used in previous research (Table 1).

It is noteworthy that the presented research was based on scientific papers, which in particular represent theoretical character. To define real key components of Industry 4.0, empirical research into companies should have been done to identify the practical solutions they use. To sum up, the authors of the paper stated that a research gap has been identified which indicates the direction of future research in which evidence from industry should be included too. It was claimed that, in Industry 4.0, the rule that, „the Practice is one step before the Research" may be observed. The above implies the necessity of conducting empirical research in companies in order to make a full analysis of Industry 4.0 and, as a consequence, to determine Industry 4.0 paradigms based on theoretical foundations verified by industry achievements.

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PRZEMYSŁ 4.0: STAN OBECNY I WYTYCZNE W ZAKRESIE POTENCJALNYCH BADAŃ

STRESZCZENIE. **Wstęp:** W ciągu ostatnich lat, koncepcja Przemysłu 4.0 przyciąga uwagę zarówno przedstawicieli nauki jak i przemysłu. Przemysł 4.0 dotyczy procesów produkcji, wydajności, zarządzania danymi czy relacjami z klientami, kwestiami związanymi z konkurencyjnością oraz wiele innych zagadnień.
Metody: W pracy wykorzystano metodę analizy literatury celem weryfikacji aktualnego stanu wiedzy w zakresie koncepcji Przemysłu 4.0. W tym celu wykorzystano dedykowaną procedurę przeprowadzania badań literatury.
Wyniki: Na podstawie opracowanej procedury przeprowadzania studiów literatury, uzyskano odpowiedzi na wskazane pytania badawcze tj.: PB1:Czy pojęcie Przemysł 4.0 jest wciąż istotne dla badaczy? PB2: Czy programy prowadzone na szczeblu krajowym wpływają na zainteresowanie badaczy w zakresie Przemysłu 4.0? PB3: Jakie są kluczowe komponenty Przemysłu 4.0? PB4: Jakie Przemysł 4.0 wywołuje implikacje na inne tematy badawcze?
Wnioski: Zaprezentowany artykuł wnosi wkład w rozwój literatury nad koncepcją Przemysłu 4.0. Wyniki uzyskane z przeprowadzonej analizy literatury nie tylko stanowią podsumowanie dotychczasowej wiedzy na temat koncepcji Przemysłu 4.0, lecz również wskazują kierunki potencjalnych badań. Rezultaty z przeprowadzonych studiów literatury mogą zostać wykorzystane jako wskazówki do przeprowadzenia dalszych badań nad koncepcją Przemysłu 4.0 oraz tematów z nią związanych, jak również służyć mogą jako wytyczne do przeprowadzenia badań literatury w wskazanym obszarze.

Słowa kluczowe: Przemysł 4.0, przegląd literatury

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ORIGINAL PAPER

TWO-STORAGE INVENTORY MODEL FOR DETERIORATING ITEMS WITH PRICE DEPENDENT DEMAND AND SHORTAGES UNDER PARTIAL BACKLOGGED IN FUZZY APPROACH

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ABSTRACT. **Background:** In this paper we developed a fuzzy two-warehouse (one is OW, the own warehouse and other is RW, the rented warehouse) inventory model of deteriorating items with price dependent demand rate and allowed shortages under partially backlogged conditions. Since the capacity of any warehouse is limited, the supplier has to rent a warehouse for keeping the excess units over the fixed capacity W of the own warehouse in practice. The rented warehouse owed higher holding cost than the own warehouse. In this paper we considered holding cost, deterioration rate, shortages cost and lost sales as triangular fuzzy numbers.

Methods: Graded Mean Integration Representation is used to defuzzify the total cost function. The result obtained by this method is compared with crisp model with the help of a numerical example. Sensitivity analysis is accomplished to changing one parameter at a time and keeping others at their archetypal.

Results and conclusions: It has been proved that graded mean integration representation method gives more accurate result as compare to crisp model.

Key words: Inventory, Two-Warehouse System, Deterioration, Shortages, Triangular Fuzzy Number, Graded Mean Integration Representation Method.

INTRODUCTION

Now-a-days the modern business environment is highly competitive in nature due to the globalization of market. The suppliers need large number of customer day by day for the increase of their business. To attract a large number of customers, an organization grabs a huge collection of goods which cannot be stored indefinitely in its own warehouse with limited capacity. Hence the organization hires one or more warehouse in rental basis to store the excess units of goods. Usually, the rented warehouse charges higher unit holding cost than the own warehouse.

In the last few decades, two-warehouse inventory models have been widely applied in business world. In 1976, Hartely first presented a basic two-warehouse model, where the cost of transporting a unit from rented warehouse to owned warehouse was not considered. Then, Sarma [1983] extended Hartely's model by introducing the transportation cost. After his pioneering contribution, several other researchers have attempted to extend their works to various other realistic situations. Goswami and Chaudhuri [1992] developed an economic order quantity model for items with two levels of storage for linear demand. Hence researchers attracted towards the development of two-warehouse inventory model considering

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different parameters. Roy et al. [2018] developed a probabilistic inventory model of deteriorating items for adopting the trade-credit policy for their customers those who are interested for their backorder demands. Chakrabarty et al. [2018] investigated a two warehouse inventory model for single deteriorating items under assumption of shortages, and partial backlogging under payments delay where the effect of inflation and time value for money is also incorporated. Mandal and Giri [2018] explored a single buyer, two warehouse inventory model with imperfect production process of the vendor. The demand depends upon the stock where the vendor offers a quantity discount to motivate the customers to buy more quantities. A credit policy approach in a two warehouse inventory model for deteriorating items with price and stock-dependent demand under partial backlogging is explained by Panda et al.[2019]. For more research in this field see Benkherouf [1997], Yang [2004], Huang [2006], Lee and Hsu [2009], Liang and Zhou [2011], Yang and Chang [2013], Jaggi et al. [2013, 2017], Bhunia et al. [2014, 2015], Xu et al. [2016], Sheikh and Patel [2017] etc.

A large number of research papers have been studied in the area of two-warehouse inventory model in crisp approach. However, a very few researchers extended their works to fuzzy environment. In this above literature review, we discussed most of the fuzzy two-warehouse inventory models. Customer satisfaction plays a crucial role for an organization in the present competitive market scenario to maximizing the profit. In this context, the inventory level should be properly set as to meet the customer's expectations. With a lost sale, the customer's needs for the item is filled by a competitor which is assumed as the lost of profit in sales. On the other hand, the organization not only loses the customer but also loses the customer's goodwill. Therefore we did not exclude the stock out cost from the total profit. No organization ignores the effect of demand in its business. There are many types of inventories as per time, price, stock etc. At the end of each calendar year for a product, the demand is same among the customer. The scarcity of a product in the market increases its demand. During this period the demand is depends upon the selling price. As we increase the selling price, the demand is decreases and vice-versa. By considering the above parameters into account, we developed a two-warehouse inventory model for deteriorating items with price dependent demand where shortages are partially backlogged. Here, we have introduced two warehouses- one own warehouse and other is rented warehouse. The holding cost of rented warehouse charges are higher than that of own warehouse. The cost components (holding cost, shortage cost, lost sales) and deterioration rates for two warehouses are assumed as triangular fuzzy numbers. The objective of this model is to maximize the profit and minimize the total cost. Graded Mean Integration Representation Method is used for defuzzification of the total cost function. The inventory total cost is obtained in both crisp and fuzzy environment. Numerical example is given to illustrate the validity of the given model. Sensitivity analysis is also carried out by the help of Mathematica 11.1 software to analyze the effect of changes of each parameter by keeping other parameters at their original.

The remainder of this paper is organized as follows. In sect. 2, assumptions of the proposed model are given. Notations of the model are provided in sect. 3. Mathematical model in Crisp and Fuzzy sense is formulated in sect. 4. In sect. 5, numerical example is illustrated to support the proposed model. Sensitivity analysis is carried out by using Mathematica software in sect. 6 followed by conclusion in sect. 7.

ASSUMPTIONS

1. The inventory system involves only one item.
2. The replenishment occurs instantaneously at infinite rate.
3. The lead time is negligible.
4. The demand rate is a function of selling price.
5. The shortages are allowed and partially backlogged.
6. The own warehouse has a limited capacity of W units.

7. The rented warehouse has unlimited capacity calculated per day basis.
8. The holding unit cost of RW is greater than that of OW.
9. The items assumed in this model are deteriorating in nature.
10. Neglecting the higher power of θ.
11. The items are stored in OW first.
12. The items kept in RW will be consumed first.

NOTATIONS

$I_r(t)$	Inventory level at time t in RW, $t \geq 0$
$I_o(t)$	Inventory level at time t in OW, $t \geq 0$
θ	Rate of deterioration
α	Initial demand rate
β	Positive demand parameter
t_1	Time point when stock level of RW reaches to zero
t_2	Time point when stock level of OW reaches to zero
W	Storage capacity of OW
C_1	Selling price per unit
S	Initial stock level
q_1	Backorder quantity during stock out
T	Cycle time
p	Purchasing cost (\$/unit/day).
k	Rate of backlogging
h_r	Holding cost (\$/unit/year) in RW
h_o	Holding cost (\$/unit/year) in OW
d	Unit deterioration cost (\$/unit/day)
C_2	Unit shortage cost (\$/unit/day).
C_3	Unit lost sale cost (\$/unit/day).
$TC(t_1, t$	Total average cost (\$/unit/day).
$\tilde{\theta}$	Fuzzy deterioration rate
$\tilde{h}_r$	Fuzzy holding cost (\$/unit/day) in RW
$\tilde{h}_o$	Fuzzy holding cost (\$/unit/day) in OW
$\tilde{C}_2$	Fuzzy shortage cost (\$/unit/day)
$\tilde{C}_3$	Fuzzy opportunity cost due to lost sale (\$/unit/day)
$\widetilde{TC}(t_1, t$	Fuzzy total cost (\$/unit/day)
$\widetilde{TC}_G(t_1,$	Defuzzified value of $\widetilde{TC}(t_1, t_2)$ by applying GMIR method

MATHEMATICAL FORMULATIONS

Suppose q units are received in the stock at the beginning from which q_1 units are utilized to satisfy backlogged demand and S units are the initial stock level. First of all W units of material stored in OW and then rest $(S - W)$ units are stored in a RW. Since holding cost h_r of RW is greater than the holding cost h_o of OW, the items in RW will be consumed first. During the consumption period of RW, the inventory level of OW is decreased due to deterioration only. At time $t = t_1$, the inventory level of RW becomes zero due to demand and deterioration. During $[t_1, t_2]$ stock is available only in OW. At time $[t = t_2]$; inventory level of OW depletes to zero due to demand and deterioration and after that shortage occurs. This is shown in the Fig. 1.

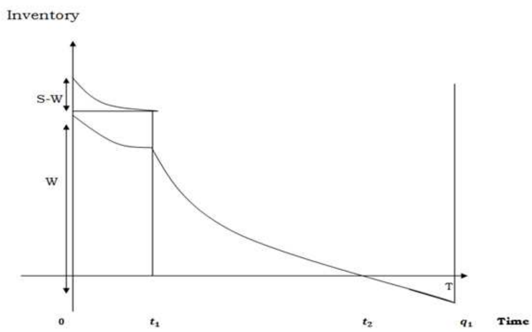

Fig. 1. Inventory time graph of two-storage inventory model

CRISP MODEL

The differential equations for this inventory level is describing as follows.

The differential equations for this inventory level is describing as follows:

$$\frac{dI_r(t)}{dt} = -\theta I_r(t) - (\alpha - \beta C_1), \quad 0 \le t \le t_1 \tag{1}$$

with $I_r(t_1) = 0$

$$\frac{dI_o(t)}{dt} = -\theta I_o(t), \qquad 0 \le t \le t_1 \tag{2}$$

with $I_o(0) = W$

$$\frac{dI_o(t)}{dt} = -\theta I_o(t) - (\alpha - \beta C_1), \quad t_1 \le t \le t_2 \tag{3}$$

with $I_o(t_2) = 0$

The solutions of the above equations (1), (2) and (3) are given by

$$I_r(t) = \frac{(\alpha-\beta C_1)}{\theta}\left(e^{\theta(t_1-t)} - 1\right), \quad 0 \le t \le t_1 \tag{4}$$

$$I_o(t) = We^{-\theta t}, \qquad 0 \le t \le t_1 \tag{5}$$

$$I_o(t) = \frac{(\alpha-\beta C_1)}{\theta}\left(e^{\theta(t_2-t)} - 1\right), \quad t_1 \le t \le t_2 \tag{6}$$

From (5), we have

$$I_r(0) = S - W$$

$$S = W + \frac{(\alpha-\beta C_1)}{\theta}\left(e^{\theta t_1} - 1\right) \tag{7}$$

At $t = t_1$, Equation (5) and (6) yields

$$We^{-\theta t_1} = \frac{(\alpha - \beta C_1)}{\theta}\left(e^{\theta(t_2-t_1)} - 1\right)$$

$$W = \frac{(\alpha-\beta C_1)}{\theta}\left(e^{\theta t_2} - e^{\theta t_1}\right) \tag{8}$$

Purchasing cost (P.C)

$$P.C = (S + q_1)p$$

$$q_1 = \int_{t_2}^{T} k(\alpha - \beta C_1)dt = (\alpha - \beta C_1)k(T - t_2)$$

$$P.C = \left\{\left(W + \frac{(\alpha-\beta C_1)}{\theta}\left(e^{\theta t_1} - 1\right)\right) + (\alpha - \beta C_1)k(T - t_2)\right\}p \tag{9}$$

Holding cost (H.C)

$$H.C = H.C_r + H.C_o$$

$$H.C_r = h_r \int_0^{t_1} I_r(t)dt = h_r \frac{(\alpha-\beta C_1)}{\theta}\left(\frac{e^{\theta t_1 - 1}}{\theta} - t_1\right) \tag{10}$$

$$H.C_o = h_o\left\{\int_0^{t_1} I_o(t)dt + \int_{t_1}^{t_2} I_o(t)dt\right\}$$

$$= \frac{Wh_o}{\theta}\left(1 - e^{-\theta t_1}\right) + h_o\frac{(\alpha-\beta C_1)}{\theta}\left(\frac{e^{\theta(t_2-t_1)-1}}{\theta} + (t_1 - t_2)\right) \tag{11}$$

Deterioration cost (D.C)

$$D.C = D.C_r + D.C_o$$

$$D.C_r = d\left\{\frac{(\alpha-\beta C_1)}{\theta}\left(e^{\theta t_1} - 1\right) - (\alpha - \beta C_1)t_1\right\} \tag{12}$$

$$D.C_o = d\{W - (\alpha - \beta C_1)(t_2 - t_1)\} \tag{13}$$

Shortage cost (S.C)

$$S.C = C_2\int_{t_2}^{T}(\alpha - \beta C_1)dt = C_2(\alpha - \beta C_1)(T - t_2) \tag{14}$$

Lost sale cost (L.C)

$$L.C = C_3\int_{t_2}^{T}(1 - k)(\alpha - \beta C_1)dt = C_3(1 - k)(\alpha - \beta C_1)(T - t_2) \tag{15}$$

Total average cost $TC(t_1, t_2)$ for this model during a cycle is given by

$$TC(t_1, t_2) = \frac{1}{T}[P.C + H.C + D.C + S.C + L.C]$$

$$= \frac{1}{T}\Bigg[\Bigg\{\Bigg(W + \frac{(\alpha-\beta C_1)}{\theta}\left(e^{\theta t_1}-1\right)\Bigg) + (\alpha-\beta C_1)k(T-t_2)\Bigg\}p + h_r\frac{(\alpha-\beta C_1)}{\theta}\left(\frac{e^{\theta t_1}-1}{\theta}-t_1\right)$$
$$+\frac{Wh_o}{\theta}\left(1-e^{-\theta t_1}\right) + h_o\frac{(\alpha-\beta C_1)}{\theta}\left(\frac{e^{\theta(t_2-t_1)}-1}{\theta}+(t_1-t_2)\right)$$
$$+d\left\{\frac{(\alpha-\beta C_1)}{\theta}\left(e^{\theta t_1}-1\right)-(\alpha-\beta C_1)t_1 + W - (\alpha-\beta C_1)(t_2-t_1)\right\}$$
$$+C_2(\alpha-\beta C_1)(T-t_2) + C_3(1-k)(\alpha-\beta C_1)(T-t_2)\Bigg] \quad (16)$$

To minimize the total cost function $TC(t_1, t_2)$ per unit time, the optimum value of t_1 and t_2 can be obtained by solving the following equations:

$$\frac{\partial TC(t_1,t_2)}{\partial t_1} = 0 \quad \text{and} \quad \frac{\partial TC(t_1,t_2)}{\partial t_2} = 0 \quad (17)$$

Equation (17) is equivalent to

$$\left[\frac{\left\{\begin{array}{c} de^{\theta t_1}(\alpha-\beta C_1) + e^{\theta t_1}p(\alpha-\beta C_1) + Wh_o e^{-\theta t_1} \\ +h_o\left(1-e^{\theta(t_2-t_1)}\right)(\alpha-\beta C_1) + \dfrac{h_r\left(e^{\theta t_1}-1\right)(\alpha-\beta C_1)}{\theta^2}\end{array}\right\}}{T}\right] = 0$$

and

$$\left[\frac{\left\{\begin{array}{c} -kp(\alpha-\beta C_1) + d(-\alpha+\beta C_1) - C_2(\alpha-\beta C_1) \\ -C_3(1-k)(\alpha-\beta C_1) + \dfrac{h_o\left(e^{\theta(t_2-t_1)}-1\right)(\alpha-\beta C_1)}{\theta}\end{array}\right\}}{T}\right] = 0$$

Provided it satisfies the equations

$$\frac{\partial^2 TC(t_1,t_2)}{\partial t_1^2} > 0\,, \ \frac{\partial^2 TC(t_1,t_2)}{\partial t_2^2} > 0 \quad \text{and}$$
$$\left(\frac{\partial^2 TC(t_1,t_2)}{\partial t_1^2}\right)\left(\frac{\partial^2 TC(t_1,t_2)}{\partial t_2^2}\right) - \left(\frac{\partial^2 TC(t_1,t_2)}{\partial t_1^2 \partial t_2^2}\right)^2 > 0 \quad (18)$$

FUZZY MODEL

Due to uncertainty in nature it is not easy to define all the system parameters exactly, subsequently let us assume that some of these parameters namely $\tilde{h}_r$, $\tilde{h}_o$, $\tilde{C}_2$, $\tilde{C}_3$, $\tilde{\theta}$ may change within some limits.

Suppose $\tilde{h}_r = (r_1, r_2, r_3)$, $\tilde{h}_o = (O_1, O_2, O_3)$, $\tilde{\theta} = (\theta_1, \theta_2, \theta_3)$, $\tilde{C}_2 = (n_1, n_2, n_3)$, and $\tilde{C}_3 = (l_1, l_2, l_3)$ be consider as triangular fuzzy numbers.

Then the total average cost is given by

$$\widetilde{TC}(t_1,t_2) = \frac{1}{T}\begin{bmatrix} \left\{\left(W + \frac{(\alpha-\beta C_1)}{\tilde{\theta}}\left(e^{\tilde{\theta} t_1} - 1\right)\right) + (\alpha - \beta C_1)k(T - t_2)\right\}p \\ +\tilde{h}_r \frac{(\alpha-\beta C_1)}{\tilde{\theta}}\left(\frac{e^{\tilde{\theta} t_1}-1}{\tilde{\theta}} - t_1\right) + \frac{W\tilde{h}_o}{\tilde{\theta}}\left(1 - e^{-\tilde{\theta} t_1}\right) \\ +\tilde{h}_o \frac{(\alpha-\beta C_1)}{\tilde{\theta}}\left(\frac{e^{\tilde{\theta}(t_2-t_1)}-1}{\tilde{\theta}} + (t_1 - t_2)\right) \\ +d\left\{\frac{(\alpha-\beta C_1)}{\tilde{\theta}}\left(e^{\tilde{\theta} t_1} - 1\right) - (\alpha - \beta C_1)t_1 + W - (\alpha - \beta C_1)(t_2 - t_1)\right\} \\ +\tilde{C}_2(\alpha - \beta C_1)(T - t_2) + \tilde{C}_3(1 - k)(\alpha - \beta C_1)(T - t_2) \end{bmatrix} \tag{19}$$

We defuzzified the fuzzy total cost function $\widetilde{TC}(t_1, t_2)$ by Graded Mean Integration Representation (GMIR) method as follows:

$$\widetilde{TC}_G(t_1,t_2) = \frac{1}{6}\left[\widetilde{TC}_{G1}(t_1,t_2) + 4\,\widetilde{TC}_{G2}(t_1,t_2) + \widetilde{TC}_{G3}(t_1,t_2)\right] \tag{20}$$

where

$$\widetilde{TC}_{G1}(t_1,t_2) = \frac{1}{T}\begin{bmatrix} \left\{\left(W + \frac{(\alpha-\beta C_1)}{\theta_1}\left(e^{\theta_1 t_1} - 1\right)\right) + (\alpha - \beta C_1)k(T - t_2)\right\}p \\ +r_1 \frac{(\alpha-\beta C_1)}{\theta_1}\left(\frac{e^{\theta_1 t_1}-1}{\theta_1} - t_1\right) + \frac{WO_1}{\theta_1}\left(1 - e^{-\theta_1 t_1}\right) \\ +O_1 \frac{(\alpha-\beta C_1)}{\theta_1}\left(\frac{e^{\theta_1(t_2-t_1)}-1}{\theta_1} + (t_1 - t_2)\right) \\ +d\left\{\frac{(\alpha-\beta C_1)}{\theta_1}\left(e^{\theta_1 t_1} - 1\right) - (\alpha - \beta C_1)t_1 + W - (\alpha - \beta C_1)(t_2 - t_1)\right\} \\ +n_1(\alpha - \beta C_1)(T - t_2) + l_1(1 - k)(\alpha - \beta C_1)(T - t_2) \end{bmatrix}$$

$$\widetilde{TC}_{G2}(t_1,t_2) = \frac{1}{T}\left[\begin{array}{c} \left\{\left(W + \frac{(\alpha-\beta C_1)}{\theta_2}\left(e^{\theta_2 t_1}-1\right)\right) + (\alpha-\beta C_1)k(T-t_2)\right\}p \\ +r_2\frac{(\alpha-\beta C_1)}{\theta_2}\left(\frac{e^{\theta_2 t_1}-1}{\theta_2}-t_1\right) + \frac{WO_2}{\theta_2}\left(1-e^{-\theta_2 t_1}\right) \\ +O_2\frac{(\alpha-\beta C_1)}{\theta_2}\left(\frac{e^{\theta_2(t_2-t_1)}-1}{\theta_2}+(t_1-t_2)\right) \\ +d\left\{\frac{(\alpha-\beta C_1)}{\theta_2}\left(e^{\theta_2 t_1}-1\right)-(\alpha-\beta C_1)t_1+W-(\alpha-\beta C_1)(t_2-t_1)\right\} \\ +n_2(\alpha-\beta C_1)(T-t_2)+l_2(1-k)(\alpha-\beta C_1)(T-t_2) \end{array}\right]$$

$$\widetilde{TC}_{G3}(t_1,t_2) = \frac{1}{T}\left[\begin{array}{c} \left\{\left(W + \frac{(\alpha-\beta C_1)}{\theta_3}\left(e^{\theta_3 t_1}-1\right)\right) + (\alpha-\beta C_1)k(T-t_2)\right\}p \\ +r_3\frac{(\alpha-\beta C_1)}{\theta_3}\left(\frac{e^{\theta_3 t_1}-1}{\theta_3}-t_1\right) + \frac{WO_3}{\theta_3}\left(1-e^{-\theta_3 t_1}\right) \\ +O_3\frac{(\alpha-\beta C_1)}{\theta_3}\left(\frac{e^{\theta_3(t_2-t_1)}-1}{\theta_3}+(t_1-t_2)\right) \\ +d\left\{\frac{(\alpha-\beta C_1)}{\theta_3}\left(e^{\theta_3 t_1}-1\right)-(\alpha-\beta C_1)t_1+W-(\alpha-\beta C_1)(t_2-t_1)\right\} \\ +n_3(\alpha-\beta C_1)(T-t_2)+l_3(1-k)(\alpha-\beta C_1)(T-t_2) \end{array}\right]$$

To minimize the total cost function $\widetilde{TC}_G(t_1,t_2)$ per unit time, the optimum value of t_1 and t_2 can be obtained by solving the following equations:

$$\frac{\partial \widetilde{TC}_G(t_1,t_2)}{t_1} = 0 \quad \text{and} \quad \frac{\partial \widetilde{TC}_G(t_1,t_2)}{t_2} = 0 \tag{21}$$

Equation (21) is equivalent to

$$\left[\begin{array}{l} \left\{\frac{de^{\theta_1 t_1}(\alpha-\beta C_1)+p(\alpha-\beta C_1)e^{\theta_1 t_1}+WO_1e^{-\theta_1 t_1} + \frac{\left(e^{\theta_1 t_1}-1\right)(\alpha-\beta C_1)r_1}{\theta_1^2} + \frac{O_1(\alpha-\beta C_1)\left(1-e^{\theta_1(t_2-t_1)}\right)}{\theta_1}}{6T}\right\} \\ +4\left\{\frac{de^{\theta_2 t_1}(\alpha-\beta C_1)+p(\alpha-\beta C_1)e^{\theta_2 t_1}+WO_2e^{-\theta_2 t_1} + \frac{\left(e^{\theta_2 t_1}-1\right)(\alpha-\beta C_1)r_2}{\theta_2^2} + \frac{O_2(\alpha-\beta C_1)\left(1-e^{\theta_2(t_2-t_1)}\right)}{\theta_2}}{T}\right\} \\ +\left\{\frac{de^{\theta_3 t_1}(\alpha-\beta C_1)+p(\alpha-\beta C_1)e^{\theta_3 t_1}+WO_3e^{-\theta_3 t_1} + \frac{\left(e^{\theta_3 t_1}-1\right)(\alpha-\beta C_1)r_3}{\theta_3^2} + \frac{O_3(\alpha-\beta C_1)\left(1-e^{\theta_3(t_2-t_1)}\right)}{\theta_3}}{T}\right\} \end{array}\right] = 0$$

and

$$\left[\begin{array}{l} \left\{\dfrac{\begin{array}{c}-kp(\alpha-\beta C_1)+d(\beta C_1-\alpha)-(1-k)(\alpha-\beta C_1)l_1\\ -(\alpha-\beta C_1)n_1+\dfrac{\left(e^{\theta_1(t_2-t_1)}-1\right)(\alpha-\beta C_1)O_1}{\theta_1}\end{array}}{6T}\right\} \\ +4\left\{\dfrac{\begin{array}{c}-kp(\alpha-\beta C_1)+d(\beta C_1-\alpha)-(1-k)(\alpha-\beta C_1)l_2\\ -(\alpha-\beta C_1)n_2+\dfrac{\left(e^{\theta_2(t_2-t_1)}-1\right)(\alpha-\beta C_1)O_2}{\theta_2}\end{array}}{T}\right\} \\ +\left\{\dfrac{\begin{array}{c}-kp(\alpha-\beta C_1)+d(\beta C_1-\alpha)-(1-k)(\alpha-\beta C_1)l_3\\ -(\alpha-\beta C_1)n_3+\dfrac{\left(e^{\theta_3(t_2-t_1)}-1\right)(\alpha-\beta C_1)O_3}{\theta_3}\end{array}}{T}\right\} \end{array}\right]=0$$

Provided it satisfies the equations

$$\frac{\partial^2\widetilde{TC}_G(t_1,t_2)}{\partial t_1^2}>0\ ,\ \frac{\partial^2\widetilde{TC}_G(t_1,t_2)}{\partial t_2^2}>0 \quad \text{and}$$

$$\left(\frac{\partial^2\widetilde{TC}_G(t_1,t_2)}{\partial t_1^2}\right)\left(\frac{\partial^2\widetilde{TC}_G(t_1,t_2)}{\partial t_2^2}\right)-\left(\frac{\partial^2\widetilde{TC}_G(t_1,t_2)}{\partial t_1^2\partial t_2^2}\right)^2>0 \qquad (22)$$

NUMERICAL EXAMPLE

To illustrate the result of the proposed model, let us consider an inventory system with the following parametric values.

Crisp Model

$\alpha=60$ units, $\beta=0.5$, $C_1=\$\ 30$/unit/day, $k=0.7$, $C_2=\$\ 10$/unit/day, $C_3=\$\ 16$/unit/day,

$p=\$\ 15$/unit/day, $\theta=0.006$, $W=100$ units, $d=\$\ 16$/unit/day, $\tilde{h}_r=\$\ 0.07$/unit,

$\tilde{h}_o=\$\ 0.06$/unit, T=365 days. The values of different parameters considered here are realistic, though these are not taken from any case study. Corresponding to these input values, the optimum value of $t_1=$ 47.4072 days, $t_2=319.925$ days and the minimum value of $TC(t_1,t_2)=\$\ 2022.03$. To show the convexity of cost function $TC(t_1,t_2)$ we plot a 3D graph. A three dimensional graph is shown in the Fig.2.

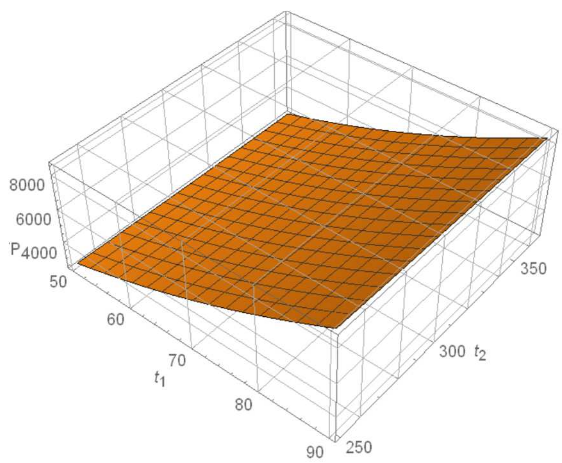

Fig. 2. The convexity of cost function

Fuzzy Model

Suppose $\tilde{h}_r = (0.06, 0.07, 0.08)$,$\tilde{h}_o = (0.05, 0.06, 0.07)$,$\tilde{\theta} = (0.005, 0.006, 0.007)$,$\tilde{C}_2 = (8, 10, 12)$, and $\tilde{C}_3 = (14, 16, 18)$ be consider as triangular fuzzy numbers and $\alpha = 60$ units, $\beta = 0.5$, $C_1 =$ \$ 30/unit, $k = 0.7$, $p =$ \$ 15/unit, $W = 100$ units, $d =$ \$ 16/unit, T= 365 days. Then the fuzzy total average cost can be determined by the Graded Mean Representation (GMIR) Method is $\widetilde{TC}_G(t_1, t_2)$= \$ 2002.17 with optimum value of $t_1 = 47.1471$days, $t_2 = 321.7036$ days.

SENSITIVITY ANALYSIS

A sensitivity analysis is carried out to study the effect of changes in the system parameters $\tilde{h}_r$,$\tilde{h}_o$,$\tilde{C}_2$,$\tilde{C}_3$, $\tilde{\theta}$. We use Mathematica11.1 software for calculation of the total cost function.

1. When $\tilde{h}_r$,$\tilde{h}_o$,$\tilde{C}_2$,$\tilde{C}_3$, $\tilde{\theta}$ are all triangular fuzzy numbers, then optimum value of $t_1 = 47.1471$days, $t_2 = 321.7036$ days with minimum total cost is $\widetilde{TC}_G(t_1, t_2)$= \$ 2002.17.
2. When $\tilde{h}_r$,$\tilde{C}_2$,$\tilde{C}_3$, $\tilde{\theta}$ are triangular fuzzy numbers, then optimum value of $t_1 = 47.1382$days, $t_2 = 319.9916$ days with minimum total cost is $\widetilde{TC}_G(t_1, t_2)$= \$ 2005.9516
3. When $\tilde{C}_2$,$\tilde{C}_3$, $\tilde{\theta}$ are triangular fuzzy numbers, then optimum value of $t_1 = 47.14025$ days, $t_2 = 319.9916$ days with minimum total cost is $\widetilde{TC}_G(t_1, t_2)$= \$ 2008.2833
4. When $\tilde{C}_2$ *and* $\tilde{C}_3$ are triangular fuzzy numbers, then optimum value of $t_1 = 47.2952$days, $t_2 = 319.7416$ days with minimum total cost is $\widetilde{TC}_G(t_1, t_2)$=\$ 2047.67

In the below tables we analyze the system parameters with different values in fuzzy sense at the same time keeping the other parameters in its original values.

Table 1. Sensitivity analysis on shortage cost parameter $\tilde{C}_2$

$\tilde{C}_2$	t_1	t_2	$\widetilde{TC}_G$
(8, 9, 10)	43.2842	312.5098	1712.145
(9, 10, 11)	47.3906	319.8978	2025.815
(10, 11, 12)	51.3978	327.1230	2362.215

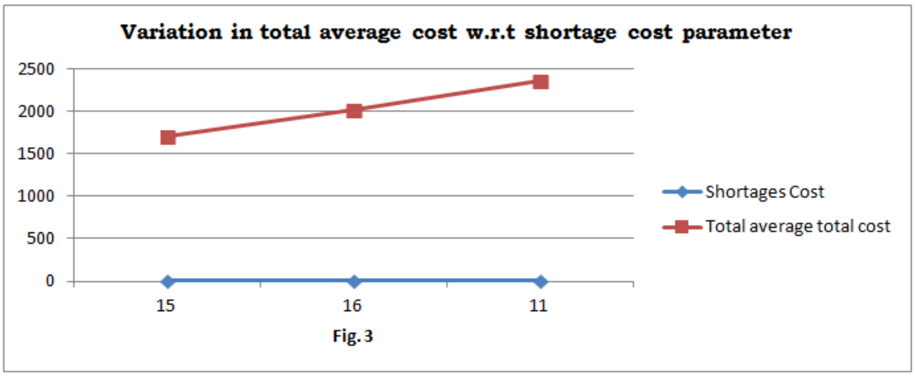

Fig. 3. Sensitivity analysis on shortage cost parameter $\tilde{C}_2$

Table 2. Sensitivity analysis on lost sale cost parameter $\tilde{C}_3$

$\tilde{C}_3$	t_1	t_2	$\widetilde{TC}_G$
(14,15,16)	46.1846	317.7236	1925.7750
(15, 16, 17)	47.4057	319.9225	2022.3683
(16, 17, 18)	48.6178	322.1065	2121.0000

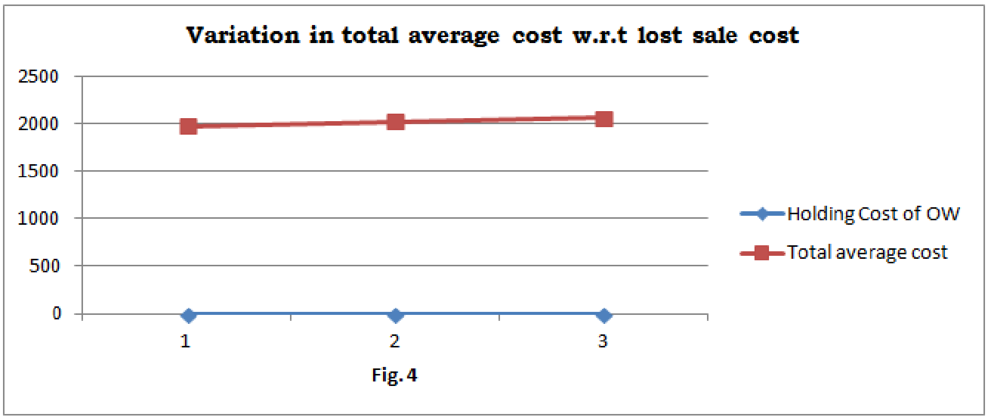

Fig. 4. Sensitivity analysis on lost sale cost parameter $\tilde{C}_3$

Table 3. Sensitivity analysis on deterioration parameter $\tilde{\theta}$

$\tilde{\theta}$	t_1	t_2	$\widetilde{TC}_G$
(0.0056,0.0058,0.006)	49.0613	326.3198	2203.9550
(0.0058,0.006,0.0062)	47.4247	319.9738	2025.8583
(0.006,0.0062,0.0064)	45.8939	313.9211	1871.3216

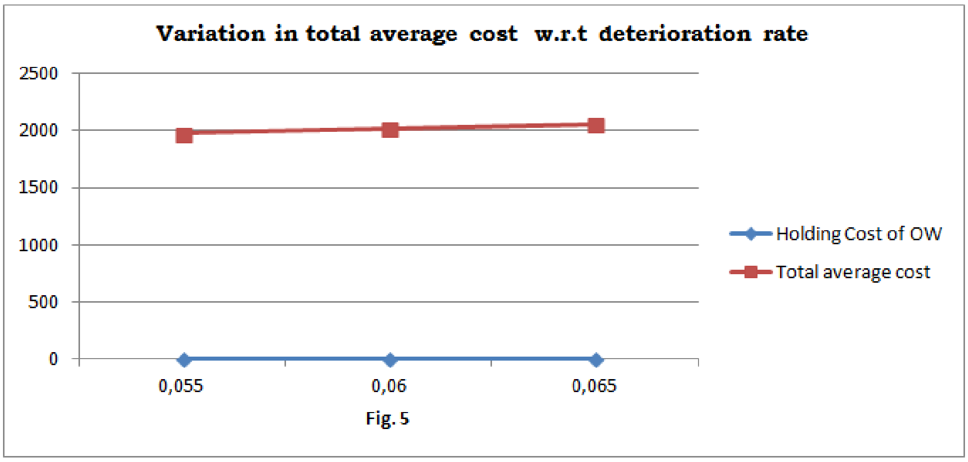

Fig. 5. Sensitivity analysis on deterioration parameter $\tilde{\theta}$

Table 4. Sensitivity analysis on holding cost parameter $\tilde{h}_o$

$\tilde{h}_o$	t_1	t_2	$\widetilde{TC}_G$
(0.05,0.055,0.06)	47.4411	331.9540	1978.4387
(0.055,0.06,0.065)	47.4072	320.1111	2021.2350
(0.06,0.065,0.07)	47.3732	309.3938	2059.2250

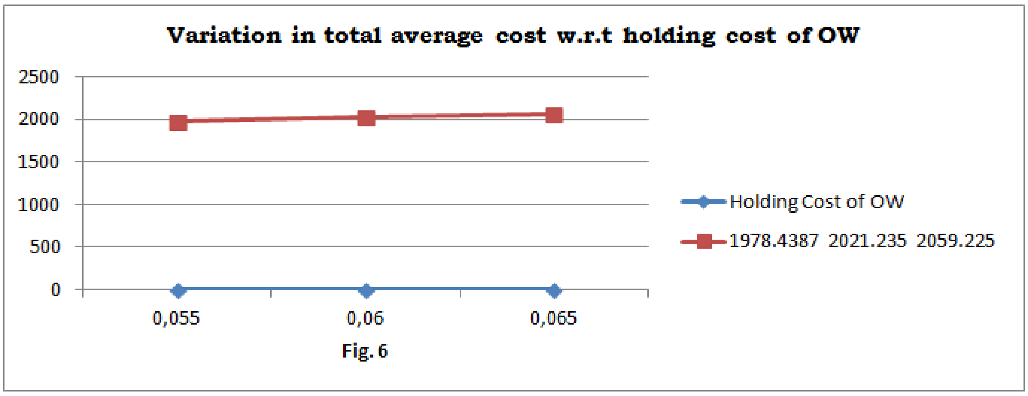

Fig. 6. Sensitivity analysis on holding cost parameter $\tilde{h}_o$

All the above observations can be sum up in fuzzy model as follows:

1) In table 1, fig. 3, if we increase the value of $\tilde{C}_2$, the optimum value of t_1 and t_2 increases. By this effect, the total average cost $\widetilde{TC}_G$ increases.

2) In table 2, fig. 4, if we increase the value of $\tilde{C}_3$, the optimum value of t_1 and t_2 increases. By this effect, the total average cost $\widetilde{TC}_G$ increases.

3) In table 3, fig. 5, if we increase the value of $\tilde{\theta}$, the optimum value of t_1 and t_2 decreases. By this effect, the total average cost $\widetilde{TC}_G$ decreases.

4) In table 4, fig. 6, if we increase the value of $\widetilde{h_o}$, the optimum value of t_1 decreases very slowly as compared to the optimum value of t_2. By this effect, the total average cost $\widetilde{TC}_G$ decreases.

CONCLUSIONS

Most of the researchers worked in two-warehouse inventory modelling have developed only crisp approach. A very few researchers extended their works in fuzzy environment. In this paper, we have developed a two-warehouse inventory model for deteriorating items with price dependent demand and shortages under partially backlogged where the demand rate is a function of selling price. Since deterioration rate, holding cost, shortage cost and lost sale are uncertain, we taken these parameters as triangular fuzzy numbers. The proposed model is discussed both in crisp and fuzzy environment. The optimum result of fuzzy model is defuzzified by Graded Mean Integration Representation (GMIR) method. From this analysis, it is concluded that due to uncertainty nature of the above system parameters, the total average cost decreases in fuzzy model as compared to crisp model. Sensitivity analysis indicates that the total cost function is more sensitive to the changes in deterioration rate. After analyze the result the decision maker can plan for the optimal value for total cost and for other related parameters.

The model can be used for the products like potato, onion, fruits etc. in the countries viz. India, Pakistan, Sri Lanka, Bangladesh etc. as the demand of the food grains increases with time for a fixed time horizon i.e. for a calendar year.

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DWUMAGAZYNOWY ROZMYTY MODEL ZAPASÓW PSUJĄCYCH SIĘ O ZAPOTRZEBOWANIU ZALEŻNYM OD CENY ORAZ UWZGLĘDNIAJĄCY BRAKI

STRESZCZENIE. **Wstęp:** W pracy zaprezentowano rozmyty model układu dwumagazynowego, składającego się z własnego magazynu (OW) oraz magazyny wynajmowanego (RW) dla asortymentów podlegających psuciu oraz o popycie zależnym od ceny przy dopuszczenia częściowych braków. Ze względu na ograniczoną powierzchnię własną magazynu, dostawca był zmuszony wynająć drugi magazyn w celu magazynowania nadwyżki. Koszt magazynu wynajmowanego jest wyższy niż koszt magazynu własnego. W pracy uwzględniono koszt utrzymywania obiektu, współczynnik psucia, koszt ubytków oraz koszt utraty sprzedaży jak liczby rozmyte.
Metody: W celu odwrócenia rozmycia funkcji całkowitego kosztu użyto metody Graded Mean Integration Representation. Otrzymane wyniki porównano z modelem Crisp przy pomocy przykładu liczbowego. Następnie wykonano analizę wrażliwości zmieniają jeden z parametrów przy utrzymaniu niezmienionych pozostałych.
Wyniki i wnioski: Wykazano, że wyniki uzyskane przy zastosowaniu metody Graded Mean Integration Representation są dokładniejsze aniżeli przy zastosowaniu modelu Crisp.

Słowa kluczowe: zapas, system dwwumagazynowy, zepsucie, braki, trójkątna liczba rozmyta, metoda Graded Mean Integration Representation

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ORIGINAL PAPER

DECOMPOSITION ANALYSIS OF FACTORS INFLUENCING SELECTED TYPES OF VEHICLE TRANSPORT IN POLAND

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ABSTRACT. Background: The paper presents the correlation between selected types of cargo transport by vehicle transport in Poland in the period 2008-2017 and selected factors influencing the types of cargo transport. The aim of this paper is to determine the correlation between vehicle transport of food products and of palletized goods, vehicle transport in total and gross domestic product (GDP).

Methods: Decomposition was conducted using the LMDI method (Logarithmic Mean Divisia Index). Three indicators were used in the analysis. The first was related to the increase and decrease in the interest in vehicle transport of food products and palletized products, the second was related to vehicle transport in general, and the third was related to changes in gross domestic product (GDP).

Results: The yearly average increase in the transport of food products in the period 2008-2017 was approximately 3.31 billion tonne-km/year and palletized goods was approximately 8.02 billion tonne-km/year. Decomposition analysis proved that the reasons for these increases are related 50% and 54% respectively to the increase in GDP, in 33% and 35% respectively to the increase of whole vehicle cargo transport and only in 17% and 11% to the interest shown by enterprises in this specific type of cargo transport.

Conclusions: The results of the analysis show that the main reason for the high increase in the transport of palletized goods and food products is the increase in economic growth expressed in GDP. The increase in vehicle transport in total has a smaller input, and the interest of enterprises in this specific type of cargo transport is the third reason in terms of its importance.

Key words: road transport, transport of food products, vehicle transport of palletized goods, decomposition analysis.

INTRODUCTION

The transport system is characterized by a set of indicators of a spatial, time, technical, organizational and economic scope, which are values that are measurable and also hard to measure (described sometimes as immeasurable ones). Transport processes can be categorized in the same way [Ide et al. 2015]. To analyse the transport system it is necessary to assign appropriate indicators to measure the quantities and values of inputs and outputs from the system [Ortuzar et al. 2011].

The transport systems, both domestic and international, determine effective and efficient goods flow and the close connection of processes between business partners on the market. The dominant position is occupied by road (vehicle) transport due to the volumes of goods transported (app. 90%) and the size of transport work (app. 80%). The organization of the transport system and the transport infrastructure in Poland and in Europe has a significant influence on many cross-sectional market, financial and operational results of cooperating enterprises, including costs, productivity, efficiency and the speed of operations, the use of resources, punctuality and the reliability of business activities [Speranza 2018].

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Efficient transport is important for the development of the Polish economy due to the fact that it provides approximately 6% of GDP yearly.

A total value of 1737.3 million tons of cargo was transported by vehicles in 2017 year, which is 13% than the previous year. The load transported by vehicle transport was 348.6 tonne-km and was 14.8% higher than in 2016. The share of food products and beverages in the total structure of domestic vehicle transport was 52.4 billion tonne-km in 2017, which means an increase of 23.3% on 2016. On the other hand, the transport of palletized goods was 131.7 billion tonne-km, indicating a rise of 13.7% on 2016 [Roczniki statystyczne GUS 2008-2017, Fechner et al. 2017].

In this paper an analysis of changes in cargo volumes by vehicle transport in Poland described by selected indicators was conducted for the following groups:

- transport of food products,
- transport of palletized products.

The selection of transport of food products for decomposition analysis was dictated by the importance of food production for Polish economy, which results in its relatively high share in total vehicle transport. On the other hand, the volume of palletized goods transport significantly influences the efficiency of the total supply chain (efficiency of logistics operations).

The aim of this paper is to determine the influence of selected factors, in terms of volume, on changes in the transport volume of food products and palletized products in the period 2008-2017.

METHODOLOGY

Decomposition analysis using the Logarithmic Mean Divisia Index method was implemented to investigate the factors influencing the volumes of transport of food products and palletized products. The following equation was used for these calculations [Ang 2016]:

$$\Delta V=\sum_{i=1}^{n}\left[\frac{V_n^t-V_n^{t-1}}{ln\left(\frac{V_n^t}{V_n^{t-1}}\right)}ln\left(\frac{x_i^t}{x_i^{t-1}}\right)\right]$$

where:

V is described by n factors (x1, x2 …),
ΔV is the sum of effects of all factors taking into account in time period [t-1, t],
t present year
t-1 previous year

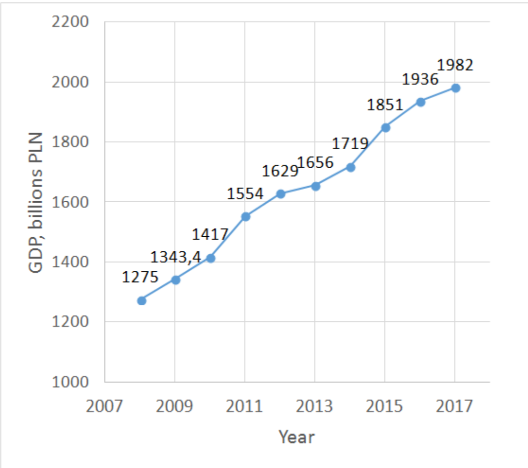
The decomposition analysis was conducted according to the methodology presented in the previous paper by the authors. The method is used mainly for research purposes, where the main aim is to determine factors that are the primary source of changes in energy consumption and environmental indicators over specific time periods [Ang 2004]. The other implementations of this method were shown in a study by [Fuji et al. 2016], where it was proposed for use in analysing innovations in green chemistry in Japan, as well as in papers related to tracking theof added value of Chinese exports [Zhao 2018] or to analyse forces propelling the economy of this country [Wang 2017].

It seems that decomposition analysis consisting of analysing the changes in the volumes of transported food products and palletized products in relations to the changes of volumes of vehicle transport as well as of Polish GDP could be useful for identifying the driving forces behind the increase in the vehicle transport of palletized goods and food products.

The data for these calculations i.e. volumes of transport of food products by vehicle transport and volumes of transport of palletized goods by vehicle transport was taken from the report "Logistics in Poland" [Fechner et al. 2017]. Central Statistical Office was the source of the information concerning the vehicle transport in total and GDP [Roczniki statystyczne GUS 2008-2017].

DISSCUSION OF FINDINGS

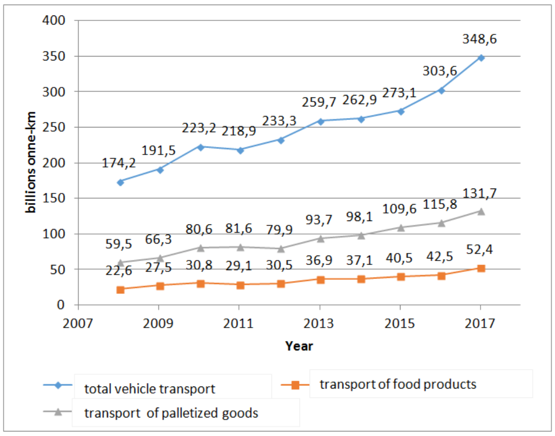
The change in Polish GDP in the period from 2008 to 2017 is presented in Figure 1. The change in the volume of total vehicle transport, vehicle transport of palletized goods and vehicle transport of food products in the same period is presented in Figure 2.



Source: own work based on GUS date

Fig. 1. GDP values in Poland in 2008-2017 years

It can be concluded from the data presented in Figures 1 and 2 that both the value of GDP and the volume of vehicle transport in this period increased significantly. Comparing the changes to 2008, it is clear that the highest growth rate of 132% was recorded for the transport of food products and 121% for palletized goods. The growth in the remaining two indicators was lower, amounting to 100% for total vehicle transport and 55% for GDP.



Source: own work based on GUS date

Fig. 2. Vehicle transport of goods: total, palletized and food products in 2008-2017 years

The changes in the vehicle transport of food products against GDP values and total vehicle transport are presented in Table 1. The influence of GDP and total vehicle transport on the changes in the volumes of vehicle transport of food products determined by the use of logarithmic decomposition LMDI is presented in Figure 3.

Table 1. The changes in transport of food products against GDP and total vehicle transport

Year	Vehicle transport of food products	Total vehicle transport	GDP	Changes in transport of food products	Influence on change of: Transport of food products	Total vehicle transport	GDP
	billion tonne-km	billion tonne-km	bilion	billion tonne-km	billion tonne-km	billion tonne-km	billion
2008	22.6	174.22	1275	0	0.00	0.00	0.00
2009	27.5	191.48	1343	4.9	2.54	1.06	1.30
2010	30.8	223.17	1417	3.3	-1.16	2.90	1.56
2011	29.1	218.89	1554	-1.7	-1.12	-3.34	2.76
2012	30.5	233.31	1629	1.4	-0.50	0.50	1.40
2013	36.9	259.71	1656	6.4	2.80	3.05	0.55
2014	37.1	262.86	1719	0.2	-0.25	-0.94	1.38
2015	40.5	273.11	1851	3.4	1.92	-1.39	2.87
2016	42.5	303.56	1936	2	-2.39	2.52	1.86
2017	52.4	348.60	1982	9,9	3.36	5.43	1.11
Total	-	-	-	29.8	5.2	9.79	14.79

Source: own calculations based on GUS date

To determine precisely the factors influencing the increase in the vehicle transport of food products in the form of quantity correlation, LMDI decomposition analysis was used [Fujii, 2016]. Three indicators were used during this analysis. The first (FoodTranspPrio) gives information about changes in the interest in enterprises' own and ordered transport of food products, the second one (RoadTransp) indicates the influence of the growth of total vehicle transport on the transport of food products, while the third one

(GDP) shows the influence of GDP on the transport of food products.

Decomposition analysis was conducted according to the following equation:

$$FoodTransp = \left(\frac{FoodTransp}{RoadTransp}\right) \cdot \left(\frac{RoadTransp}{GDP}\right) \cdot GDP$$

$$= FoodTransPRIO \cdot RoadTranspPRIO \cdot SCALE$$

to compare the changes in various years:

$$\frac{FoodTransp^t}{FoodTransp^{t-1}} = \frac{FoodTranspPRIO^t}{FoodTranspPRIO^{t-1}} \cdot \frac{RoadTranspPRIO^t}{RoadTranspPRIO^{t-1}} \cdot \frac{SCALE^t}{SCALE^{t-1}}$$

where:
t means present year and
t-1 previous year

After finding the logarithm and multiplying by coefficient:

$$\omega^t = \frac{FoodTransp^t - FoodTransp^{t-1}}{\ln(FoodTransp^t) - \ln(FoodTransp^{t-1})}$$

the following equation was obtained:

$$\Delta FoodTransp^{t,t-1} = \omega^t ln\left(\frac{FoodTranspPRIO^t}{FoodtranspPRIO^{t-1}}\right) + \omega^t ln\left(\frac{RoadTranspPRIO^t}{RoadTranspPRIO^{t-1}}\right) + \omega^t ln\left(\frac{SCALE^t}{SCALE^{t-1}}\right)$$

A similar method was used to analyse the vehicle transport of palletized goods. The influence of selected factors on the vehicle transport of food products and palletized goods was analysed on the basis of the data obtained.

CORRELATION ANALYSIS OF VEHICLE TRANSPORT OF FOOD PRODUCTS

It can be concluded on the basis of data from Table 1 and Figure 3 that changes of GDP have the biggest and most positively stable influence on the changes in the transport of food products.

Source: own calculations

Fig. 3. Impact of GDP and total vehicle transport on the changes in volumes of transport of food products

The accumulated impact during the period of nine years is at the level of 14.79 billion tonne-km, which constitutes 49.6% of the total impact on the changes in vehicle transport of food products, estimated at the level of 29.8 billion tonne-km.

The influence of the volumes of total vehicle transport imitates the trend in changes in the transport of food products and shows, especially a positive impact, but also a negative one, as a result of which the sum of values of influences is 9.79 billion tonne-km. Therefore the influence given in a percentage is relatively high, standing at 32.9%.

The calculated volumes of the influence of interest in transport of food products show low values and big changes and as a result give the low value of the influence indicator - 5.2 billion tonne-km - which is translated into 17.5% of influence on the increase in the transport of food products.

It can be concluded in general that the average yearly increase in the transport of food products in the 2008-2017 period is at the level of 29.8 billion tonne-km/9 years = 3.31 billion tonne-km/year. 50% of this increase is due to GDP growth, 33% of this increase is due to the growth in the total increase in vehicle transport and only slightly more than 17% is due to the increase in the interest of enterprises in vehicle transport of food products.

CORRELATION ANALYSIS OF VEHICLE TRANSPORT OF PALLETIZED GOODS

Analysing the reasons for the increase in the transport of palletized foods, a similarity can be observed with a previous case where the changes in GDP result in a stable increase in this type of transport of 39.19 billion tonne-km over the period of 9 years. This ensures the high impact on the increase of transport of palletized goods - 54.2%.

Table 2. The changes in transport of palletized goods against GDP and total vehicle transport

Year	Vehicle transport of palletized goods	Total vehicle transport	GDP	Change in vehicle transport of palletized good	Influence on changes in		
					Transport of palletized goods	Total vehicle transport	GDP
	billion tonne-km	billion tonne-km	billion	billion tonne-km	billion tonne-km	billion tonne-km	billion
2008	59.5	174.22	1275	0	0	0	0
2009	66.3	191.48	1343	6.8	0.86	2.67	3.27
2010	80.6	223.17	1417	14.3	3.09	7.28	3.93
2011	81.6	218.89	1554	1.0	2.57	-9.06	7.48
2012	79.9	233.31	1629	-1.7	-6.85	1.35	3.81
2013	93.7	259.71	1656	13.8	4.52	7.86	1.42
2014	98.1	262.86	1719	4.4	3.24	-2.42	3.58
2015	109.6	273.11	1851	11.5	7.53	-3.71	7.68
2016	115.8	303.56	1936	6.2	-5.71	6.85	5.06
2017	131.7	348.60	1982	15.9	-1.20	14.19	2.90
Total	-	-	-	72.2	8.05	25.01	39.13

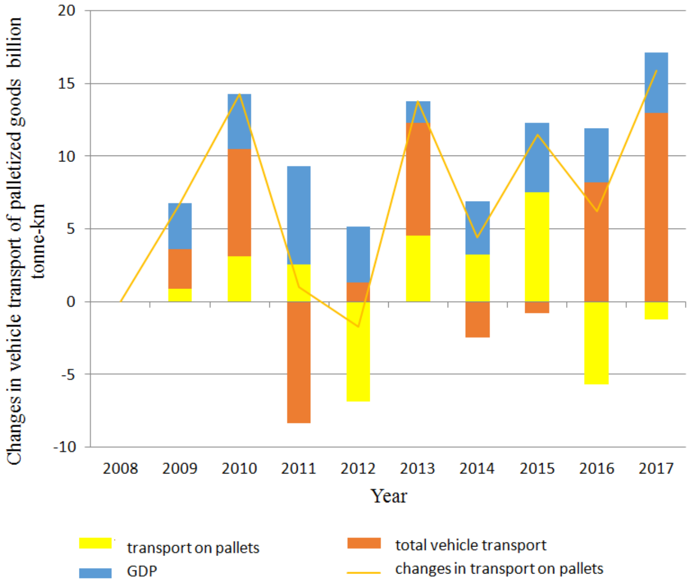
Source: own calculations based on GUS date

The influence of total volumes of vehicle transport mirrors the same trend as the change in the transport of palletized goods and shows both a positive and negative impact in particular years. The total sum of the value of influences is 25.01 tonne-km, which gives a total increase in transport of 34.6%.

The volume of influences of interest of enterprises on transport of palletized goods that were calculated show a great yearly fluctuation around zero, which as a result has a low impact on the increase of transport of palletized goods of only 11,2%.

It can be concluded that the average yearly increases in the transport of palletized foods in the period 2008-2017 are at the level of 72.2 billion tonne-km/9 years = 8.02 billion tonne-km/year. 54% of this increase is due to GDP growth, almost 35% of this increase is due to the growth in the total increase of vehicle transport and only a little above 11% is due to the increase in the interest of enterprises in vehicle transport of palletized goods.

These results of the analysis of factors influencing the increase in the transport of food products and also palletized foods enable this trend to be interpreted in a different way from the traditional one. These findings lead to the conclusion that the increase in GDP is the main factor in the increase in the transport of food products and palletized goods, the second factor (of importance) is the increase in total vehicle transport, while the third most important factor is the increase in interest in this type of transport.



Source: own calculations

Fig. 4. Impact of GDP and total vehicle transport on the changes in volumes of transport of palletized goods

CONCLUSIONS

It can be concluded from the results of this analysis that the high values of indicators of the increase of transport of food products as well as for palletized foods from 2008-2017 are 50% due to the increase in economic development expressed in GDP and 33% due to the high speed of the increase of total vehicle transport. The third reason of significance is interest in this type of transport. This factor stood at 17% of all factors for foods products and 11% for palletized goods.

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ANALIZA DEKOMPOZYCYJNA CZYNNIKÓW WPŁYWAJĄCYCH NA WYBRANE RODZAJE PRZEWOZÓW ŁADUNKÓW TRANSPORTEM SAMOCHODOWYM W POLSCE

STRESZCZENIE. **Wstęp:** Artykuł analizuje korelacje pomiędzy wybranymi rodzajami przewozu ładunków transportem samochodowym w Polsce w latach 2008 – 2017, a określonymi czynnikami wpływającymi na rodzaje przewozów ładunkowych. Celem pracy jest określenie korelacji pomiędzy przewozami transportem samochodowym produktów spożywczych oraz spaletyzowanych, transportem samochodowym ogółem i PKB (Produkt Krajowy Brutto) oraz korelacji pomiędzy tak dobranymi zmiennymi.

Metody: Dekompozycję wykonano metodą logarytmicznej średniej ważonej indeksu Divisia LMDI (Logarithmic Mean Divisia Index). W analizie wykorzystano trzy wskaźniki. Jeden odnosił się do wzrostu lub spadku zainteresowania transportem samochodowym w przewozie produktów spożywczych lub ładunków spaletyzowanych, drugi odnosił się do transportu samochodowego ogółem, a trzeci do zmian PKB.

Wyniki: Średnio roczne przyrosty przewozów produktów spożywczych w latach 2008-17 kształtują się na poziomie 3,31 mld tkm/rok, a przewozów ładunków paletowych 8,02 mld tkm/rok. Analiza dekompozycyjna wskazuje, że przyrosty te wynikają odpowiednio w 50% i 54% ze wzrostu PKB, w 33% i 35% ze wzrostów przewozów samochodowych ładunków ogółem, a tylko w 17 % i 11% ze wzrostu zainteresowania przedsiębiorstw danym rodzajem gałęzi transportu w przewozach ładunków.

Wnioski: Wyniki przeprowadzonych analiz wykazują, że główną przyczyną wysokiego wzrostu przewozów produktów spożywczych oraz ładunków na paletach jest wzrost rozwoju gospodarczego wyrażonego w PKB. W mniejszym natomiast stopniu wpływa na to rozwój przewozów samochodowych ogółem, a dopiero trzecim czynnikiem rozwoju jest większe zainteresowanie przedsiębiorstw danym rodzajem przewozów.

Słowa kluczowe: transport samochodowy, przewozy produktów spożywczych, transport samochodowy ładunków na paletach, analiza dekompozycyjna

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ORIGINAL PAPER

AN EXAMINATION OF LOTKA'S LAW & AUTHOR'S PRODUCTIVITY IN THE FIELD OF SUPPLY CHAIN MANAGEMENT

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ABSTRACT. **Background:** The development of supply chains appeared in a structured way in the 1990s. Previous studies have not examined in detail the research productivity patterns of the distribution of individual supply chain management authors with a lengthy time frame. Previous studies have also not set standards of individual research productivity, in terms of both quantity and quality, which are necessary to be ranked among the leading contributors in the field.

Methods: To address the above mentioned issue in this field, the paper examine 458 articles written by 980 authors from 2005 through 2014. The study presents six metrics concerning quality and quantity of productivity and identifies the aggregate productivity standards necessary for individual authors to be ranked at various positions in the field of supply chain management. In the last, the paper examines the validity of Lotka's law to authorship pattern in the field of supply chain management. Lotka's law was tested using generalized form, and K-S goodness-of-fit tests were applied.

Results: This study provides a set of comprehensive, useful and recent standards for individual publication productivity in supply chain management discipline within the selected journal outlets. The findings suggests that to be in position top 10, top 20, and top 50 an author required h-index value 4, 3, and 2 respectively. This work contributes to the literature by identifying standards of individual research performance across six different metrics of quantity and/or quality. The results can inform current supply chain management scholars and administrators of productivity standards as implicitly established by the body of scholars in the SCM field.

Conclusions: The result found that the author productivity distribution data in the supply chain management field follow Lotka's law. The results of this study provide a new outlook on supply chain management research. In the last, major research areas and potential future directions were also provided.

Key words: supply chain management, benchmarking, authorship pattern, Author's productivity, K-S test, Lotka's law.

INTRODUCTION

The research played an important role in knowledge discovery of a discipline [Powers et al. 1998]. Thus examining trends and productivity patterns in academic research have been of scholarly interest because it helps in defining individual careers and institutional success within the field [Shrivastava, Kumar 2019, Kumar 2016]. This has certainly been true of supply chain management, where [Kumar, Kushwaha 2015, Kumar 2016] among many others, have helped to understand the state of development of the supply chain management field. These types of studies also provide some degree of productivity for individual authors and institutions as they show research outcome and see progress toward such goals. Publication productivity assessments provide useful information which can be useful in faculty recruitments, promotion and tenure decisions. However, the previous literature on research and publication productivity in supply chain management has been largely concentrated on a number of publications by an individual or the institute [e.g. Kumar, Kushwaha 2015]. Prior research has largely focused on quantity measures (such as a number of publications), and not as much

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on quality measures (such as the number of citations received). Thus, the previous study does not provide particular standards of productivity of an author that can necessarily be used directly by an individual researcher to assess their contributions.

The aim of the study is to address these gaps in the literature by addressing the key question: what are the appropriate standards for excellence in publication productivity in Supply chain management. The aim of this paper is to provide a set of empirical standards for establishing research productivity. In sum, we identify the particular standards of performance that are necessary to place an individual at various positions of publication productivity in supply chain management. Using a time frame of 10 years (2005-2014) of publications from supply chain management: an international journal, we investigated four general research questions, three are based on the study of [Coleman et al. 2012] for the field of supply chain management as well as in the last question testing the Lotka's law for the dataset.

1. How many articles are required for an author to be ranked among the leaders in supply chain management publication productivity to measure quantitative productivity?
2. How many citations are required for an author to be ranked among the leaders in supply chain management to measure quality productivity?
3. What level of combined quantity and quality is required to be ranked among the leaders in supply chain management publication productivity?
4. Does the dataset follow the Lotka's law?

Furthermore, to measure the productivity in a quantitative way, we use two versions of a number of publications in this study. A number of publications represent the frequency of an author's contribution to the field and are perhaps the most commonly used method of research productivity in the academic field. Similarly, we use two versions of a number of citations in this study to measure the productivity in terms of quality. Finally, as a combination of quality and quantity measure, we use h-index to present the productivity. h-index is a popular measure because it provides the broad impact of a scientist's cumulative research contributions [Hirsch 2005] and combines a number of publications and citation counts in a "balanced way" [Shrivastava, Kumar 2019]. The paper is organised as in the next section 2, an overview of previous literature; in the next section 3 research methodology; in the next section 4, an analysis with the results; in the next section 5 testing of Lotka's law; next in section 6 conclusions and in the last section 7 limitations and future research scope of this study presented.

LITERATURE REVIEW

These days it is common in most of the discipline to rank and evaluate the research productivity. Even many European countries are in the process of developing national measures of research quality and impact [Harland 2013]. An objective way of measuring productivity through no of publications of an individual or an institution and number of citations an article received used by various researchers in the different domain of research [Shrivastava, Kumar 2019, Kumar 2016, Tsai, Chi 2011].

The study conducted by Valencia [2004], in the Philippines since 1998-2002 for science and engineering departments of the two lead research universities and found that the average productivity of the faculty surveyed is less than one.

Swihart et al. [2016], conducted research on 437 tenure-track faculty members at 33 universities in the United States belonging to the National Association of University Fisheries and Wildlife Programs. For each faculty member, they computed 8 commonly used performance metrics based on numbers of publications and citations. They found that there is variation in publication and citation metrics due to academic age, sex, research appointment, and sub-disciplinary focus.

Due to the importance of research in the field of SCM, many papers published in SCM journals over the last decade related to research productivity, impact, and/or quality [Gorman, Kanet 2011, Ellinger, Chapman 2011, Rao et al. 2013, Maloni et al. 2009, Kumar 2016, Shrivastava, Kumar 2019].

Kumar [2016] presented productivity by year of publication, study type, methodology, type of supply chain investigated, authorship pattern, country wise distribution of articles. Crum et al. [2011] do the same for the first 40 years of the International Journal of Physical Distribution and Logistics Management. Kumar and Kushwaha [2015], presented a number of publications by an individual author/ institute from 2005-14 in the supply chain management field through a single journal. Most of these studies are either based on a number of publications of an individual or number of publications of an institute in a particular discipline. In the present scenario, the focus has been shifted from the quantitative & qualitative analysis of productivity to the combined productivity of an individual to set standards for productivity measurement. However, such research is very limited in the field of supply chain management. While the aforementioned studies have made important contributions to the supply chain management discipline, there remains an opportunity for additional research that identifies individual publication productivity standards in terms of both quantity and quality. Addressing these opportunities is the rationale for the current research.

RESEARCH METHODOLOGY

The study examined the authorship of each article published in the 10-year period from 2005-2014, in the supply chain management: an international journal. Emerald was used as the source for data collection. Over the years of 2005-2014, a total number of 458 articles from supply chain management: an international journal abstract has been downloaded from the website. The required data of all the articles related to the productivity analysis, such as the title of the articles, number of authors etc. were taken from the Emerald database. Our data set includes 458 articles, a number that represents a near to 50% of all articles published so far since journal start publishing [1996] over this 10-year span. The new articles excluded from dataset intentionally because new articles do not have citations and the results may be biased. Thus to avoid this, this dataset was chosen for the study purpose.

The collection of the various author names associated with each article helped us to develop quantitative metrics for each author. For quality measurement of each contribution, we also collected the number of citations that were generated by each article as of May 2016. Authors used Google Scholar instead of the Thomson ISI Web of Science to calculate its citations because it is freely available to anyone [Bosman et al. 2006] and presents a better complete picture of an academics impact than the Thomson ISI Web of Science. The study conducted by [Meho, Yang 2007], concluded that there is no significant change in the ranking of the academics when citations are calculated using Google scholar and web of science.

The use of citations in this study helps specifically to captures each author's collective contribution to the field. While recently published papers by newer contributors to the field, by definition received lower citation counts, this lower score is arguably appropriate given the still-limited exposure of the article / author. While authors in such a position may be strong researchers, they clearly have not yet established themselves as productive authors in the field.

To answer our first research question setting standards for a number of articles an author needs to be among the leading contributors to the supply chain management field. We computed two versions of an article count for each author through direct count method and equal credit method. The direct count method assigns a value of 1.0 for each author, regardless of the number of authors. This metric gave full credit for an article to each and every author on that article and treated single authorship and joint authorship as the same, but this approach is seen as having two major drawbacks. First, researchers who tend to work independently can potentially receive lower scores than researchers who tend to work collaboratively. Second, this method negatively impacts the ranking of those who tend to co-author a large number of papers with multiple authors while keeping their contribution to each paper marginal. This approach was used in various past studies [Kumar, Kushwaha 2015, Shrivastava, Kumar 2019, Kumar 2016].

For the measurement of the second version of quantity, we employed an equal credit method. In this method, each author receives an equal portion of the score regardless of the authorship order. This addresses the problems discussed above. A per-person score is obtained by taking the inverse of the number of authors. For instance, an author of a single work receives1 point; each author of a two-authored work obtains as a score of 0.5; three-authored, 0.333, etc. This method was employed in other previous studies [Maloni et al. 2009, Shrivastava, Kumar 2019].

To address our second research question regarding yardsticks/standards value for the publication quality threshold necessary to be among the leading contributors to the supply chain management field. Again, we computed two versions of a citation count for each author. One represented the total number of citations received for all articles on which that individual appeared as an author, i.e. direct count method. Like our first quantity measure, this metric gave full credit for all of an article's citations to each and every one of its authors, regardless of the number of authors. The second version of quality metric developed by equal credit method, where the citation credit assigned to each author on a given article was computed as the number of citations for that article, divided by the number of authors. For examples, on a two-author article with 100 citations, each author would be assigned credit for 50 citations, whereas each author on a three-author article with 100 citations would receive credit for 33.33 citations.

Now how the answer for research question third can be obtained by identifying the combination of quantity and quality necessary to be among the leaders in supply chain management research. The literature provides an option for combining quantity metrics (as measured by a number of publications) and quality metrics (as measured by citation counts): the Hirsch index, or h-index. This index was first used by Hirsch in 2005. According to Hirsch [2005] "A scientist has index h if h of his or her Np papers have at least h citations each and the other (Np - h) papers have <h citations each", where Np = number of papers. Thus, to address our third research question, we computed two versions of the h-index of each author in our sample, First one, by direct count method and another through equal credit method.

Once the raw values of each metric were computed for each author, we prepared frequency tables based on each of the six metrics (two quantity, two quality, and two combined), and arranged each frequency table from the highest value of the metric to the lowest and assign the rank. This approach gives us six separate publication productivity rankings tables. For each table, we also computed the percentile associated with each value of the metric; i.e., the percentage of all authors in the data with totals below that threshold. The resulting tables thus allow any author to easily compare his/her own totals to the entire distribution of authors that have published in this journal from 2005-2014, and to determine where they would have ranked as well as what percentage of the authors in the discipline they would have surpassed. We examine the tables to identify the minimum value necessary to lead the discipline, and to rank at various positions in the field according to each metric (e.g., the top 10, top 20, top 50, etc.).

Lokta's law

In the last Lotka's law was tested to see that our dataset follows it or not. Lotka's law is used to measure the author productivity in the given field. Lotka's basic proposition was that about 60 percent of authors who contribute to a given field make only one contribution to that field, and the pattern of contributions of more productive authors can be described by the equation

$$f(x) = C/x^n$$

where x is the number of papers published in a period; f (x) is the number of authors publishing x papers; n is a parameter to be determined from the data that taking a value close to two, and C is a normalizing constant that the sum over all x of the f (x) is equal to one.

RESULT ANALYSIS

Among the 458 articles collected, a total of 980 different individuals contributed at least one paper, indicating an average of 2.14 authors on each article, and an average of .47 articles for each author.

Table 1 contains the ranking table for a total number of articles based on the direct count method, and Table 2 contains the ranking table for a total number of articles based on equal credit method. It would be worth mentioning here that the ranks are shown in these, and the subsequent tables reflect the impact of ties in the particular metrics. (For example, in Table 1 the ranking jumps from 3 directly to 7 at one point. This implies that three authors were tied for the 10th position).

Table 1. Ranking based on the number of publications through the direct count

Rank	No of papers	Percentile
1	9	99.9
2	8	99.8
3	6	99.69
7	5	99.39
9	4	99.18
18	3	98.26
31	2	96.94
126	1	87.24

From the Table 1, it is clear that the highest number of articles published during our study time period 9, with only two authors have published more than 6 articles. Further analysis of the number of articles depicts that the necessary minimum value for the top 10, top 20, and top 30 were 4, 3, and 2 articles, respectively.

Table 2. Ranking based on the number of publications through equal credit method

Rank	No of papers	Percentile	Rank	No of papers	Percentile
1	4.5	99.9	32	1.06	96.74
2	4.33	99.8	33	1	96.64
3	3.52	99.69	96	0.92	90.2
4	3.5	99.59	98	0.83	0.9
5	2.41	99.49	115	0.78	88.27
6	2.33	99.39	116	0.75	88.17
8	2.25	99.18	124	0.7	87.34
9	2.16	99.08	125	0.67	87.24
10	2	98.98	144	0.6	85.31
12	1.83	98.76	145	0.58	85.21
13	1.75	98.66	155	0.57	84.18
14	1.72	98.56	156	0.53	84.08
15	1.56	98.46	162	0.5	83.47
16	1.53	98.36	407	0.45	58.47
17	1.5	98.26	412	0.4	57.96
24	1.41	97.55	413	0.33	57.86
25	1.33	97.45	722	0.3	26.33
27	1.2	97.25	730	0.25	25.51
28	1.16	97.15	913	0.2	6.84
30	1.08	96.94	959	0.16	2.14

From the table 2 which is based on equal credit method, it is clear that for necessary minimum value for the top 10, top 20 and top 30 were 2, 1.5 and 1.08 articles respectively. So to be in the top 50 an author needs at least 1 publication while a total of .83 articles would have placed an author in the top 100.

Table 3 is showing the rank-ordered citation frequencies through the direct count method. From the table 3 it is clear that top rank holders are having 1027 citations while the second rank holder is quite back and having 602 citations. Furthermore, the table indicates that to be in the top 10, top 20, top 50 and top 100, an author need to be 380, 290, 214 and 166 citations respectively. From the table it is also clear that about 81% of authors have less than 100 citations. .20 % of the authors have to be cited yet so it means 99.8 % of the authors have been cited. It signifies that the authors included in the dataset are doing good quality research in the field of supply chain management.

Table 3. Ranking based on citations through direct count method

Rank	Citations direct count method	Percentile	Rank	Citations direct count method	Percentile	Rank	Citations direct count method	Percentile
1	1027	99.9	115	154	88.28	337	63	65.61
2	602	99.8	116	151	88.18	340	61	65.31
5	537	99.48	117	148	88.08	346	60	64.69
6	466	99.38	118	146	87.96	349	58	64.39
7	422	99.28	120	145	87.76	355	57	63.78
8	417	99.18	121	144	87.66	358	56	63.48
9	380	99.08	123	137	87.56	363	55	62.96
11	355	98.88	125	136	87.36	365	54	62.76
14	349	98.57	127	133	87.16	366	53	62.66
16	318	98.37	130	132	86.73	372	52	62.04
17	316	98.27	133	130	86.43	379	51	61.33
18	306	98.17	134	128	86.33	380	50	61.23
19	290	98.07	135	126	86.23	386	49	60.61
21	281	97.86	137	125	86.03	391	48	60.11
22	277	97.76	139	124	85.82	397	47	59.49
23	275	97.66	140	122	85.72	405	46	58.67
25	266	97.46	142	121	85.52	410	45	58.16
26	259	97.36	144	117	85.32	422	44	56.94
29	249	97.06	145	116	85.22	427	43	56.44
30	248	96.94	149	115	84.79	439	42	55.2
31	244	96.84	151	114	84.59	442	41	54.89
33	243	96.64	155	110	84.19	454	40	53.67
37	241	96.22	158	108	83.88	460	39	53.06
38	240	96.12	166	107	83.06	473	38	51.73
39	238	96.02	168	106	82.86	482	37	50.82
40	225	95.92	170	104	82.66	496	36	49.39
41	224	95.82	171	103	82.56	508	35	48.16
43	221	95.62	179	102	81.73	513	34	47.65
45	220	95.42	182	101	81.43	524	33	46.53
46	219	95.32	183	100	81.33	535	32	45.41
48	214	95.12	185	98	81.12	548	31	44.08
52	213	94.69	189	97	80.71	560	30	42.86
53	212	94.59	193	96	80.31	570	29	41.84
55	211	94.39	198	95	79.79	581	28	40.71
56	207	94.29	200	94	79.59	591	27	39.69
57	201	94.19	204	93	79.18	604	26	38.37
60	199	93.88	207	92	78.88	614	25	37.35
63	197	93.58	208	91	78.78	616	24	37.15
64	195	93.48	210	89	78.58	643	23	34.39
67	193	93.18	215	88	78.06	650	22	33.67
68	192	93.08	218	87	77.76	664	21	32.24
69	187	92.96	224	86	77.14	683	20	30.3
71	179	92.76	228	83	76.73	705	19	28.06
72	178	92.66	233	82	76.22	722	18	26.32
73	177	92.56	241	81	75.41	728	17	25.71
74	176	92.46	246	80	74.89	739	16	24.59
78	174	92.06	253	79	74.18	756	15	22.85
79	173	91.94	257	77	73.78	768	14	21.63
80	172	91.84	264	76	73.06	791	13	19.28
81	171	91.74	274	75	72.04	813	12	17.04
85	170	91.34	279	74	71.53	826	11	15.71
89	168	90.92	286	73	70.82	843	10	13.98
92	167	90.62	295	72	69.89	860	9	12.24
98	166	90	305	71	68.88	873	8	10.92
101	165	89.69	310	70	68.37	890	7	9.18
103	163	89.49	313	69	68.07	899	6	8.27
105	161	89.29	322	68	67.14	922	5	5.92
107	160	89.09	327	67	66.63	936	4	4.49
109	158	88.88	328	66	66.53	954	3	2.65
110	157	88.78	331	65	66.23	957	2	2.35
112	155	88.58	332	64	66.13	962	1	1.8
						979	0	0.1

Table 4. Ranking based on citation through equal credit count

Rank	citation through Equal credit method	Percentile	Rank	citation through Equal credit method	Percentile	Rank	citation through Equal credit method	Percentile
1	780.5	99.9	155	44	84.19	429	17	56.23
2	330.66	99.8	162	43.5	83.47	435	16.5	55.61
3	266	99.69	163	42.75	83.37	440	16	55.11
4	249	99.59	166	42.5	83.07	446	15.83	54.49
5	243	99.49	170	42.39	82.65	447	15.66	54.39
6	240	99.39	171	42	82.55	448	15.5	54.29
7	232	99.29	172	41.75	82.45	450	15.33	54.09
8	224.58	99.19	175	41	82.15	452	15	53.88
9	217	99.09	177	40.66	81.94	462	14.5	52.86
10	193.06	98.97	179	40.5	81.74	467	14	52.36
11	183.5	98.87	184	40.25	81.24	472	13.8	51.84
12	178	98.77	185	40	81.14	476	13.66	51.44
13	174.5	98.67	187	38.99	80.92	486	13.5	50.41
15	168.13	98.47	188	38.66	80.82	488	13.16	50.21
18	168	98.16	191	38.5	80.52	489	13	50.11
19	159	98.06	194	38	80.22	492	12.7	49.79
20	156.33	97.96	196	37.5	80.02	493	12.66	49.69
21	155	97.86	198	37	79.79	497	12.5	49.29
22	153	97.76	200	36.66	79.59	501	12.33	48.88
23	147.5	97.66	203	36.33	79.29	504	12	48.58
24	141.5	97.56	204	36	79.19	517	11.75	47.24
25	138.5	97.46	211	35.32	78.47	521	11.66	46.84
26	126	97.36	213	35	78.27	522	11.5	46.74
28	118.33	97.16	215	34.5	78.07	523	11.33	46.64
31	112.8	96.84	218	34.33	77.75	527	11.25	46.24
32	112	96.74	223	34.23	77.25	529	11.2	46.04
34	110.5	96.54	224	34	77.15	530	11	45.92
36	108	96.34	231	33.5	76.43	537	10.75	45.2
37	106	96.24	232	32.66	76.33	545	10.66	44.39
39	100	96.04	234	32.33	76.13	550	10.5	43.88
40	99.83	95.92	237	32	75.82	556	10	43.27
41	98.5	95.82	242	31.49	75.32	560	9.8	42.86
42	98.33	95.72	243	31.33	75.22	564	9.66	42.46
43	97.66	95.62	246	31.25	74.89	569	9.5	41.94
44	96.66	95.52	247	31	74.79	585	9.33	40.31
46	95	95.32	250	30.5	74.49	591	9.25	39.69
47	93	95.22	251	30.33	74.39	599	9	38.88
48	91.66	95.12	253	29.83	74.19	613	8.66	37.45
50	88	94.89	254	29.33	74.09	620	8.5	36.73
51	86.33	94.79	256	29	73.88	629	8.33	35.82
54	85.5	94.49	258	28.75	73.68	631	8	35.62
56	84	94.29	261	28.5	73.38	642	7.91	34.49
57	81.5	94.19	264	28	73.08	647	7.66	33.97
60	81	93.88	265	27.5	72.96	652	7.5	33.47
63	80	93.58	267	27.33	72.76	662	7.33	32.45
64	79.16	93.48	271	27.16	72.36	670	7.2	31.63
65	79	93.38	272	27	72.26	671	7	31.53
66	76	93.28	273	26.66	72.16	676	6.75	31.03
67	74	93.18	274	26.5	72.06	680	6.66	30.61
69	73.33	92.96	275	26.33	71.94	694	6.5	29.18
70	73	92.86	281	26.32	71.34	710	6.33	27.55
74	72.5	92.46	282	26	71.24	715	6.08	27.04
75	72	92.36	286	25.76	70.82	717	6	26.84
79	70.99	91.94	287	25.75	70.72	729	5.66	25.61
80	70.25	91.84	290	25.66	70.42	731	5.5	25.41
81	70	91.74	293	25.33	70.12	740	5.4	24.49
82	69	91.64	302	25.32	69.18	744	5.33	24.08
83	68.5	91.54	304	25	68.98	750	5.25	23.47
85	68	91.34	305	24.5	68.88	759	5	22.55
86	67.83	91.24	307	24.33	68.68	776	4.75	20.82
87	67.33	91.14	314	24	67.96	777	4.66	20.72
88	66.5	91.04	318	23.75	67.56	780	4.6	20.42
90	65.16	90.82	319	23.5	67.46	781	4.5	20.32
91	65	90.72	322	23.33	67.14	790	4.43	19.39
96	63	90.22	323	23	67.04	797	4.33	18.67

Rank	citation through Equal credit method	Percentile	Rank	citation through Equal credit method	Percentile	Rank	citation through Equal credit method	Percentile
98	62.5	90.02	328	22.83	66.53	802	4.2	18.16
100	62.41	89.79	329	22.25	66.43	805	4	17.86
103	62	89.49	333	22	66.02	830	3.66	15.31
104	61	89.39	338	21.75	65.51	835	3.5	14.79
105	60.5	89.29	342	21.66	65.1	841	3.4	14.18
107	59.66	89.09	343	21.5	65	842	3.33	14.08
108	59.5	88.98	351	21.4	64.18	850	3.25	13.27
109	58.75	88.88	352	21.33	64.08	855	3	12.76
110	57	88.78	357	21.16	63.57	865	2.8	11.73
111	55.66	88.68	358	21	63.47	870	2.75	11.23
113	55.58	88.48	361	20.91	63.17	872	2.66	11.04
114	55.33	88.38	362	20.75	63.07	875	2.5	10.71
117	54	88.08	363	20.57	62.96	879	2.33	10.31
122	53.5	87.55	364	20.5	62.86	891	2.2	9.08
128	53	86.94	371	20.33	62.16	896	2	8.57
130	52	86.74	375	20.25	61.73	906	1.75	7.55
131	51.75	86.64	377	20	61.53	908	1.66	7.35
132	51.66	86.54	384	19.5	60.82	920	1.6	6.12
136	51	86.14	390	19.33	62.22	925	1.5	5.61
137	50.25	86.04	392	19.25	62.02	931	1.33	5
140	49	85.71	393	18.66	59.89	934	1.2	4.69
142	48.8	85.51	397	18.5	59.49	943	1	3.78
146	48	85.11	405	18.25	58.67	957	0.66	2.35
148	46.5	84.89	408	18	58.37	962	0.5	1.84
149	46.33	84.79	417	17.75	57.45	964	0.33	1.63
150	45	84.69	421	17.66	57.05	970	0.25	1.02
152	44.72	84.49	424	17.5	56.73	973	0.16	0.71
153	44.5	84.39	426	17.33	56.53	979	0	0.1

Table 4 is showing the ranking based on citations through equal credit method. It is clear from the table that to be at first place an author needs 780.5 citations while for the second position 330.66 citations needed. To be in the top 50, top 100, and top 200 an author needs 88 citations, 62.41 citations and 36.66 citations respectively. Moreover it is also clear from the table that more than 85 % of authors are having less than 50 citations so only 15% of authors are having above 50 citations. It is also clear that about 2.5% of authors have less than 1 citation. Two papers yet to be cited.

Table 5 is showing the h-index value through direct count method. This table is showing that to be in position first an author must have h-index 9. To be in position top 10, top 20, top 50, and top 100 an author required h-index value 4, 3, 2 and 2 respectively. It is also clear from the table that more than 87% of authors are having either 1 or less than 1, h-index value. Thus only 13 % of the authors are having above 1, citations from the dataset.

Table 5. Ranking based on h-index through the direct count

Rank	h – index	Percentile
1	9	99.89
2	7	99.79
3	6	99.69
7	5	99.28
9	4	99.08
18	3	98.16
31	2	96.83
125	1	87.24

Table 6. Ranking based on h-index through equal credit count

Rank	h-index through equal credit method	Percentile
1	7	99.89
2	5	99.79
5	4	99.48
14	3	98.57
29	2	97.04
114	1	88.37
175	0	82.14

The table 6 is showing h-index values based on equal credit method. From the table it is clear that the h-index values for the top 10, top 20 and top 30 are 3, 3 and 2 respectively. It is also clear from the table that about 18% of authors are having h-index value at-least 1. It means they have at least one paper having citation one or more than one. Thus the work of the rest of the authors remains unrecognised yet.

Lotka's law

Authors extended the analysis on research productivity by exploring the overall productivity distribution patterns of all authors being active in the field of supply chain management. This helps not only to understand the structure of this field, but also enables comparison with other fields and an estimation of future research productivity. For this, prior productivity studies tested the application of Lotka's law [Serenko, Bontis 2004], which describes a frequency distribution of scientific productivity in a certain field of research. It is also called "the inverse square law of scientific productivity" [Lotka,1926]. Lotka [1926] found the publication data and formulated it to predict an approximate number of authors with a certain frequency of publications. Lotka's distribution function is given by the expression:

$$f(x) = C/x^n \qquad (2)$$

where x is the number of papers published in a period; f (x) is the number of authors publishing x papers; n is a parameter to be determined from the data that taking a value close to two; and C is a normalizing constant that the sum over all x of the f (x) is equal to one.

The least-squares method described by [Pao 1985] was employed for this study and he suggested these steps to verify the reliability of Lotka's Law: (1) collecting data, (2) list author frequency distribution table, (3) calculating n value (slope), (4) calculating constant C value, and (5) using K-S (Kolmogorov-Smirnov) test to evaluate whether to matched Lotka's Law.

Table 7. Productivity Analysis of Authors

No of papers (x)	Author(y)	Observed % of Authors	X = Log x	Y=Log y	XY	XX
1	855	87.24	0	2.93	0	0
2	95	9.7	0.301	1.98	0.596	0.0906
3	13	1.33	0.477	1.11	0.529	0.2275
4	9	0.92	0.602	0.9542	0.574	0.3624
5	2	0.2	0.699	0.301	0.21	0.489
6	4	0.41	0.778	0.602	0.468	0.605
8	1	0.1	0.90308	0	0	0.815
9	1	0.1	0.95424	0	0	0.91
Total	980	100	4.71432	7.8772	2.377	3.4995

In this stage, the n value was calculated by Lotka's method using the following equation:

$$n = \frac{N \sum XY - \sum X \sum Y}{N\sum X^2 - (\sum X)^2}$$

Applying the values from above table into above equation, we can get the value of n = -3.14.

In the fourth stage, the value of constant C was calculated using the following equation:

$$C = \frac{1}{\sum_1^{P-1} 1/x^n + 1/(n-1)P^{n-1} + 1/2P^n + n/24(P-1)^{n+1}}$$

Putting the value of n, x & P we get the value of C which is 0.8474576. According to Pao [1985], the absolute value of n should be from 1.2 to 3.8 which was formulated by the generalized Lotka's law. In order to test whether our observed value match with the theoretical value, we further used the K-S test for evaluation. The K-S critical value at 5% level of significance is calculated as $1.36/\sqrt{\sum y}$, where $\sum y$ is the total number of authors under study. If the absolute maximum difference (Dmax) is less than the K-S critical value, then the null hypothesis is accepted that the observed and theoretical distributions are the same. K-S test at 5% significance level was used to obtain "best fit" for the dataset. Finally, according to the K-S test, below Table

8 found Dmax= 0.025. (Dmax= Absolute Value│Fo(X) / Sn(X))│). The critical value is equal to .052. Since the value of Dmax is less than the critical value, the result matched the generalized Lotka's law, that is, the author productivity distribution data is consistent with supply chain management studies.

Table 8. Authors' productivity Analysis

No of papers (x)	No of Authors(y)	Observed value	Accumulated Value Sn(X)	Expected Value by Author(s) %	Accumulated Value Fo(X)	Absolute Value Dmax= |Fo (X)-Sn(X)|
1	855	0.8725	0.8725	0.8475	0.8475	0.025
2	95	0.0969	0.9694	0.0961	0.9436	0.0258
3	13	0.0134	0.9827	0.0269	0.9705	0.0122
4	9	0.0092	0.9919	0.0109	0.9814	0.0105
5	2	0.002	0.9939	0.0054	0.9868	0.0071
6	4	0.004	0.9979	0.0031	0.9899	0.009
8	1	0.001	0.9989	0.0012	0.9911	0.0079
9	1	0.001	0.9999	0.0008	0.9919	0.008

The reason for the higher value of n in the area of supply chain management is that approximately 87.24% of contributors have published only one publication, whereas Lotka assumed that approximately 60% of contributors have a single publication [Coile 1977].

CONCLUSIONS

This study provides a set of comprehensive, useful and recent standards for individual publication productivity in supply chain management discipline within the selected journal outlets. Past bibliometric supply chain management research has primarily focused on ranking academic journals and academic institutions. Our work contributes to the literature by identifying standards of individual research performance across six different metrics of quantity and/or quality. The results can inform current supply chain management scholars and administrators of productivity standards as implicitly established by the body of scholars in the discipline through the selected journal.

LIMITATION AND FUTURE RESEARCH SCOPE

The biggest limitation of this work is that we have taken only a single journal thus results cannot be generalised. Assessing how individual publication productivity develops in the future represents an excellent area for further research. The establishment of productivity standards also provides an opportunity to see whether there are specific demographic or research environment factors that are related to whether an author meets or exceeds these standards. Furthermore researchers can also investigate cross-institutional collaboration effects and success factors for research productivity as further research in the field of supply chain management.

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ANALIZA PRAWA LOTKI ORAZ PRODUKTYWNOŚCI AUTORÓW W OBSZARZE ZARZĄDZANIA ŁAŃCUCHEM DOSTAW

STRESZCZENIE. **Wstęp:** Rozwój łańcuchów dostaw w formie ustrukturyzowanej pojawił się w latach 90-tych. Wcześniejsze badania nie analizowały szczegółowo wzorów produktywności dystrybucji poszczególnych autorów tematyki zarządzania łańcuchem dostaw w dłuższym okresie czasu. Nie określały również standardów badania produktywności, zarówno pod względem jakościowych jaki i ilościowych, co jest niezbędne w procesie wyłowienia liderów w tym obszarze.

Metody: W celu realizacji proponowanej tematyki, analizie poddano 458 prac napisanych prze 980 autorów w okresie 2005 do 2014. W pracy użyto sześciu miar określających produktywność zarówno pod względem jakościowym jak i ilościowym, identyfikujących standardy zagregowanej produktywności dla poszczególnych autorów, umiejscowionych w różnych obszarach tematycznych odnośnie zarządzania łańcuchem dostaw. Następnie poddano analizie wiarygodność prawa Lotki odnośnie wzorów autorstwa w obszarze zarządzania łańcuchem dostaw. Prawo to było testowane przy pomocy standardowej formy jak i testów K-S.

Wyniki: Wyniki pracy umożliwiają stworzenie użytecznych i kompleksowych standardów dla produktywności poszczególnych publikacji w obszarze tematyki zarządzania łańcuchem dostaw dla wybranych czasopism. Zgodnie z wynikami, aby autor był umieszczony odpowiednio na pozycjach: pierwszych 10-ciu, 20-stu i 50-ciu musimy uzyskać h-index odpowiednio 4, 3 oraz 2. Zidentyfikowano standardy analizy przy użyciu sześciu różnych miar zarówno ilościowych jak i jakościowych. Wyniki badań mogą być wsparciem w pracy naukowców oraz administratorów w zakresie standardów produktywności w obszarze zarządzania łańcuchem dostaw.

Wnioski: Na podstawie otrzymanych wyników stwierdzono, że rozkład produktywności autorów w obszarze zarządzania łańcuchem dostaw podlega prawu Lotki. Otrzymane wyniki umożliwiają nowe spojrzenie na badania w obszarze zarządzania łańcuchem dostaw. Dostarczają również informacji o potencjalnych kierunkach badań w przyszłości.

Słowa kluczowe: zarządzanie łancuchem dostaw, benchmarking, patent autorski, produktywność autora, test K-S, prawo Lotki

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ORIGINAL PAPER

MARKETPLACE AS A KEY ACTOR IN E-COMMERCE VALUE NETWORKS

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ABSTRACT. **Background:** E-commerce is one of the most dynamic and important sectors of the Polish economy. Its development is driven by rapidly expanding Internet access. Worldwide e-commerce is dominated by marketplaces with a great market share. There are both advantages and disadvantages related to the use of marketplaces, for sellers and buyers alike.

The aims of this paper are to indicate the nature of marketplaces, develop a classification for them, and also to indicate new challenges related to them and development directions in Poland.

Methods: For the needs of this paper, research was conducted using the methods of direct observation and analysis of primary and secondary sources. The primary materials included data obtained from companies providing marketplaces in Poland and abroad, and the secondary ones – reports, studies and Internet sources. In addition, in-depth interviews were performed with experts on marketplaces.

Results: The article provides a detailed description of marketplaces. The authors describe the division and characteristics of marketplaces and discussed the potential trends in this field. It presents marketplace-related benefits and disadvantages, and how the authors classify them.

Conclusions: Marketplaces create new opportunities for expansion on a larger scale for online sellers. Companies do not need to invest in a sales platform or have knowledge of legal aspects. Moreover, they have access to innovative solutions. Obviously, there are many disadvantages, such as very strong competition from numerous sellers in one place, becoming dependent on this sales channel, and neglecting the growth of the seller's own online shop.

Key words: e-commerce, marketplace, value network.

INTRODUCTION

The global value of retail e-commerce in 2018 reached over USD 2.84 T. In 2019 it is expected to exceed USD 3.45 T and climb to USD 4.88 T in 2021 [Statista 2019a]. The share of e-commerce in retail has been growing steadily. Last year, it was 11.9%, reaching 13.7% in 2019 and 17.5% in 2021 [Statista 2019b]. Fashion products (clothes, footwear, accessories), electronics and media (personal electronics, music, games) are the products purchased online most often.

Customers purchase products both from online shops and marketplaces, with the latter enjoying particular popularity. Last year, the top 100 biggest marketplaces generated turnover of USD 1.86 B. This accounted for over 95% of the revenues across all platforms and around 65% of the world's e-commerce combined. The massive share of these platforms and their dynamic growth (23% in relation to 2017) shows how important they are in shaping e-commerce domestically and internationally. Of the largest 100 platforms, 61 are in the USA, 17 in Asia, 14 in Europe, 5 in South America and 3 in Africa. Interestingly, 59 marketplaces have been founded in USA and 39 are not older than 9 years [Ali 2019].

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In terms of turnover, in 2018, the two largest marketplaces were the Chinese Taobao (USD 515 B) and Tmall (USD 432 B), both owned by the Alibaba Group. These were followed by Amazon (USD 344 B), JD.com (USD 259 B) and eBay (USD 96 B) [Ali 2019]. Alibaba's turnover stems both from the purchasing power of China and other Asian states, where the marketplace is active and from the amazing popularity of the group's platforms. 80% of products purchased in China is sold on these portals. Apart from China, marketplaces had over 50% of market share in just two countries. In Germany, where Amazon had a 55% market share, and in Poland, with Allegro registering 50% market share [Ecommerce Foundation 2016]. Currently, Allegro's share in Polish e-commerce stands at around 40%.

Apart from micro and small businesses, medium-size and large firms also sell their products on marketplaces. Recently, more and more of the largest businesses have been joining marketplaces. These new forms of selling have become an important part of both e-commerce and the entire economy. This is because marketplaces eliminate entry barriers to new businesses and the expansion of existing ones. They also create new solutions and show new directions in the digital economy. Amazon, Alibaba and JD.com invest billions in logistics infrastructure, thus helping the regions where they operate to grow.

What is the nature of marketplaces and what marketplaces other than Allegro are available in Poland? What new challenges do marketplaces face and what are their development directions? These are some of the questions we will try to address in the article.

The aims of this paper are to indicate the nature of marketplaces, develop an original classification of them, and to indicate new challenges they face and development directions in Poland.

The paper is divided into three main parts. The first section discusses the nature of marketplaces, the second presents and describes the types of marketplaces, and the third speaks of the future directions for the development of marketplaces.

For the purpose of this article, the authors conducted research by means of direct observation and analysis of secondary sources such as reports, publications, press materials and marketplace websites. Additionally, the article draws on the authors' expert knowledge acquired during over a dozen years of market observations and the previously conducted analyses and reports.

THE NATURE OF MARKETPLACES

Speaking in the most general terms, a marketplace is a platform that offers products and services of numerous sellers, which can be bought by clients [Tian et al. 2018, Li et al. 2019]. Most of the products come from external companies, although some platforms also offer their own products (e.g. Amazon, Allegro). Other businesses must be able to sell their products to make the platform a marketplace, otherwise it is just an online shop. Sometimes the term "marketplace" is wrongly used for online stores with a very wide selection of products. As previously noted, marketplaces can also offer services for sale. However, this article focuses on goods, because their turnover is more complex and requires more attention.

Sellers trade on popular platforms frequently visited by users in exchange for a part of their sales profits. Most often, the marketplace business model is based on collecting fees for sales made through them. These fees differ depending on the platform and the category of products. Some marketplaces collect fees for listing the product (e.g. Allegro). The sellers agree to such fees, because marketplaces allow them to enter the market with low financial outlays. Consequently, such platforms are key selling venues for many sellers.

Marketplaces offer undeniable advantages, such as prompt access to a lot of clients, high recognizability, first contact venue (many buyers start looking for products on marketplaces), ready technical solutions, a payment system and logistics. They are great venues for testing products and new sales markets and for collecting information from clients. A small batch of pilot goods can be launched to test demand and get feedback from clients, all without making big investments in sales and distribution channels. Some of the limitations are very strong competition (for example, 363,000 new sellers offering identical or very similar products joined Amazon in Europe in 2017), listing systems (some online shop suppliers offer integration and automated listings), communication with clients from abroad, and fees.

Some marketplaces seek ways of generating additional revenues other than from sales commission. One such example may be fulfilment services, consisting in the marketplace taking over processes related to warehouse logistics, i.e. receiving goods, storage, picking, packing, shipping and handling returns [Semeijn et al. 2005]. This is Amazon's speciality, as they operate numerous warehouses across the world. The seller is not obliged to ship their goods to Amazon warehouses, but this may mean that their listings are poorly positioned.

The leading marketplace sellers owe their success to their unique approach to customers [Church, Oakley 2018]. They draw on clients' emotions and provide them with a product- and delivery-related experience. The emotional aspect applies to lifestyle, fashion, trends and social affiliation. This reinforces the relationship between the client and the platform. Mainly due to customization, the Internet has made it possible to know clients better, in particular their shopping experience, and consequently to adapt the offer to their preferences and to increase their loyalty. Learning the needs of their potential clients allows sellers to offer their products more consciously. Add-on sales are used for existing clients. This may be take the form of cross-selling, where products from other categories (often of complementary nature) are sold, or selling more expensive or more advanced products from the same category (up-selling).

As shown in the analysis, there are both advantages and disadvantages related to the use of marketplaces, and both for sellers and the buyers. These have been specified in Tables 1 and 2.

Table 1. Advantages and disadvantages for sellers

Advantages	Disadvantages
• Marketplace brand recognizability • A high number of clients in one place • Low entry barrier (no need to invest in a sales platform or to know legal aspects etc.) • Additional channel of sales and a source of revenue • Ability to reach clients abroad • Sales and logistics support • Better promotion of products (lower expenses on SEO and advertising) • Increased seller credibility • Access to innovative solutions (new tech, marketing and logistics solutions used by marketplaces) • Access to analytical and benchmarking data	• Very strong competition from numerous sellers in one place • Becoming dependent on this sales channel and neglecting the growth of the seller's own online shop • Frequent changes to the sales and fees policy • Service costs (subscription or listing fee, promotion fees and sales commissions) • Restrictive requirements concerning product descriptions and images, customer service • Risk of competitors copying ideas or marketplaces / other sellers offering the popular products • Limited possibilities of promoting the seller's own online shop

Source: authors' own analysis

Table 2. Advantages and disadvantages for buyers

Advantages	Disadvantages
• Access to numerous products in one place • Possibility to compare prices of products offered by various suppliers • No need to learn the operation of various online shop platforms (product data base put in order and catalogued) • Higher credibility of sellers • Higher safety of transactions (customer protection programs) • Feedback on sellers from other users • Access to attractive loyalty programs (e.g. Amazon Prime, Allegro Smart) • Availability of used products • Access to products from abroad, with payments possible in local currency	• Becoming dependent on one marketplace • Difficult contact with the seller • No individual approach from the marketplace • Shipments from different sellers divided (fees for additional shipments, delivery in different time)

Source: authors' own analysis

CLASSIFICATION OF MARKETPLACES

As e-commerce develops, new marketplaces emerge. The biggest players offer practically all types of products that can be purchased from bricks & mortar stores. Their platforms often offer items that are only available there, e.g. hand-crafted goods. However, just like there are specialized online shops, marketplaces also become segmented. Consequently, platforms focusing on specific products and business areas have been launched, e.g. fashion, electronics, home or hand-crafted items. An omnichannel strategy is yet another emerging trend, based on the seller's presence in various online and off-line sales channels. Some marketplace owners expand and launch traditional sales channels, and some of the biggest websites open their own marketplaces.

Price comparison sites and best deal sites are not marketplaces by definition. Many buyers start searching for products on websites such as: Ceneo.pl, Nokaut.pl, Alleceny.pl, Okazje.info, and Skapiec.pl. Currently, 67% of Polish web users compare prices of products and services and 19% make their first purchases on the basis of results from price comparison sites (Gemius 2018). Every third online shop in Poland uses price comparison sites as promotion tools [Skorupska 2017]. Apart from the price, products are tiered based on criteria such as popularity or positive feedback about the store or the product. As e-commerce grows, the role of price comparison sites changes. The entire shopping process can now be conducted on a price comparison site, so such sites are more and more commonly treated as marketplaces.

Another group of emerging marketplaces are platforms available only to business clients (B2B). The reasons driving both individual and business clients are largely the same. Low prices, time savings and convenience are the most important ones. Additionally, businesses want to buy as many goods and services as possible from one place and want to integrate their processes with a selected B2B operator. Research shows that business using online purchasing systems can save up to 15%. Today, only 35% of Polish businesses use such solutions [Aleo, Deloitte 2017].

The types of marketplaces, divided according to various criteria, are presented in Table 3.

Table 3. Classification of marketplaces according to division criteria

Division criterion	Types of marketplaces	
Source of origin	**Primary** – platforms created in digital version	**Secondary** – platforms, whose digital versions were created on the basis of traditional operation or online shops complementing their offer
Sales channels	**Online only** – platforms only available in digital form (pure players)	**Online and offline** – platforms operating in traditional and digital version (bricks and mortar players)
Type of relation	**Direct** – platforms through which goods can be purchased directly	**Indirect** – platforms aggregating information from other sellers and directing clients to them (e.g. price comparison sites)
Reach	**Domestic** – platforms only available in local languages and handling clients from one country only	**International** – platforms available in many languages and handling clients from multiple countries
Product presentation	**Product catalogue** – platforms presenting offers as catalogued products, to which new sellers attach their listings (the platform is the owner of the product description website, where offers from at least 1 seller) are available	**Product list** – platforms presenting offers as lists of products created by individual sellers (the seller is the owner of their listing)

Division criterion	Types of marketplaces		
Types of clients	**B2C** – the clients are mainly natural persons, but most of the products can also be purchased by business clients	**C2C** – the sellers and the clients are mainly natural persons	**B2B** – the sellers and the clients are mainly businesses
Types of listings	**Merchandise** – platforms where only goods are offered	**Service** – platforms where only services are offered	**Mixed** – platforms where both goods and services are offered,
Types of products	**Horizontal** – platforms where various sellers offer different products (in numerous categories, fields etc.)	**Vertical** – platforms where various sellers offer goods in the same category (per branch, application, specialization, etc.)	**Mixed** – platforms where both sellers and the platform itself offer different products
Intended use	**External** – open platforms that can be used both by sellers and buyers who satisfy specific criteria	**Internal** – closed platforms that can only be used by selected buyers or sellers	**Mixed** – platforms limited for selected sellers who satisfy specific criteria (e.g. shopping clubs)

Source: authors' own analysis

GROWTH OF MARKETPLACES IN POLAND

Marketplaces are increasingly becoming the main selling channels for bricks & mortar sellers and online sellers. Many traders find them convenient, because they attract new clients and provide ways of serving them. Thanks to their brand, marketplaces make products of less-known sellers more credible. Additionally, marketplace owners invest heavily in advertising, promotional activities and PR. The seller's role boils down to providing information about the listing (which is often transferred automatically to the marketplace from the seller's system) and preparing the product for shipment (which may be a part of Amazon's fulfillment service). Marketplaces are also great testing grounds for new products, as large numbers of clients may be reached through them without having to incur substantial costs. In the case of international marketplaces, sellers may reach foreign buyers without speaking their language, having legal knowledge, logistics infrastructure etc.

A lot of evidence points to marketplaces being some of the key actors in the e-commerce value network. Experts anticipate that by 2020 around 40% of online trade will be done through marketplaces [MarkMonitor 2016]. Online sellers have no other alternatives. Apart from thinking of developing their online business, they also have to consider joining this sales channel or strengthening their current presence in marketplaces. Their 40% share of the Polish market was reached a long time ago. This is mainly due to the history of our e-commerce, as for many years, Allegro was the buyers' first choice. The sales structure only started to change with the presence of competition, such as producers, retail networks, professional online shops and foreign marketplaces.

Every year, several new marketplaces emerge in Poland. This is possible, because the entry barriers do not seem difficult to cross. Unlike with online shops, no warehouses, goods or logistics employees are needed. The cost of developing the IT tools is not an insurmountable obstacle. Upkeep of the site and developing it are the biggest problems. The optimal scale of operation, building brand awareness and ongoing promotional activities seem to be the key to success. Most new marketplaces build their potential in the initial stages of operations by offering free of charge services. However, this can only be done with significant financial back-up. Additionally, the largest marketplaces continue to improve their tools and go to great lengths to attract and keep their clients. Polish e-commerce has seen numerous promising marketplaces that failed to withstand the pressure from competitors, e.g. Świstak.pl or DaWanda.pl.

Given the stiff competition, new marketplaces must do everything to stand out in the market. One of the ways to do this is to specialize in certain fields or products.

Although marketplaces are very "spacious" and can carry all categories of products, buyers look for specialized products in specialist shops. It is true that millions of products can be browsed on eBay, Amazon or Allegro, but these sites will not replace vertical platforms with knowledgeable sellers offering assistance and, often, better prices. This is why some experts claim that following the development of marketplaces offering a wide range of goods, more specialized platforms will emerge and be active in respective fields. The beginnings of this trend can be seen in Poland, as a relatively large number of new marketplaces have recently emerged in the fashion sector (clothes and footwear). Apart from electronics, this is one of the largest segments of the market and one that keeps growing dynamically. Many producers active in this field sell their products themselves. For them, marketplaces are a great way to complement their sales channels, with clients having access to a wide assortment of goods in one place. Research shows that clients care increasingly about a wide range of online sellers and would like to shop in one place. This follows the one-stop shopping concept, where all purchases can be handled in one place. Apart from that, fashion items are high-margin goods. The situation is different with electronics, where the margins are very low and where large retailers known for traditional sales predominate, such as Euro.com.pl, Mediaexpert.pl, Mediamarkt.pl or Komputronik.pl. Consequently, there is practically no space in this field for a middleman, such as a marketplace, specializing in electronics.

The dynamic growth of e-commerce means that it is not only individual clients want to shop online. More and more companies that only deal with business clients are becoming interested in this sales channel. This give rise to marketplaces dedicated to B2B. One of the newest outfits in Poland is OEX24.com, which was launched in February 2019. This is a B2B platform that not only allows the listing of products for domestic and international markets, but also deals with customer service and logistics processes. With its platform, OEX wants to cover the entire e-commerce value chain – from supplier management through sales to handling returns.

More marketplaces should be expected to be launched soon by sellers who are well known in the market, and who have significant potential in the form of networks of suppliers, human resources, IT and clients. They will be able to expand their product portfolio with a new, complementary assortment. This will drive more traffic on their websites and be a source of additional revenues. A good example of this might be IKEA, which is considering starting their own marketplace. IKEA wants to sell its own products and products from other retailers on the marketplace. The offer will not be limited to furniture, but will also include home-related items, in particular DIY and art merchandise. IKEA has been testing sales on Alibaba and Amazon, apparently, with good success. However, creating such a marketplace will be a challenge for IKEA, as other furniture producers and distributors will have to be invited to cooperate. IKEA has declared that no negotiations with their competitors are currently taking place, but apparently, they are interested in creating a sales platform for the entire industry [Fedorenko 2019].

We should also be mindful of competition that marketplaces face from tech companies. Facebook, enjoying great popularity in Poland, runs its own marketplace. The service operates like a noticeboard similar to OLX.pl and Gumtree.pl. It connects sellers and buyers who live close by to start the transaction online and complete it in person during pick-up. It is mostly used by individual clients [Wei et al. 2019]. Marketplaces face more danger from Google Shopping. So far, Google in Poland has been collecting data about products, aggregating them, showing them as Product Listing Ads (ads displayed at the top of the Google search engine page) and redirecting to online sellers. At the beginning of 2019, Google announced they were planning to launch their own marketplace, which, apart from listing offers, will handle payments and provide integration with other solutions. Sellers will be responsible for customer service and logistics. Google is planning to test the new solution first in France. If these tests are concluded successfully, we can expect to see the platform in Poland, too.

Today, the keys to success in e-commerce are technology and logistics [Bask, Lipponen, Tinnilä 2012]. Marketplaces will continue to invest in these two fields in the coming years. Experts expect marketplaces to keep growing in the field of artificial intelligence (AI), machine learning and real-time personalization [Columbus 2018]. With regard to logistics, the focus will be on making shipments quicker and cheaper, offering warehousing services, picking and handling returns. Some related activities can be seen on Allegro in this regard. In March 2019, Francois Nuyts, Allegro's CEO, announced several new solutions. Their objective is to turn the marketplace into a sort of an ecosystem comprised of sellers and providers of complementary services. One of the proposals for change will be a tool with which sellers will be able to analyse their own business against the competition. More attention will be paid to evaluating the sellers in terms of logistics – the time of shipment and delivery, along with return possibilities will be scored. Allegro also wants to implement uniform standards for providers of logistics services with regard to delivery time. Same-day delivery is to be available in selected places. Delayed payment for goods purchased is to be a breakthrough solution. This way, the client will have 30 days from the date of delivery to pay for their order. Credit will not only be extended to clients, but also to sellers, e.g. through a working capital facility and a revolving facility.

The world's biggest shopping platforms, Alibaba and Amazon, are going one step further with regard to logistics. Alibaba has already built numerous warehouses where they perform fulfilment services for their sellers, while continuing to invest in new technologies and expand into new markets. The company is currently at the acquisition stage and is broadening its logistics services. Recently, Alibaba bought 14% of shares in STO Express, the fifth largest Chinese carrier. Previously, the company had also bought shares in YTO Express Group, Best Inc. and ZTO Express [Kapadia 2019].

It has been known for quite some time that Amazon is aiming at the position of the leader in logistics services. The evidence for this is the company's own warehouse, fleet of trucks, own airline, drone delivery system and numerous patents related to logistics and last-mile management, which is the most complex and costly element of the entire logistics process in e-commerce. In the USA, Amazon has its own parcel lockers and courier vehicles, which reduces the number of parcels handled by courier operators. Recently, the company also launched courier services in Europe, namely in France, Germany, GB and Austria. This expansion caused DHL to withdraw their operations from Austria and made the Austrian postal service apprehensive as to their own future in this market [CEP-Research, 2019]. Amazon may repeat these steps when they launch sales in Poland. Consequently, the courier, express and parcel sector should be ready for this scenario.

When analysing the growth of marketplaces in Poland, we should also remember about the very dynamic development and growing popularity of other, foreign platforms in Poland. GearBest.com, Wish.com and Banggood.com are some of these.

SUMMARY

This study extends current understanding of the essence of marketplaces in e-commerce. It develops an original approach to marketplace classification to facilitate a better understanding of their wide range. Moreover, it indicates their advantages and disadvantages.

Thanks to marketplaces, trade in Poland has become easier and more convenient than ever before. Its beneficiaries are both companies and customers. Almost each firm has the potential to become a successful trader. Marketplaces create new opportunities for already existing entities to expand on a larger scale and offers prospects for rapid development to emerging entities. This is possible due to low entry barriers that encourage more and more companies to sell their products on the Internet. They can offer a wider range of products without great effort. Companies are able to save on both fixed and variable costs, such as rent, labour and other overheads associated with the presence on their own websites. It is particularly important in the case of cross-border trade, because companies do not have to spend a lot of money on international expansion. Moreover, they have access to innovative solutions (new tech, marketing and logistics solutions used by marketplaces). Obviously, there are many dark sides of marketplaces in e-commerce, such as very strong competition from numerous sellers in one place, becoming dependent on this sales channel and neglecting the growth of the seller's own online shop.

Even though our research offers new insights into marketplaces understanding, it has some limitations, e.g. its theoretical character. However, our study can provide a basis for the preparation of empirical studies which will allow new hypotheses to be tested.

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MARKETPACE JAKO KLUCZOWY UCZESTNIK SIECI WARTOŚCI W HANDLU ELEKTRONICZNYM

STRESZCZENIE. **Wstęp:** Handel elektroniczny w Polsce jest jednym z najbardziej dynamicznych i ważnych sektorów gospodarki. Jego rozwój pobudzany jest przez szybko rozwijający się dostęp do Internetu. W światowym e-commerce dominują marketplace'y o dużym udziale w rynku. Korzystanie z nich wiążą się jednak zarówno z licznymi zaletami i wadami zarówno dla sprzedających, jak i kupujących.
Celem artykułu jest charakterystyka marketplace'ów oraz opracowanie ich oryginalnej klasyfikacji, wskazanie nowych wyzwań i kierunków rozwoju w Polsce.
Metody: Na potrzeby artykułu przeprowadzono badania z wykorzystaniem metod bezpośredniej obserwacji i analizy źródeł pierwotnych i wtórnych. Materiałami podstawowymi były dane uzyskane od firm prowadzących marketplace'y w Polsce i za granicą, a materiałami wtórnymi - raporty, badania i źródła internetowe. Ponadto przeprowadzono wywiady pogłębione z ekspertami ds. marketplace'ów.
Wyniki: W artykule scharakteryzowano szczegóły dotyczące marketplace'ów. Autorzy opisali ich podział i charakterystykę oraz omówili potencjalne trendy na rynku marketplace'ów. Przedstawiono korzyści i straty z nimi związane oraz sposób ich klasyfikacji.
Wnioski: Marketplace'y stwarzają nowe możliwości ekspansji na większą skalę dla sprzedawców internetowych. Firmy nie muszą inwestować w platformę sprzedaży ani znać aspektów prawnych. Ponadto mają dostęp do innowacyjnych rozwiązań. Oczywiście, istnieje wiele wad, takich jak bardzo silna konkurencja ze strony wielu sprzedawców w jednym miejscu, uzależnienie od tego kanału sprzedaży i zaniedbanie rozwoju własnego sklepu internetowego sprzedawcy.

Słowa kluczowe: e-handel, marketplace, wartość dla klienta

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ORIGINAL PAPER

HEALTHCARE SUPPLY CHAIN MANAGEMENT: MACRO AND MICRO PERSPECTIVES

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ABSTRACT. **Background:** The concept of supply chain management is to coordinate and collaborate among supply chain players in order to achieve system efficiency. Supply chain coordination and collaborations deal with the connection of operations throughout the chain with material and information flowing smoothly across these supply chain operations in achieving efficiency. Healthcare supply chain is one of such complex systems involving many stakeholders in the supply chain. Coordinating a single platform for these stakeholders is a challenge by achieving smooth flow of operations on this platform. Therefore, the purpose of this paper is to explore the operations in this healthcare supply chain materials and information flows across the players at two levels, macro and micro perspective.

Methods: The supply chain infrastructure enabling efficiency is investigated in the hospital environment. Multiple case studies have been conducted at 13 hospitals which include secondary hospitals and primary hospitals. Triangulation techniques, including interviews, site visiting and document analysis, are employed for data collection so as to enhance reliability and validity of the study.

Results and conclusions: The study found that the healthcare supply chain efficiency could be achieved at 2 levels, namely supply chain level and firm level. The main concerns of the organizations of both levels are process efficiency and patient safety.

Key words: healthcare service, supply chain management, information management, operations management, Thailand.

INTRODUCTION

Supply chain and logistics management has become increasingly important in recent years as its perspective has led the industry to see through the process integration from upstream to downstream.

The supply chain and logistics management involves three-key flows across the boundaries of players in the supply chain – product /material, information, and finance/cash [Stock, Lambert 2001]. Successful integration or coordination of these three-key flows has improved efficiency and effectiveness for the players. The supply chain and logistics management has been defined as a system of suppliers, manufacturers, distributors, retailers, and customers where the material typically flows downstream from the suppliers to the customers, and the information flows in both directions. Additionally, it involves managing the connected series of activities, which concern planning, coordinating, and controlling movement of material from the suppliers to the customers [Chandra, Kachhal 2004]. The key factors enabling successful supply chain and logistics management include inventory cost, information, customer service, and collaboration relationships [Coyle et al. 2002].

Generally, healthcare supply chain has a similar core structure to other industries' as it composes of input, process and output. There

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are also material flow and information flow along the chain [Kritchanchai, Suwandecho-chai 2010]. Under the concept of supply chain and logistics management, medicine is produced and delivered in the right quantities to the right location and at the right time [Krichanchai 2015]. However, Turhan and Vayvay [2012] state that it is a must in healthcare industry as a cost of error might be someone's life. They also mention that healthcare supply chain management differs from other industries' in term of key elements as it tends to be misalignment, high costs for healthcare providers and heavy dependence on the third party.

Healthcare supply chain therefore is unique and different from other industries. It is a complex network consisting of many different parties at various stages of the value chain [Rossetti et al. 2012; Turhan, Vayvay 2012; Noorfa Haszlinna, Andrew 2009; Burns et al. 2002].

The stakeholders from the supply side and the demand side have different interest in operating healthcare supplies. The suppliers were driven for profit maximization while the healthcare providers focus more on cost and patient safety [Vikram et al. 2012; Krichanchai 2015]. Consequently, it is very challenging to implement the concept of supply chain and logistics management within healthcare context . Furthermore, experts state that supply chain and logistics management practices of the healthcare industry are ten years behind retail and manufacturing industry [Uthayakumar, Priyan 2013].

In addition, Gattorna [1998] describes a healthcare business as the operations provided by a variety of products and services enterprises including medical consumables, pharmaceuticals, catering, laundry cleaning, waste management, home-care products, information technology, vehicle fleet management and general supply. de Vries [2011] highlights that inventory management is influenced by these stakeholders who have different perception and interests in setting inventory policy. Moreover, it is found that healthcare staff in the hospital has limited knowledge of inventory management and supply chain practices, but they need to manage the inventory without any proper guideline. This leads to inefficient operation management [Chen et al. 2013; Uthayakumar, Priyan 2013].

Muangchoo and Kritchanchai [2015] claim that healthcare supply chain is generally dominated by manual activities and regulatory pressures with product data maintained by fragmented IT systems in the entire supply chain. Consequently, healthcare organizations related to patient safety face a number of challenges in supply chain such as traceability, logistics efficiency and quality of patient care.

Likewise at the operational level, a research project entitled Business Architecture Design and Integrated Performance Measurement for Hospital Supply Chain in Thailand, Kritchanchai [2012] describes that drug manufacturers deliver drugs to healthcare providers (hospital or clinic); then the pharmacists in the healthcare providers dispense the drugs to patients without sharing medical information among the stakeholders. Comparing to other industries, product information is visible to target stakeholders from upstream to downstream.

Lack of medical information sharing not only negatively affects the efficiency in the healthcare supply chain, or makes the organizations unable to track and trace medical products but also leads to the patient safety issue. Day by day, a large amount of data has been generated in healthcare industry. The data includes record keeping, compliance & regulatory requirements, and patient care. If the data can be interpreted and translated into information and shared among the supply chain members, healthcare cost can be reduced, and the quality and effectiveness of the healthcare system can be improved. [Tiwari et al. 2017]. In addition, Stecca et al. [2016] also confirm the importance of the information sharing at the operational level. To have a better planning of inventory replenishment policies inside the hospital, there is a need of the share of information.

Moreover, it is also noticed that drug dispensing does not depend on customers or patients' demands, but it is driven by clinical treatment. Drug selection is heavily based on the clinical preference of physician. Without medical training, the patients or end customers do not fully understand medical practices, and they cannot select the appropriate products for themselves [Pedroso, Nakano 2007]. Also, there is an interrelationship between patient condition and drug utilization. The patient condition impacts on drug demand, but how patients respond to the drugs is also uncertain. This has a great impact on the inventory management since the demand is unpredictable [Vila-Parrish et al. 2008].

A study by Kritchanchai and Meesamut [2015] show that only one inventory policy cannot apply entire drug items in the hospital. The drug demand characters are various. Therefore, applying only one single policy causes stock shortage or over stock problems. Thus, the inventory policy should be developed according to drug demand characters.

In addition, Supeekit [2014] studies internal transportation within the hospital under limited number of staff and transport equipment such as elevators. Demand of the elevator usage is high and uncertain. Patients and medical physicians struggle to get rid of the heavy traffic in vertical transportation within the hospital building especially in the rush hours. It is found that the business process in the hospital should be re-designed and developed with the assistance of related information technology.

When patients enter the hospital, they obtain services, and seize multiple resources at the same time. Therefore, it is necessary for the hospital to manage the operations and the flow of patient efficiently. Zonderland and Boucherie [2012] study a queuing network in healthcare system. They suggest that queuing theory is the value making a trade-off between patient waiting time and healthcare provider idle time. They introduce a basic queuing network like a Poisson process and also present exponential queues for the situations that either have a single or multiple servers. Kritchanchai and Hoeur [2018] study the patient flow in outpatient department (OPD) building. By applying the value chain concept, the congestion can be reduced in the floor area of the OPD's clinics when the primary facilities are separated from support facilities.

Apart from managing patient flow and material flow within the hospital, nurse scheduling should be well-managed in order to ensure that nurses are available at the right place and the right time. Lim et al. [2012] study nurse scheduling problems in a general clinic and operational suite. The study demonstrates an optimization model and solution approach for the problems.

Another major concern in healthcare is to provide services to the patients at low cost, efficiently and timely. Niakan and Rahimi [2015] use multi-objective mathematical model to minimize the cost which consists of inventory and transportation cost. They investigate three main issues of healthcare supply chain namely inventory management, drug distribution from suppliers to healthcare facilities, and demand management.

In summary, most of the past literatures show that healthcare supply chain and logistics management is complex with variety of areas. Regarding the supply chain context, there are various stakeholders who have different interests in managing healthcare supplies. The healthcare staff has more concern about providing patient safety while the suppliers are interested more in gaining profits. This divergent goal leads to more complicated to enhance collaboration among the stakeholders. The demand is not desired based on the actual customer preference but it is made by the healthcare's staff decision based on clinical treatment. The hospital is the one that can obviously see the actual demand that generated daily. However, that demand is not really visible to other members in the chain. This affects the drug manufacturer and distributors on managing the drug procurement, production, and delivery.

From the literatures, it can be seen that supply side and demand side have different interest. Moreover, product data is on the fragmented IT system through the entire supply chain. Hence, it is very difficult to visualize product information from upstream to downstream. On the other hand, the demand in hospital is very uncertain; one inventory policy cannot apply to entire drug items in the hospital. Transportation is another area. The challenge at operational level is to manage limited staff and transportation resources. Likewise, patient queuing and nurse scheduling are also critical.

Therefore, healthcare supply chain and logistics management can be analyzed into two levels: supply chain level and operational level. The supply chain level is about material and information management between stakeholders in the system such as drug procurement from healthcare providers to suppliers, and drug delivery from the suppliers to the healthcare supply chain providers. The operational level is logistics operations within the healthcare providers such as drug inventory management, transportation, queuing and scheduling.

AN EXPLORATORY STUDY

This section aims to investigate a macro-perspective in supply chain and logistics management in healthcare industry in order to see how the stakeholders in the chain have been considered as a critical issue for the suppliers and the hospitals to enhance collaborative and integrative supply chain. There are various reports of supply chain and logistics management in healthcare from global trend and best practices. We has explored and reviewed case studies from Australia, Canada, Japan United, Kingdom practices in order to investigate macro-perspective of healthcare supply chain and related infrastructure in this setting.

In Canada, a system of supply chain standard has been concerned by healthcare institutions [ISMP 2013; Sheppard et al. 2009]. Since 2008, the healthcare providers and suppliers within Canada's healthcare gear toward improving patient safety, optimizing supply chain processes, enabling traceability, and maximizing the intellectual capital of healthcare professionals across the country. Members of healthcare industry implemented the standard product identification to connect the supply chain operations nationwide. Pharmaceutical products are identified not only by barcode on exterior package labels but also at the unit-of use packaging, such as ampoules, vials, and blister packs [Sheppard et al. 2009]. There is a national collaborative effort as the Institute for Safe Medication Practices Canada (ISMP Canada) and Canadian Patient Safety Institute (CPSI) have worked with pharmaceutical manufacturer to ensure that the automated identification technology helps improve patient safety on medication dispensing and administration systems as well as the benefits from enhancing efficacies along the entire supply chain [ISMP Canada 2013; GS1 Canada 2012].

In Australian health sector, electronic commerce is one of the important concerns [Vikram and Caroline 2011; NEHTA 2016]. Researcher Clarissa et al. [2019] shows that electronic database would help in the identification of Prescription Opioids abuse or misuse. Additionally, it would also help improve individualized patient care, reduce over-prescribing, identify the concern pharmacy or doctor shopping and fraudulent prescriptions.

The core function of effective electronic commerce system is a global way to identify trade items and logistic units. In order to gain unilateral support across the Australian pharmaceutical/healthcare sector for 'one standard' identification system, the Monash Pharmacy Project team needed to illustrate the benefits, such as accurate inventory management and increased efficiency to all industry suppliers [Vikram, Caronline 2011]. In 2016, National eHealth Transition Authority (NEHTA) proved the benefits of application of the system of identification, bar coding and electronic messaging in the areas of hospital pharmaceutical ordering, picking, packing, dispatch, and receipt of goods. The benefits included 25 per cent reduction in stock receipt time at the hospital pharmacy, improving accuracy in order fulfilment, and an embracing of the new processes and technologies by staff [Vikram, Caroline 2011]. It is reported that the system composed of:

- Identification and bar coding of trade items
- Electronic messaging and improving order fulfilment accuracy
- Data synchronization via the National Product Catalogue (NPC)

- Future requirements for batch/expiry date tracking

In Japan, the healthcare stakeholders struggle to reduce medical incident and error, and increase counterfeit of drugs and medical devices. The solution to solve the problem is implementation of unique product identification and a single database of master data called MEDIS-DC, The Medical Information System Development Center, which is registered by manufacturers and shared to target healthcare providers instead of individual non-compatible Hospital Information System [Takekuma 2008]. The implementation of global standard and the datapool in Japan provides several benefits to healthcare stakeholders both suppliers and healthcare providers, the precise data of actual usage of the instruments, appropriate purchase control, and adequate stock management that lead to high motivation of the hospital staff [GS1 Japan 2009; GS1 Japan 2015].

In United Kingdom, since 2006, the Department of Health (DH) has announced a guideline called "Coding for success" which is related to an implementation of Automatic identity and Data Capture programmed (DH 2010). To addresses patient safety issues, National Health System Connecting for Health (NHS CFH) enters into the agreement with GS1 UK to issue the adoption of GS1 coding standard. In addition to coding, it also encourages the manufacturers to implement GTINs while driving the NHS to implement effective supply chain technologies. The objective of this project is to improve patient safety together with greater efficiency [GS1 2010].

Table 1 shows the common practices in each country for their healthcare supply chain.

Table 1. Practices for supply chain and logistics in each country

Country	Practices
Australia	Implement one standard identification system and data synchronization.
Canada	Implement the use of standard product identification to connect supply chain nationwide.
Japan	Implement the unique product identification and a single database.
UK	Announce a guideline called "coding for success" using GS1 standard.

According to the case studies, it reveals that healthcare system around the globe is facing challenges that affect the entire supply chain, from manufacturers through to wholesalers, distributors, group purchasing organizations and healthcare providers. Every member is concerned primarily with two main issues: increasing supply chain efficiency and, more importantly, ensuring patient safety.

Standardized healthcare infrastructures are the important means of managing healthcare supply chain and logistics to increase visibility and security. The infrastructures composed of five main areas.

- Standardized Product and Location Identification (GTIN-Global Trade Identification Number and GLN-Global Location Number respectively)
- Electronic product catalogues
- eProcurement enabled by Electronic Data Interchange (EDI)
- Automatic Identification and Data Capture (AIDC) systems, including barcodes and RFID
- Traceability Systems

Global supply chain standards enable products and information to flow accurately, efficiently and quickly across jurisdictions and borders. GS1 is the world's leading supply chain standards organization. As such, global GS1 standards like barcodes and other automatic product identifiers enable traceability, efficiency, cost savings and a host of key benefits in various industries, including healthcare.

As mentioned earlier, these five main infrastructures can enhance efficient processes and contribute to patient safety. They not only help a particular stakeholder gain advantages from the collaboration but also provide benefits to all in the entire supply chain. In addition, they should not disregard the operations and service within the hospital as they directly affect healthcare service delivery to the patients. Therefore, it is important to understand the operations management in hospital setting.

AN EMPIRICAL STUDY

The objective of this part is to explore an operational level or micro-perspective within the hospitals from the healthcare providers' point of view. In-depth case study was employed at the hospital because it is a point where supplies meet demand [Krichanchai 2015]. Improving operational performance at the hospital has a huge impact on both supply chain performance and quality of care for the patients.

Also, it is noted that the multiple case studies can provide the external validity and create more testable theory than a single case [Barratt et al. 2011]. Therefore, multiple case studies were conducted at thirteen hospitals which include tertiary, secondary, primary and private hospitals. The hospital cases were selected based on theoretical sampling in order to present similar results or show differences and diversities among case studies [Yin 2013]. The brief description of case studies was presented in Table2. The cases were conducted at both public and private hospitals. The first ten of the thirteen cases were the public hospitals which can be divided into three types namely primary, secondary and tertiary, based on the size of the hospital and the characteristics of healthcare service. The least of the cases were conducted at the private hospitals.

Semi-structures interview was used as a primary data collection approach. Also, triangulation techniques, including interviews, site visit and document analysis, are employed for data collection so as to enhance reliability and validity of the study. Table 2 shows the profile of each hospital.

Table 2. Hospital profile involved in this study

Case	Name	General data			
		Type of hospital	**Patient per day**	**Beds**	**Drugs (SKU)**
1	Hospital 10	Primary	708	30	324
2	Hospital 5	Primary	458	58	413
3	Hospital 6	Primary	435	62	354
4	Hospital 20	Primary	433	67	368
5	Hospital 12	Primary	431	30	619
6	Hospital 13	Primary	425	69	378
7	Hospital 3	Primary	400	54	433
8	Hospital 17	Primary	364	48	302
9	Hospital 11	Primary	281	60	294
10	Hospital 2	Primary	260	70	300
11	Hospital 1	Primary	206	46	471
12	Hospital 7	Primary	149	27	296
13	Hospital 4	Secondary	864	186	523
14	Hospital 16	Secondary	642	177	450
15	Hospital 8	Secondary	635	90	480
16	Hospital 15	Secondary	532	97	515
17	Hospital 9	Secondary	511	96	356
18	Hospital 18	Secondary	355	113	415
19	Hospital 19	Secondary	318	120	375
20	Hospital 14	Secondary	245	200	711

Analysis from the hospitals

From the hospital perspective, we see a similar pattern of hospital operations. Generally, the operations insides the hospital can be analyzed into three aspects-the structure of nodes and links, Information management, and material flow management. This is illustrated in Figure 1.

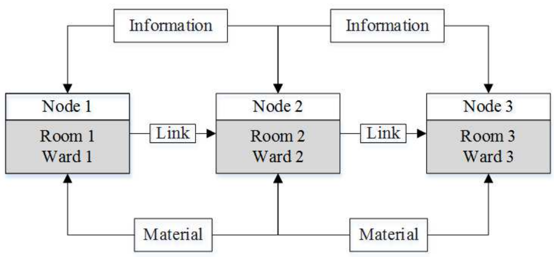

Fig. 1. Structure within hospital operations

Firstly, within the hospital, there is an interconnecting among healthcare staff within various rooms, wards, and departments in order to share information, resources and materials which are necessary to provide healthcare services. The complexity of hospital operations is different among various types of hospitals which we conduct the case studies. However, we can simplify the structure of hospital operations into two constitutes-Nodes and Links. Nodes can be either an origin station, in which information is generated or a material is delivered, or a terminated station, in which information or a material is received. An origin station or a terminated station can be a ward, a storeroom, a warehouse and a department even somewhere else in the hospital. In term of link, it is an activity enhancing the flow of information or material interconnecting between two nodes. Given an example, the hospital typically has a warehouse where medicines are kept once they are received from the suppliers and the storeroom where medicines are located before being prescribes to patients. A warehouse and a storeroom can be defined as a node. A link is an activity including ordering process from the storeroom to the warehouse, distributing process from the warehouse to the storeroom and information sharing between both nodes.

It is noticed that all of the case studies have very similar characteristics and locations of these nodes and links. They put effort to manage resources in the nodes. Resource management such as staff utilization and inventory management is critical. On the other hand, to manage the links, they focus on facilitating working flow processes between nodes network. Information sharing and network flow management are targeted.

Secondly, information management is another aspect that is critical for the hospital operations. Hospitals deal with a volume of information which flows simultaneously all day all night. The larger size hospitals, which reflect by the number of patients being served and the number of beds, are likely to handle a load of information which is greater and more complicated than the smaller size hospitals. Generally speaking, this information can be generalized into two types, the information that is necessary for providing healthcare services and information that is necessary for hospital operations. The first type of information includes patient information, lab results, X-ray films, clinical information. The purpose of this information is directly used for providing treatment and healthcare services to patients. Another type of information is not directly related to patient care but it helps support the operations within the hospitals. This includes a status of room, a status of patients, and the number of medicines in a warehouse. Regardless of information type, there is a need of enhancing information sharing and visibility among those who are eligible to access. For example, patient information is available for doctor, nurse and pharmacist who are responsible for providing treatment to patients. Although a pharmacist at the warehouse might refer to only an authorized pharmacist who can access pharmaceutical purchasing activity, the entire usage must also be visible.

Based on the study from hospitals, the results show that information system and system integration can be defined into two characteristics: integrated information system and separated information system. The integrated information uses a single system to operate information within the hospitals. This system is used to operate both information that is necessary for healthcare services and operations management in the hospitals. It is found that using this integrated information system helps information flow smoothly, and be accurate and consistent throughout the processes in the hospitals. Therefore, it enables the hospital to operate efficiently and ensure patient safety. Regarding a separated system, it is found that some hospitals usually implement two systems to manage information, front office and back office. The front office refers to a node or operation dealing directly with the patients, clinics, ward, pharmacy storeroom, emergency department and finance. Hence, this system supports the function related to medical services, transactions and operations management at the pharmacy storeroom. The information being operated by the front office system includes information related to patient care like patient status, scheduling, lab results and patient's payment.

In addition, the back office refers to any operations which are not related to patient care but they are typically related to hospital operations. These systems deal with human resource, resource, hospital finance, warehouse management and inventory management. Sometimes, these both systems are not integrated due to the compatibility of the systems or the complicated functions. Some hospitals like primary hospitals or small size hospitals sometimes have only a single system to operate the front office while the operations at the back office is done manually. It is found that the separated system can lead to the problem due to inconsistent information and inaccurate information. Given an example, when the hospitals operate the information related to medicine inventory level, the actual total stock level is invisible as the inventory level can be seen at the warehouse and the storeroom separately. Interestingly, the hospitals give the patient care as a priority regardless of any other operations that do not deal directly with the medical services even these operations help support the medical services provided by the healthcare staff. It has been seen that the information related to patient care is not consistent and standardized, and the information supporting hospital has not yet been standardized. Worse, it sometimes uses different set of product code in different systems as the systems are used for different purposes. Lack of consistency and inaccurate data can lead to inefficient hospital operations. Consequently, this can negatively affect the patient care.

Thirdly, material flow management is another operation that is important to healthcare services. There are various products that are delivered among departments, wards or units within the hospitals including food, clothes, sterile equipment, pharmaceutical medicine, patients and so on. Types of material management and transportation can be classified based on the responsibility into three types. Firstly, a supply unit delivers material to a service unit. To illustrate the point, a washing unit delivers clean clothes to wards and patients or central distributing unit delivers sterile products to dental units. Secondly, a terminal service unit picks up material at the distributing point; for example, pharmaceutical products and non-pharmaceutical products can be picked up at the pharmacy storeroom. Thirdly, both service unit and supporting unit share responsibility. A service unit collaborates with a supporting unit to manage material and transportation. For instance, an in-patient ward collects used clothes and delivers to the collecting point. Then, a washing unit picks up the clothes from the collecting point and is responsible for cleaning the clothes. Also, it can be classified based on the frequency of delivering service. For example, food is delivered three times a day while clothes are delivered two times a day. Storeroom prescribes pharmaceutical products for out-patient and emergency case every day. However, medical supplies are distributed less frequent as they are prescribed every week.

Common problems related to material flow management within the hospitals are high service frequency and limited space in the unit. Firstly, it has been identified that various products are delivered, and there is high delivering frequency per day. This is inefficient process especially when a lift is used as a transporting medium in a high building since the lift is used for delivering pharmaceutical, non-pharmaceutical products and patients. The number of lifts is limited, and it is not capable to support the delivering process during a rush hour. This delays processes and consequently leads to inefficient healthcare services. Moreover, some particular wards or units may require large space for holding inventories. For example, operation unit and in-patient ward typically hold various materials including medicines, sterile products, medical supplies, clothes in order to stock enough materials for one order cycle. However, it is typically found that space in the ward and unit are not enough to store the materials properly. It can be seen that limited resources within the hospitals affect the delivering process.

Therefore, it is important to classify the material management in the hospital into three types namely patient logistics, pharmaceutical logistics, and non-pharmaceutical logistics. It is suggested that the hospitals should be centralized to control the logistics activities. It requires a central transport unit to carry out these three logistics activities. The purpose of this unit is 1) to manage people and the medium of transportation efficiently and suitably for each task in order to deliver the materials as requested. 2) to manage delivery lead time efficiently regarding the limited resources in the hospitals. The mission of this unit is to deliver the materials to the right place, at the right time and quantity, in a good quality of material, and under the right condition or cost.

Issues at operation level regarding these three aspects – nodes and links, information management and material management can be illustrated in Figure 2.

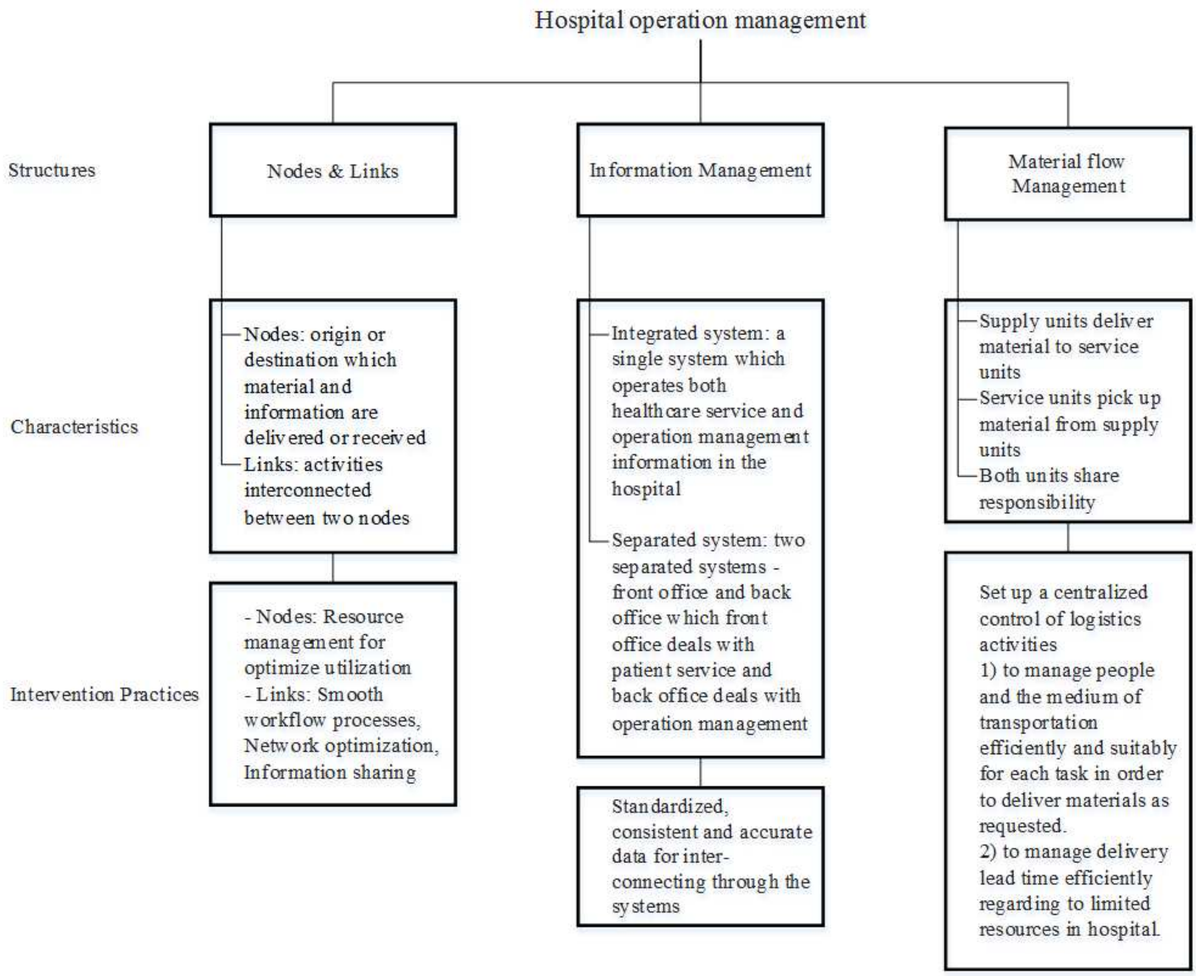

Fig. 2. Hospital operation management

ANALYSIS AND DISCUSSION

When conducting an investigation of the statement of knowledge in a field, two approaches have been used. The first approach is an exploratory review which literatures related to supply chain and logistics management in healthcare are studied in order to explore the global trends and best practices. The second approach is to conduct the exploratory case study within one focal player – hospital, which is analyzed in depth. This emphasizes on the operations and services within the hospital context. According to the explorative reviews and case studies, to enhance the collaboration among supply chain partners and better healthcare service level, two aspects namely macro-perspective and micro-perspective level are taken into consideration.

In macro-perspective, the explorative reviews present a global best practice and a major concerning issue which contain five infrastructures. These include standardized Product and Location Identification (GTIN-

Global Trade Identification Number and GLN-Global Location Number respectively), Electronic product catalogues, eProcurement enabled by Electronic Data Interchange (EDI), Automatic Identification and Data Capture (AIDC) systems such as barcodes and RFID, and Traceability Systems.

At the macro-level, it shows the need for all stakeholders to get accurate and consistent information [Vikram, Caronline 2011]. That is the reason why it is opted for the standardized product code and electronic product catalogue. This information helps stakeholders from supply side to demand side to communicate with each other efficiently. Therefore, this kind of information is required to support both clinical activities and logistics activities. Also, national standard code may not be sufficient to help the stakeholders in the industry communicate with each other. Generally speaking, the stakeholders involving in the industry are not only domestic organizations and local pharmaceutical companies but also multinational pharmaceutical companies and international distributors. The global standard code is evidenced to be implemented as a medium to communicate among the stakeholders in the industry [NETAH 2016; ISMP Canada 2013].

Moreover, e-procurement is suggested to facilitate the order and demand information among the stakeholders in the chain. To enhance e-procurement, it is suggested that the suppliers and the customers need to have an integrated system, by using EDI system, which as a consequence it will be more collaborative than using traditional approach for the procurement process. Employing e-procurement process means that the customers or the hospitals have to simplify the previous procurement process and shorten administration lead time. Therefore, the procurement process can be operated efficiently and enhanced collaboratively among trading partners.

Additionally, when dealing with a volume of information and simultaneous flow of demand in the healthcare, it will be difficult to operate manually like operating under a conventional system [Tiwari et al. 2017]. Automatic Identification and Data Capture like barcoding are now suggested in order to help capture and collect information. Typically, this automatic identification is used at the exterior package to support the logistics activities of the pharmaceutical manufacturers, the distributors and the hospitals. However, it has been less concerned and regarded to implement the barcode at the interior level. Once the medicines are unpacked from the box or from the pallet, they are difficult to be tracked or traced. Hence, it is now concerned that the automated identification system should be employed to operate product at the unit for the sake of better medication administration.

At the micro-perspective, the focus should be on the operations in the hospital. This is because the hospital is a linkage between the suppliers and the actual customers. The healthcare services or operations occur within the hospital context. Therefore, if there is anything affecting the operations within the hospital, it will negatively affect the healthcare services and patient safety [Vikram et al. 2012; Krichanchai 2015].

The hospitals are where the operations occur and the healthcare services are generated to serve the patients. In the hospital setting, it typically consists of the structure of nodes and links, information management and material management. Among various types and sizes of hospitals, there is a difference in term of the number of nodes and links within the hospitals and the complicated process either information management or material management. The larger size of hospitals contribute to the number of nodes or operations, the number of materials and the high volumes of information. It is necessary that the hospitals should enhance information visibility and implement an integrated information system. Information visibility not only enables the clinical staff to make a right decision and provide right treatments to the patients, but also enables the healthcare staff who operate the supporting activities including queuing and scheduling system, to perform the operations efficiently. Regarding the material flow management, there should be the integrated and centralized department providing the authorized logistics activities. Due to limited resource and the number of materials in the hospitals, the flow of the materials should be planned and managed properly. This presents that even at the operations level in the hospital, the concept of supply chain and logistics management should not be ignored. The conceptual framework of macro and micro perspective can be summarized in Figure 3.

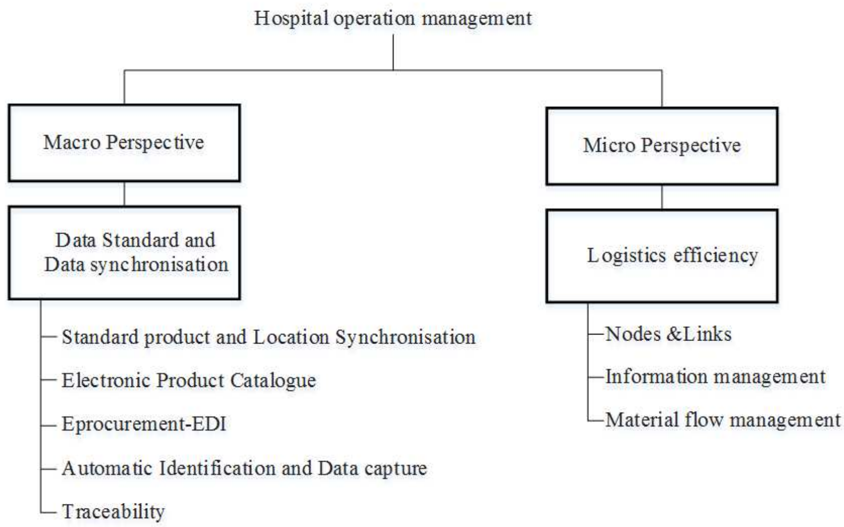

Fig. 3. Macro and micro perspective in Healthcare Supply Chain

CONCLUSION

Supply chain and logistics management has become increasingly important in recent years. It has been taken in consideration that collaboration among stakeholders and an integrated supply chain not only provide benefits in term of supply chain performance, but also help the healthcare improve services for the patients. As the result, it leads to an efficient process and greater patient safety. An explorative review of supply chain and logistics management in healthcare provides a clear picture of the best practices from five countries. It suggests five main standardized infrastructures namely Standardized Product and Location Identification, Electronic product catalogues, eProcurement enabled by Electronic Data Interchange (EDI), Automatic Identification and Data Capture (AIDC) systems such as barcodes and RFID, and Traceability Systems. Furthermore, the explorative studies present an in-depth analysis within a focal point at the hospitals. Based on the study with the hospitals in Thailand, there are the structure of nodes and links, information management, and material management. In the micro-perspective, the current operations in the hospitals are still fragmented and disintegrated. It is suggested that the concept of supply chain and logistics management should be taken into account. Therefore, it will lead to a collaborative among the nodes and the operations within the hospitals. Moreover, it can enhance an integrated information system and centralized material management (Tiwari et al. 2017). Consequently, it contributes to an efficient process and patient safety (Vikram et al. 2012; Krichanchai 2015).

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ZARZĄDZANIE ŁAŃCUCHEM DOSTAW W SŁUŻBIE ZDROWIA: PERSPEKTYWA MICRO I MAKRO

STRESZCZENIE. **Wstęp:** Zarządzanie łańcuchem dostaw to koordynacja i kooperacja pomiędzy różnymi podmiotami, będącymi członkami tego łańcucha w celu osiągnięcia jak najwyższej efektywności działania. Koordynacja i kooperacja łączy się nieodzownie z tworzeniem połączeń pomiędzy operacjami w obrębie łańcucha dostaw, przepływów materiałowych i informacyjnych. Łańcuch dostaw służby zdrowia jest skomplikowanym systemem włączających wielu udziałowych do łańcucha dostaw. Koordynacja pojedynczej platformy dla tych współudziałowców w celu osiągnięcia płynnego przepływu operacji jest dużym wyzwaniem. Celem tej pracy jest rozpracowanie operacji w obrębie łańcucha dostaw służby zdrowia, obejmującego przepływu materiałowe jak i informacyjne na dwóch poziomach: makro oraz mikro.
Metody: Analizie została poddana infrastruktura łańcucha dostaw szpitali umożliwiająca osiągnięcie efektywności operacji. Badania te zostały wykonane w 13 szpitalach dwóch szczebli organizacyjnych. Techniki trójkątne, obejmujące wywiady, wizyty w poszczególnych obiektach oraz analizę dokumentacji zostały użyte w celu zebrania danych o wymaganym stopniu rzetelności.
Wyniki i wnioski: Efektywność łańcucha dostaw służby zdrowia można uzyskać na dwóch poziomach, a mianowicie na poziomie całego łańcucha dostaw jak i na poziomie poszczególnej firmy. Najistotniejszym czynnikiem determinujących sposób organizacji na obu poziomach jest efektywność oraz bezpieczeństwo pacjentów.

Słowa kluczowe: służba zdrowia, zarządzanie łańcuchem dostaw, zarządzanie informacją, zarządzanie operacjami, Tajlandia

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ORIGINAL PAPER

IMPORTANCE OF KEY SUCCESS FACTORS FOR LOCAL AND INTERNATIONAL NGOS IN HUMANITARIAN SUPPLY CHAIN

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ABSTRACT. **Background:** Local and international non-governmental organizations play a pivotal role in a relief operation. However, as the number of disasters and their complexity is increasing, the challenges these organizations face during a relief operation are also growing exponentially. It is crucial for relief organizations to not only understand but also to prioritize the factors, which can make their supply chain work better. Therefore, this research aims at understanding the relationship between the key success factors, which can dramatically enhance the efficiency and effectiveness of the relief operation. Moreover, this study also highlights how LNGOs and INGOs differentiate between these KSFs and how they rank them.

Methods: To address the objective of this study, the Likert scale style questionnaire was developed and distributed online to all such NGOs (worldwide), which take part in the relief operation. The collected data was then tested for its empirical significance on SPSS using Spearman's Rho, Pearson Chi-square, to understand the relationship and importance of these factors. Whereas, the odds ratio was calculated to rank each KSF.

Results: The results of the study indicate that there exist strong correlation among all selected factors and all KSFs affect INGOs supply chain at least twice as much as they do of LNGOs.

Conclusion: According to our findings and in the light of literature discussed in this research, a successful relief supply chain depends not only on greater and stronger coordination & collaboration but also on sharing information and resources among LNGOs and INGOs.

Key words: KSF, Key Success Factors, CSF, Critical Success Factors, Humanitarian Supply Chain, NGO.

INTRODUCTION

In the last couple of decades, there has been a significant increase in the number of disasters worldwide. These disasters are affecting the world in a pronounced economical and geographical manner. Tatham and Houghton [2011] point out that the disasters have raised from around 220 per year in the mid-1990s to approximately 350-400 disasters per annum in recent years, affecting over 200 million people and are estimated to cost around US$200 billion. This sudden increase in disasters has also put much pressure on all actors involved in the humanitarian supply chain to improve their performances and to facilitate the beneficiaries efficiently and effectively [Ngwenya, Naude 2016]. A typical relief operation involves several actors like donors, host government, local non-governmental organizations (LNGOs) or international non-governmental organizations (INGOs), military, and suppliers [Maghsoudi et al., 2018, Costa et al. 2012]. However, LNGOs and INGOs have a pivotal role to play; they act as an agent to jell all the components of the humanitarian supply chain and more importantly, in the time of misery, beneficiaries look towards them for all the possible help they can get [Van Wassenhove 2017].

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Nonetheless, neither LNGOs nor INGOs have adequate means to respond to the disaster effectively and efficiently on their own, and hurdles like high urgency, uncertainty, lack of resources and local infrastructure can make relief operation even more challenging for such organizations [Martinez et al., 2011, Balcik et al. 2010]. Therefore, Yadav and Barve [2015] suggest breaking down the management process into the factors, might help responsible individuals to systematically manage and improve the disaster management processes. These factors are often referred to as critical success factors or key success factors, and they have been extensively studied in the commercial supply chain [Kabra, Ramesh 2015a]. However, According to Van Wassenhove [2017], Literature on humanitarian supply chain or humanitarian logistics is almost 15 years behind its commercial counterpart. Still, in the past few years handful of researchers like [Celik et al. 2014, Dasaklis, Pappis 2018, Kabra, Ramesh 2015b, Pettit, Beresford 2009, Sridhar, Nagabhushanam 2008] have shown some interest in understanding the impact of these success factors on the humanitarian supply chain. Nonetheless, there work mainly refers to some specific scenarios or is based on some fuzzy approaches or qualitative interviews for identifying the significance of these factors. Therefore, in this study, we try to empirically examine the relationship between some of the most important and most discussed KSFs in humanitarian literature. Furthermore, we also try to identify the differences in opinions of LNGOs and INGOs about the selected KSFs and see how they rank these factors. Thus, it leads to the following research questions we are going to answer through this research.

RQ1: Is there any significant relationship among KSFs in the humanitarian supply chain?

RQ2: What is the importance of KSFs for LNGOs and INGOs for a successful humanitarian relief operation?

LITERATURE REVIEW

In this section, we briefly explain the humanitarian supply chain; it's functioning, involved actors, and compare it to its commercial counterpart. Furthermore, we briefly explain the selected KSFs and highlight their importance in the humanitarian supply chain.

Humanitarian supply chain and key success factors

There is no simple way to explain the humanitarian supply chain, in principle, it is different from its commercial counterpart, and it adapts accordingly to the type of disaster [Eriksson, Karlsson 2017]. The humanitarian supply chain is a complex network of different tasks and activities built by several actors involved in a relief operation [Van Wassenhove 2017]. According to Maghsoudi et al. [2018] a typical humanitarian operation mostly consists of disaster relief supply chain, this includes but is not limited to activates like needs assessment, planning, procurement, warehousing, and distribution of the supplies to beneficiaries. Costa et al. [2012] further explain that humanitarian supply chain resembles a lot with its commercial counterpart, for instance, they share similar activities like preparation, planning, procurement, transportation, storage tracking, and customs clearance. However, the main objective of the humanitarian supply chain in action is to provide the right supplies to the beneficiaries at the right time and location. Maghsoudi et al. [2018] further suggest that the first 72 hours are the most crucial hour, and that is the time when needs are assessed and resources are mobilized. According to Abidi et al. [2014], an effective, efficient and timely supply chain management is directly proportional to the success of disaster relief operation, the speed with which medicine, food, shelter, and water is provided to the beneficiaries can be the difference between life and death. Therefore, it puts much stress on humanitarian organizations (LNGOs / INGOs) to perform each task and activity as efficiently and effectively as possible. Delays in providing relief to the beneficiaries could result in an augmented number of causalities. However, according to Celik et al. [2014], no actor involved in a humanitarian relief operation has enough capacities or resources to deal with the disaster on its own. Therefore, to respond to a disaster efficiently and effectively it is important for all participating LNGOs and INGOs to develop their performances. Yadav and Barve [2015] suggest, to improve the effectiveness and efficiency of a humanitarian supply chain and to systematically manage certain activities, it is essential to divide management processes into factors. In humanitarian literature, these factors are referred as Critical Success Factors [Pettit, Beresford 2009, Yadav, Barve 2015, Kabra, Ramesh 2015b, Eriksson, Karlsson 2017] or Key success factors [Oloruntoba 2010]. However, for this particular study, we have selected the four most discussed key success factors in humanitarian literature and they are explained underneath.

Donor restrictions

Donors donate billions of dollars to international and local LNGOs for relief activities, and many LNGOs solely rely on these donations to provide aid to the victims of a disaster. Some of the key contributors for this cause are, the European Union, governments of different countries, and a substantial amount comes from the private donors [Burkart et al. 2016]. Although donors do not have an obligation to fund any disaster, they do so out of the goodwill and for humanitarian causes. However, they demand strict scrutiny of the funds provided to relief organizations and if relief organizations fail to adhere to the demands of donors like accountability, transparency, and value for money. The donor may exit the collaboration with specific or all relief organizations involved in relief activities [Costa et al. 2012]. According to Scholten et al. [2006], disasters are becoming more sophisticated and it is a very challenging task to keep trail of the money spend during the operation, which puts an enormous amount of pressure on relief organizations and limits their freedom to use the funds as they see fit. Researchers like Balcik et al. [2010] and Besiou et al. [2011], discuss that donors often issue earmarked funds, which are intended to be used for specific disaster or purpose only. Therefore, we can assume that donors are an integral part of a humanitarian supply chain and it is crucial to understand what relation they as a KSF have with other important factors under discussion in this study.

Limited resources

Shortage of resources like transport vehicles, human resources, funding and capacities during a relief operation has been reported by several researchers [Balcik et al. 2010, Ngwenya, Naude 2016, Pettit, Beresford 2009]. These researchers also suggest that disasters' unique characteristic of 'uncertainty' in time, location and intensity makes it even more challenging to match demand and supply. The threshold of each organization to handle operations and supplies also vary, which is often referred to as capacity constraints. Therefore, it is important for all actors involved in relief operation to develop their capabilities and capacities to respond to a disaster more effectively and efficiently [Celik et al. 2014]. Balcik et al. [2010] also mentioned that it is nearly impossible for LNGOs or INGOs to own and operate fleet vehicles; therefore, they rely on the third-party/local vehicles and drivers to supply relief to the affected area. However, at the time of the disaster several LNGOs or INGOs compete with each other to get hold of scarcely available transport vehicles in the disaster area. Which results in a surge of the price and shortage of vehicles, which at the end hampers the efficiency of the relief operation. Therefore, this is also one such factor we are interested to explore in this study and examine how LNGOs and INGOs rate the importance of this factor.

Information collection and needs assessment

Along with understanding the needs of the beneficiaries, it is also important to have reliable and accurate information about disaster's location, intensity, infrastructural damages and a reasonable estimate of causalities or affected people [Moshtari, Gonçalves 2016, da Costa et al. 2014]. Such information can facilitate the relief operation in several ways, for instance, it helps in understanding the logistical needs, manage resources optimally and based on the location and type of disaster LNGOs or INGOs can prioritize, which sort of supplies could be more helpful in early stages for the victims. It also helps relief organizations in avoiding forecasting errors, which might have led to over or under delivery of supplies to beneficiaries. The first information about a disaster and needs assessment can dramatically enhance the response efficiency and effectiveness [Balcik et al. 2010, Maghsoudi et al. 2018]. Ngwenya and Naude [2016] add, if the host government or the relief organizations provide incomplete, inconsistent or inaccurate first information about the disaster's aftermath or beneficiaries, it can result in a significant loss of time in delivering relief aid, which may not even be needed by the beneficiaries. Thus, based on the above discussion, it may be concluded that Information and needs assessment plays a pivotal role in a relief operation. However, we shall further analyze how relief organizations think about this KSF and what relation it has with other factors under study in this paper.

Coordination and collaboration

Several actors who participate in the relief operation brings with them different structures, cultures, roles, and mandates, these differences eventually lead to the coordination barriers between different actors involved in a relief operation [Maghsoudi et al. 2018, Kabra et al. 2015, Kabra, Ramesh 2015a]. McLachlin and Larson [2011] suggest that apart from the reasons mentioned above chaotic post-disaster relief environment and lack of sufficient resources creating the atmosphere of urgency also often results in the unsuccessful coordination and collaboration efforts. Coordination among actors is one of the most challenging tasks to accomplish and it has direct consequences on the performance of relief operation. However, According to Lijo et al. [2018] confirms that it is common to see a lack of coordination and communication among different actors during a relief operation. Thus, resulting in making the already complex and difficult task even more challenging. The victims are the ones which most affected by this lack of coordination and collaboration. Therefore, it is safe to say that coordination among all key actors for a successful relief campaign has the utmost importance. As, Lack of coordination is often one of the biggest causes of delays in emergency relief, which adds to the sufferings of victims [Dasaklis, Pappis 2018]. Therefore, the question arises, why this most important task becomes so difficult. Researchers like Balcik et al. [2010] and Moshtari and Gonçalves [2016] explains that due to the competing interests of the key actors, the simple task of coordination has become very complicated and challenging. They highlight a few key elements, which discourage the actors to coordinate and collaborate. For instance, LNGOs or INGOs have to show their presence in the field to get donations from the donors especially in the early stages of a disaster.

Moreover, they also compete with each other to gain more media attention, as it has a twofold impact, not only they can get more donations by showing their presence on media but also it helps in gaining the support of local networks. Furthermore, another significant issue that causes hindrance in coordination efforts is the cost of coordination. The organizations need to organize training and courses to update the knowledge of their staff members and it has certain costs associated with like salaries and travel allowances, which discourages organizations to spare already scarce resources like money and workforce for training purposes. However, Sandwell [2011] suggests that humanitarian actors involved in relief organizations should understand that coordination and collaboration would give them a competitive edge and they would be able to achieve the humanitarian goals more effectively and efficiently. Therefore, as stressed by all the researches in the discussion above, we can sum it up with a notion that coordination holds extreme importance as a KSF for a successful humanitarian operation.

METHODOLOGY

This section briefly describes how we gathered the data for this research and which statistical tests were applied to answer the research questions.

Selection of KSFs

For the selection of KSFs, we did an extensive the literature review. According to Leiras et al. [2014], literature review helps in understanding the concepts, analysis, and interpretation of the results of the subject matter. Therefore, we looked up into two academic databases 'Web of Science' and 'Pro-Quest' and used references of key articles to collect 24 peer-reviewed academic articles, which discussed the Critical Success Factors, Key Success Factors, Critical Factors, or Success factors in the humanitarian supply chain [Dasaklis, Pappis 2018]. We discovered that the factors discussed in this research are some of the most discussed factors in humanitarian literature. Therefore, we selected these four factors and made a questionnaire to test their empirical significance.

Data collection and respondents

As discussed by Azmat et al. [2019], [2018], Meek et al. [2007] data were collected using a 5-point Likert Scale questionnaire (5 strongly agree – 1 strongly disagree). An online platform 'Lime Survey' was used to develop the questionnaire and later it was distributed with the help of World Association of Non-Governmental Organizations (WANGO) to all its member organizations in over 120 countries. The online method of distributing survey was used because it provides wide-ranging sample size, saves time, resources, and provides convenient access at lower costs [Bealt et al., 2016]. Moreover, the research team also sent out several emails; however, the response rate was very less and only 30 responses were collected. In total, we received 91 responses, and only 72 out of them were complete and fit for analysis.

For this study, we were interested in only such Local and International organizations, which actively participate in relief operations or have previously been participating in humanitarian relief. Through this survey, we collected the data from 25 LNGOS (incl. City level, Regional Level, National Level), and 47 INGOs. Furthermore, the data collected through this questionnaire was completely anonymous.

Data analysis technique

Collected data was tested for its normality using SPSS, and it was found that the collected data did not meet the assumption of approximate normal distribution [Azmat et al. 2019]. Therefore, non-parametric Spearman's correlation was used to find the relationship between selected factors. According to Abraham et al. [2016], the Spearman's rho or Spearman's rank correlation calculates the linear relationship of at least two ordinal variables. The advantage of rank correlation analysis is that the data does not need to be normally distributed; thus, we could use it to evaluate the relationship between KSFs understudy. Later on, the non-parametric Pearson Chi-Square test and odds ratio tests were used to see the differentiation in importance and ranking between LNGOs and INGOs.

Data reliability test

To check the internal consistency of the responses, we applied the Cronbach's Alpha test. According to Bland and Altman [1997], this test adds to the validity and accuracy of the interpretation of the data. They further suggested that, before employing a test for analysis, internal consistency should be determined to ensure the validity of the data. The acceptable values of alpha are between 0.70 and 0.95. However, for our responses, the value of Alpha is approximately 0.75 (Table 1), which indicates the data is consistent and fit for analysis.

Table 1. Cronbach's Alpha value for the collected data

Cronbach's Alpha	N of Items
.747	28

RESULTS AND DISCUSSION

This section presents the analysis of the data and discusses the main findings of this study.

RQ1 – Is there any significant relationship between different KSFs in the humanitarian supply chain?

To see whether there is any significant relationship among the factors under study, we used Spearman's correlation (Table 2). The results indicate that there exists a strong linear positive correlation among all the factors with a p-value smaller than alpha at 1% ($P<0.01$ valid for all factors). However, values of correlation coefficient vary for all factors and indicate that there is a very strong correlation between Information Collection and donor restrictions (.923), which translates, donor's restriction apply based on the information collected after the disaster or vice versa. Similarly, Limited resources and Donor restrictions (.812), indicates that donors restriction also influence the limited resources factor or vice versa. Whereas, a slightly lower correlation between donor restrictions and coordination has been observed (.533), which indicates these two factors influence each other but not as much compared to the other two. Moreover, there exists a strong correlation between information collection and limited resources (.731), but a relationship between limited resources and coordination and collaboration is significant but not very strong (.325). Similarly, the relationship between Coordination and information collection is also significant but not very strong compared to the relations ship with other factors (.486). Thus, to conclude the outcome of responses collected through this survey, it can be assumed that these factors have a statistically significant relationship with one another.

Table 2. Spearman's rho correlations among selected factors

		Donor restrictions	Limited resources	Information collection & needs ass.	Coordination & collaboration
Donor restrictions	Correlation coefficient	1.000	.812**	.923**	.533**
	Sig. (2-tailed)	.	0.000	0.000	0.000
Limited resources	Correlation coefficient	.812**	1.000	.731**	.325**
	Sig. (2-tailed)	0.000	.	0.000	0.005
Information collection & Needs Ass.	Correlation Coefficient	.923**	.731**	1.000	.486**
	Sig. (2-tailed)	0.000	0.000	.	0.000
Coordination & collaboration	Correlation coefficient	.533**	.325**	.486**	1.000
	Sig. (2-tailed)	0.000	0.005	0.000	.

** Correlation is significant at the 0.01 level (2-tailed). N of Valid Cases = 72

RQ2 – What is the importance of KSFs for LNGOs and INGOs for a successful humanitarian relief operation?

The results indicated in Table 3 are discussed under each subheading below.

Table 3. Summary of results of Pearson Chi-Square & Odds Ratio

	Donor Restrictions	Limited Resources	Information Collection & Needs Ass.	Coordination & Collaboration
Pearson Chi-Square (P-Value)	0.000*	0.000*	0.003*	0.012*
Odds Ratio (1.00 / 2.00)	0.129	0.073	0.179	0.175
For cohort LLNGOs & INGOs = LNGOs	0.335	0.262	0.395	0.415
For cohort LLNGOs & INGOs = INGOs	2.596	3.583	2.211	2.366

*$\alpha = 0.05$ N of Valid Cases = 72

Donor restrictions

Since p-value is less than significance level of 5% ($\alpha = 0.05$) i.e. $p<0.05$ (Table 2). Therefore, we conclude that there is a strong association between an organization's type (NGO / INGO) and Donors restrictions. Furthermore, the result of the cohort (LNGOs and INGOs) tells us that donor restriction are approximately twice as important factor for INGOs (2.596) compared to local LNGOs (0.335). We speculate that this could be because local LNGOs mostly rely on the local contributions and the local donors understand that these funds would be utilized for the disaster relief of the affected region with in the country and their country mates, thus resulting in fewer or no restrictions on utilization of funds. However, international organizations operate in multiple countries and often at the same time. Therefore, donors can restrict the usage of such donations, for instance, which country they can use the funds and for what purpose the funds may be utilized, can strictly be controlled by the donors. However, the odds ratio value of 0.129 helps us understand that among all four factors under discussion Donor restrictions can be ranked as the third most important factor.

Limited resources

Similar to the factor discussed above, a strong association is observed between organizations type and limited resources. In this case, again P-Value for limited resources is less than $\alpha = 0.05$ i.e. $p<0.05$ (Table 2). However, the result of cohort LNGOs & INGOs tells us that limited resources are approximately thrice as important for INGOs (3.583) compared to LNGOs (0.262). This might be due to the reason that local LNGOs have strong networks within the country and they are the first one to avail the scarce resources at better prices like transport vehicles, driver, supplies, and donations as discussed by (Balcik et al., 2010, Ngwenya and Naude, 2016, Pettit and Beresford, 2009). This gives them an edge on International organizations. On the other hand, when INGOs arrive in the affected region, they face issues in finding the resources, hence this could be the reason INGOs give it more importance than local organizations. Moreover, the odds ratio value of 0.073 tells us that among all other factors, this factor is ranked at the fourth most important factor.

Information collection & needs assessment

As discussed in the literature, accurate and complete information about disaster and needs of beneficiaries is essential for the successful relief operation. In this study, our results also indicate that information collection holds significant importance when it comes down to LNGOs and INGOs. The results in table 2 show that the P-Value is significantly smaller than $\alpha = 0.05$ i.e. $0.003<0.05$. However, if we compare the cohorts LNGOs & INGOs, we see that this factor is approximately twice as important for INGOs (2.211) compared to local LNGOs (0.395). Which suggests that local LNGOs have more chances of having accurate information about the location of the disaster and a good approximation of the affected people as they mostly rely on local networks for such information and they are mostly the first ones to arrive on the affected location. On the other hand, INGOs rely on this information mostly through media, which in many cases might exaggerate the figures and numbers, or they might understate the impact of a disaster. Moreover, the results of the odds ratio (0.179) tells us that this particular factor is ranked first among all other factors under discussion in this research.

Coordination & collaboration

Coordination & collaboration is one of the most discussed factors in humanitarian literature. Many researchers agree that the success and failure of a humanitarian operation heavily rely not only on the coordination among different relief organizations but within the organization as well. The results of this study are also in line with the existing literature, with a p-value smaller than $\alpha = 0.05$, i.e. $0.012<0.05$ it can be said that coordination and collaboration is a statistically significant factor for both LNGOs and INGOs. However, the cohort analysis of LNGOs and INGOs indicates that this particular factor is almost twice as important for INGOs (2.366) compared to local LNGOs. Which again boils down to an assumption that LNGOs mostly understand not only the culture of beneficiaries but also the organizational culture of other local relief organizations thus it is relatively easier for them to coordinate and collaborate with other organizations. On the other hand, INGOs bring their organizational structure and culture and find it difficult to coordinate and collaborate with the local NGOs and with other INGOs as more international organizations follow a more hierarchical structure, which makes this complicated issue even more challenging (Eriksson and Karlsson, 2017). However, according to the value of Odds ratio

(0.175), this is the second most important factors among other factors.

CONCLUSIONS

Humanitarian supply chain faces numerous challenges, which are different from its commercial counterpart. These challenges are fairly reflected in the key success factors selected for this study. In this study, we examined the relationship between these factors and found out that there exists a strong relationship between all four factors discussed in this study. Therefore, it helps relief organizations in identifying critical challenges and let them understand the humanitarian supply chain in a better way. Furthermore, we also examined how LNGOs and INGOs differentiate among these factors. The results of the studies address that all four factors understudy have significant importance in the humanitarian supply chain of both local and international non-governmental organizations. However, the magnitude at which these factors affect their supply chain varies significantly; Especially for INGOs, the impact of these factors on their supply chain is at least twice as higher as for LNGOs. This makes sense from a broader perspective, as the scope of operation of both organizations compared in this research also varies significantly. LNGOs, mostly have a competitive edge over INGOs as they not only understand the culture if the beneficiaries and are aware of norms and customs but also due to their presence in the society make them more trustable compared to the INGOs. INGOs on the other need to make stronger ties with LNGOs to improve the efficiency and effectiveness of their supply chain. According to our findings and in the light of literature discussed in this research, a successful relief supply chain depends not only on greater and stronger coordination & collaboration but also on sharing information and resources among LNGOs and INGOs.

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WAŻNE KLUCZOWE CZYNNIKI DLA LOKALNYCH I MIĘDZYNARODOWYCH POZARZĄDOWYCH ORGANIZACJI W OBRĘBIE HUMANITARNYCH ŁAŃCUCHÓW DOSTAW

STRESZCZENIE. **Wstęp:** Lokalne jak i międzynarodowe organizacje pozarządowe odgrywają kluczową rolę w realizacji poszczególnych operacji. Jednak ze względu na wzrastającą liczbę katastrof oraz ich wzrastającą kompleksowość, przed tymi organizacjami wzrastają coraz to większe wymagania i wyzwania. Dlatego też organizacje te nie tylko musza rozumieć, ale też umieść ustalać priorytety dla czynników wpływających na pracę łańcucha dostaw. Celem pracy jest zrozumienie zależności pomiędzy kluczowymi czynnikami prowadzącymi do sukcesu, które to istotnie wpływają na efektywność i wydajność prowadzonych operacji. Celem pracy jest również określenie jak lokalne i międzynarodowe organizacje pozarządowe rozróżniają te czynniki oraz które Suprze nich uważane za najważniejsze.

Metody: W celu uzyskania danych, opracowano ankietę korzystającą ze skali Likerta, którą następnie wysłano do pozarządowych organizacji na całym świecie. Uzyskane w ten sposób dane zostały poddane obróbce statystycznej przy pomocy SPSS (Spearman's Rho, Pearson Chi-square) umożliwiającej zrozumienie zależności i istotności poszczególnych czynników. Dodatnie zależności zostały wykorzystane w celu utworzenia rankingu tych czynników.

Wyniki: Wyniki przeprowadzonych badań potwierdzają istnieje silnej korelacji pomiędzy wszystkimi wybranymi kluczowymi czynnikami a efektami działania łańcuchów dostaw międzynarodowych organizacji pozarządowych, minimum dwa razy silniejszej niż w przypadku lokalnych organizacji pozarządowych.
Wnioski: Zgodnie z uzyskanymi wynikami oraz w świetle dostępnej literatury na ten temat, efektywne działanie łańcucha dostaw zależy nie tylko od silnej koordynacji i kooperacji ale również do współdzielenia się informacją i zasobami pomiędzy lokalnymi organizacjami pozarządowymi jaki i międzynarodowymi organizacjami pozarządowymi.

Słowa kluczowe: kluczowe czynniki sukcesu, krytyczne czynniki sukcesu, humanitarny łańcuch dostaw, organizacje pozarządowe

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ORIGINAL PAPER

TOWARDS EXPLORING BULLWHIP EFFECTS IN NATURAL GAS SUPPLY CHAIN

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ABSTRACT. **Background:** Bullwhip (or Forrester) effect is well studied phenomenon in many supply chains where small variations in customer demand have a tendency to become larger and larger when created by upstream members of the supply chain resulting in unneeded increasing in upstream inventory. However, there is substantial deficiency of scientific research on bullwhip effect in natural gas supply chain. Due to relatively smaller number of supply chain members and huge volumes flowing through the natural gas supply chain, benefits of decreasing or even eliminating negative consequences of bullwhip effect could be enormous. This paper aims to provide more insights in reasons for the occurrence, nature and consequences of bullwhip effect by measuring and analysing it in natural gas supply chain of Republic of Croatia.

Methods: After observation of orders and consumption from natural gas supplier, comparisons were made on monthly and yearly level. Well known and accepted metrics were used to calculate existence of bullwhip effect.

Results: Results didn't show existence of bullwhip effect on lowest level of natural gas supply chain what is in accordance with other researches. Best solution for mitigating potential or real bullwhip effect are information sharing while working on joint demand forecast in supply chain and use of newer forecasting method

Conclusion: Expected results should contribute to better understanding of bullwhip phenomenon in natural gas supply chain, but also provide possible avoiding strategies based on building trust in supply chain and on appropriate use of information and communication technologies.

Key words: natural gas, bullwhip effect, supply chain, information distortion.

INTRODUCTION

Natural gas is fossil fuel (not renewable resource) that can be find below the surface of the earth, and is made of many components – with methane being predominant. Although it is not as clean as renewable sources of energy, it is still most environmental friendly fossil fuel (it emits less quantities of harmful emissions in environment). Therefore it is considered as the best transitional fuel between fossil fuels and different renewable sources [Fernandez et al, 2018]. Due to ratio of price and efficiency, as well as availability (it can be found almost everywhere in the world) and environmental friendliness, natural gas has become one of most important energy sources. According to International Energy Agency [2018], natural gas supplies 22 % of the energy used worldwide, it is used for almost 25 % of electricity generation (in natural gas power plants) and it can be said that industry as a whole is main driver of growing demand for natural gas. Growing demand for natural gas in future will be determined by global economy growth as well with rising consumption that comes with rising living standards, and with a fact that natural gas is good bridge to prevailing or (hopefully) complete use of only renewable resources in the future.

Due to its growing usage today and in future, but also to relatively frequent price changes (same as for other fossil fuels), cost optimization becomes crucial issue in natural

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gas business. Price of natural gas generally consists of two parts: price of gas as commodity at the well (the "wellhead" price) and the "basis" price. The basis is so called location differential part of the price which consists of cost of transport via pipeline, suppliers and brokers profit margins, and risk/liquidity premium (depending on the state of the market, customers' credit and other factors). As it can be seen, major contribution to the price consists of supply chain or logistics costs, and managing this cost can substantially improve competitiveness of an organisation or whole natural gas supply chain. Jacoby [2012] talks about complexity of gas and oil supply chain management and points out two generic strategies most applicable to companies from this supply chain: rationalization and synchronization. Substantial savings in logistics costs (rationalization) could be achieved by reducing or even avoiding the Bullwhip effect (through synchronization). The bullwhip effect is the tendency of small variations in demand to become larger as their implications are transmitted upstream through the supply-chain. Usually it is resulting in unneeded increasing in upstream inventory levels that consequently results in other problems for supply chain members. Certain studies [Bray, Mendelson 2012; Shan et al. 2013] estimate that around two-thirds of companies are affected with bullwhip effect. Although bullwhip effect is well studied phenomenon in most of supply chains, there is still significant lack of researches regarding bullwhip effect in natural gas supply chain or in natural gas industry at all. Due to relatively smaller number of supply chain members and huge volumes flowing through the natural gas supply chain, benefits of decreasing or even eliminating negative consequences of bullwhip effect could be enormous. Additionally, it is not uncommon that companies on different echelons of natural gas supply chain have same owner and therefore avoiding negative bullwhip effects should be even easier – but it is still happening

The main goal of this paper is to present natural gas supply chain on model of Croatian natural gas supply chain system and to investigate possibilities of occurrence of bullwhip effect in it. To achieve the main goal, the authors have set two research questions.

Demand from final consumers to gas supplier is in substantial share unpredictable. Although, it depends on some known factors like weather and seasonality, still many suppliers struggle with accurate demand forecast. In theory, this should be fertile ground for the bullwhip effect and reason for forming first research question.

Q1: Does Bullwhip effect exists in the natural gas supply chain in Croatia?

From initial talks to natural gas supply chain member was concluded about lack of knowledge about bullwhip effect, as well as about activities to prevent it or decrease it. Second research question was formed in quest for appropriate bullwhip avoiding/decreasing activities in natural gas supply chain.

Q2: What can be done to decrease negative consequences of bullwhip effect in natural gas supply chain?

The paper is organised as follows. After introduction part, paper follows with literature review on bullwhip effect and its occurrence in natural gas supply chain. A next chapter describes natural gas supply chain of Republic of Croatia – its members, relationships, main flows and system functionality. Methodology and research results of measuring bullwhip effect in Croatian natural gas supply chain are presented next, while paper ends with discussion and conclusion remarks.

LITERATURE REVIEW

Bullwhip effect

Bullwhip effect is well known phenomena in supply chains defined as the amplification of order volatility along the supply chain [Wang, Disney 2016]. Its first written research is connected to book by Jay Wright Forrester Industrial Dynamic from 1961 [Forrester 2013] where he describes his empirical findings of increasing demand fluctuation seen by each new upstream supply chain member. Therefore, bullwhip effect is often also called Forrester effect. Although researches has be done novelty in this area arises slowly - one of most important was introduction of Beer game simulation game by Sterman in late 1980's [Sterman 1992] as an adequate behavioural decision model. Term bullwhip was first used by company Procter & Gamlbe (P&G) in 1990's who noticed order variance amplification phenomenon between the company and its suppliers [Wang, Disney 2016]. Furtherly, huge breakthrough happened in 1997 when Lee et al. [1997] suggested new causes, calculation, results and counter activities to avoid bullwhip effect. This paper is credited with considerable widespread of term bullwhip effect in academic sphere. Until today, bullwhip effects are noted in nearly all industries.

As Pilevari et al [2016] highlights, bullwhip generates fluctuation in three aspects in supply chain - information, physical and financial. They lead to revenue decrease (stock-out lost sale, low customer service/satisfaction, low quality, free return policies, forecast inaccuracy) and cost increase (high inventory carrying cost, high stock-out cost, high faster shipping cost, high setup and change-over cost, high labour cost - due to overtime, high material cost, high outsized facilities to handle peaks in demand, resulting in alternating under or over-utilisation).

Bullwhip effect main causes are: updating demand forecast, order batching / large lot size, price fluctuation (promotional sales), long lead times and / or to many intermediaries, and increased orders due to lack of information sharing [Lee et al 1997]. For other connected more detailed causes of bullwhip effects see Pilevari et al. [2016], but most important fact is that all causes have their roots in lack of coordination between supply chain members.

According to Domanski et al. [2009], one of critical factors in fighting the bullwhip effect is a proactive approach taken by managers. Therefore, organizations and supply chain should conduct some of activities for decreasing (or even avoiding) bullwhip effect like [Chopra, Meindl 2016; Balasubramanian et al. 2001]:

- reducing uncertainty (POS data and other information sharing, centralising demand information and forecasting),
- reducing lead time (through cross docking, faster suppliers, or decreasing information flow in lead time),
- reduce variability (reduce order batches and avoid price variability – e.g. every-day-low-price programs),
- forming alliance (e.g. Vendor Managed Inventory approach and eliminate gaming in shortage situation).

There is also different classification of bullwhip effects researches. Wang & Disney [2016] categorised all researches on bullwhip effect according to methodologies used into empirical, experimental, analytical and simulation-based approaches. Sari et al. [2004] categorized bullwhip effect researches according to main discipline in which they are conducted: system dynamics discipline, statistics and operations research discipline and control engineering discipline. While bullwhip effect research started from system dynamics discipline, authors point out additional contribution given by these two other disciplines.

The first step for supply chain members is to be aware of bullwhip existence. This is a prerequisite for organisations and whole supply chains to managing it and reducing it, as well as its effects. According to Azhar [2011], bullwhip effect could be observed on:

- one company level in different industries – e.g. apparel [Mack 1953], food [Hammond, 1994; Lee et al 1997], electronics industry [Holt et al 1968; Terwiesch 2005];
- whole industry (or more companies from one industry] – e.g. automotive industry [Blanchard 1983], machine tool industry [Anderson et al 2000] or textile industry [Zymelman1965]; or
- multiple industries - Miron and Zeldes [1988] compared food, tobacco, apparel, chemicals, petroleum and rubber industry, Cachon et al. [2007] categorized companies into three levels of a supply chain: manufacturing, wholesale and retail industry level.

When it comes to measuring the bullwhip effects, there are different approaches [Parra-Pena et al. 2012; Fransoo, Wouters 2000; Fu et al. 2015; Chen, Lee,2012; Centeno, Perez

2008; Cannella et al. 2013], but most accepted metric is called bullwhip effect ratio (BEratio). According to Chen & Lee [2012], BEratio can be calculated in two ways:

- as ratio of variance of orders and variance of demand, or
- as ratio of variance of production and variance of demand.

In first case BEratio depicts distortion of information flow (by comparing variance of orders with variance of demand), while in second case BEratio represents distortion of material flow (by comparing variance of production and variance of demand). In all options there is consensus that bullwhip effect exists if BEratio value is larger than 1.

In different settings researchers choose different metrics, mostly according to available data about organisations and their supply chains, but Chen and Lee [2012] here highlight that BEratio is more suitable metric than absolute difference metric – especially when there is a need to compare bullwhip effect for different products.

Bullwhip effect in natural gas industry

Bullwhip effect research in natural gas industry are extremely rare, and if they are made they are analysed jointly with oil industry [Chima 2007; Miron, Zeldes 1988; Cachon et al. 2007; Azhar 2013]. Binlootah & Sundarakani [2012] elaborate using of VMI (Vendor Managed Inventory) as a tool for mitigating bullwhip effect in oil and gas industry. There are even less or no studies on lower downstream natural gas supply chain level, and this is area where this paper is trying to fill the gap. Zhang and Zhang [2013] detected a delay as main reason for bullwhip effect. Tomasgard et al. [2007] gave a review of optimization models for the natural gas value chain. Sherhart [2013] studied bullwhip in British Petroleum (uses Theory of Constraints to mitigate the bullwhip effect). There are only few studies of bullwhip effect on multiple levels of natural gas supply chain [Azhar 2013; Jacoby 2012]. Azhar [2013] have found bullwhip effect in most of studied companies but not totally consistent increase in demand variability upstream the supply chain. She also concluded that smaller companies had larger bullwhip effect, while larger integrated companies exhibited a lower bullwhip effect.

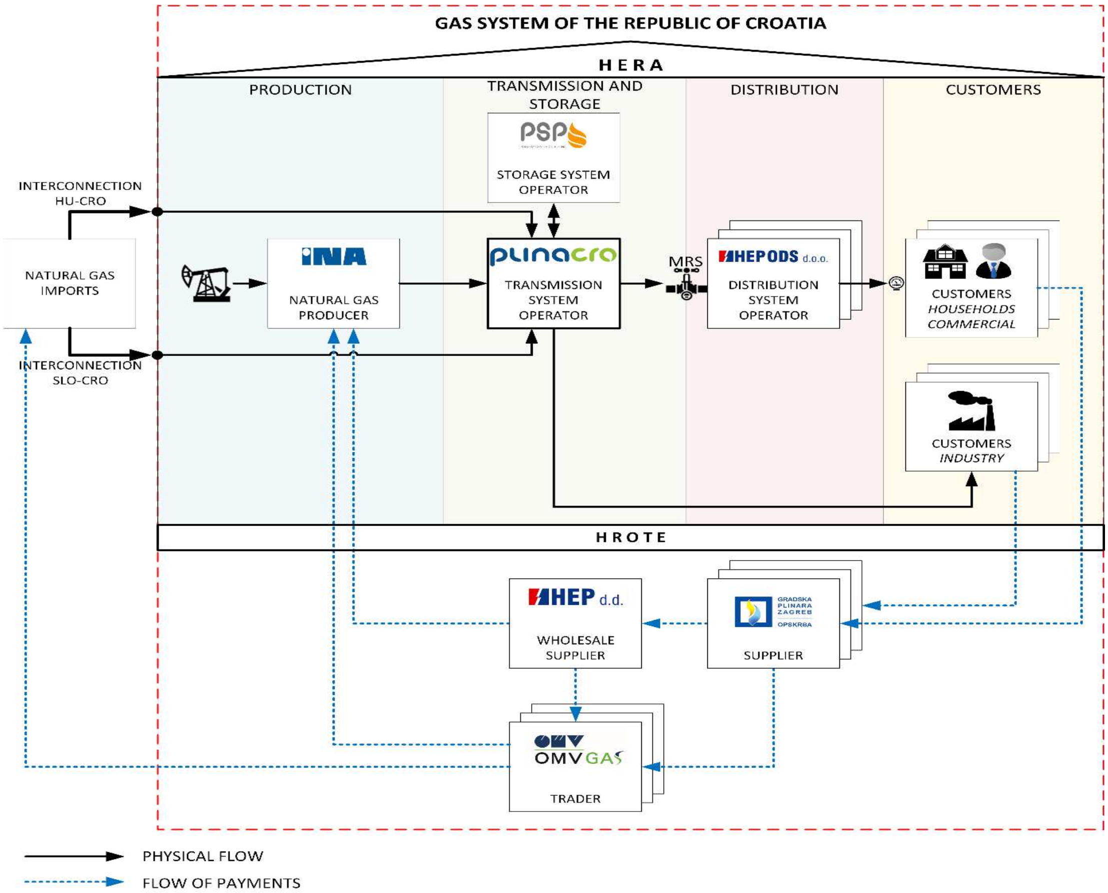
Recent studies in the oil and gas equipment industry have shown existence of bullwhip effect in upper parts of oil and gas supply chain [Jacoby 2012]. As a result of this study, Jacoby [2012] points out on for types of economic inefficiency: paying higher prices, having excess inventory during "the boom", making excessive capacity investments near the peak with low or negative return on investment on it, and loosing orders because of inability to fulfil them (inadequate capacity and long lead time in time of increased orders – "peak").

- Companies that are closer to final customer (more downstream) have lower level (or no) bullwhip effect ratio
- Smaller companies tend to have higher bullwhip effect ratio then bigger ones

According to Jacoby [2012], one of the reasons why oil and gas industry are so concentrated, is a fact that companies in oil and gas supply chain use vertical integration, scale and market dominance to protect themselves from bullwhip effect negative consequences.

NATURAL GAS SUPPLY CHAIN IN CROATIA

According to Strelec [2014], members of natural gas supply chain or gas market participants in Croatia can be divided into four basic groups: natural gas producer, system operators (transmission system operator, storage system operator, distribution system operator, gas market operator, LNG terminal operator), suppliers and traders, and customers. Supply chain of natural gas in Croatia with its members and physical and payment flows is shown at Figure 1. Some of them form logistical part of natural gas supply chain (gas physically flows through them), and some of them just participate in market or trade channels - they buy and sell natural gas without any physical contact with it. Examples of such supply chain members are certain suppliers or wholesalers who are intermediaries, but are not involved in any physical flow of natural gas.



Source: Šebalj, D., Mesarić, J. & Dujak, D., 2018

Fig. 1. Natural gas supply chain of Croatia

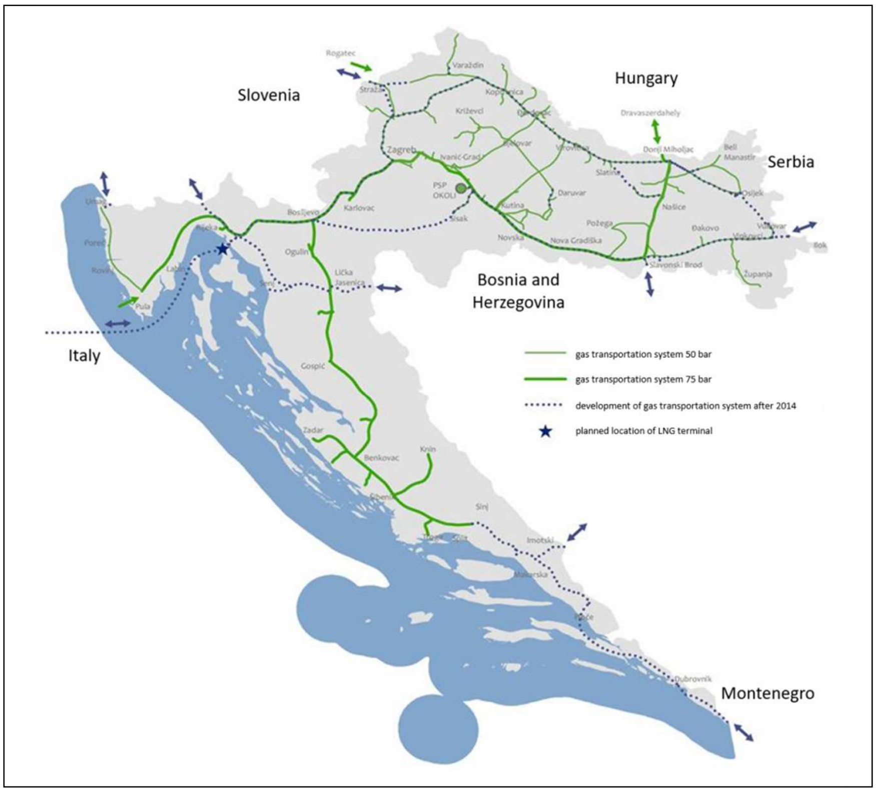
Croatian natural gas supply chain starts with gas production in Croatia or with gas import from some of most important European gas markets like Russia and Italy. Today, Republic of Croatia imports around 60% of natural gas needed, while only 40% is produced in Croatia. Domestic production is steadily declining and is performed by only one, partly state owned company, who has a license for gas production – INA d.d.

The natural gas transmission or transportation is a regulated energy activity performed as a public service and is also performed by the state-owned company Plinacro d.o.o., owner and operator of the transmission system [Energy in Croatia, 2016]. Figure 2 presents natural gas transmission system of the Republic of Croatia.

The transmission system currently covers about 95% of the territory of the Republic of Croatia. The total length of the pipeline in the transmission system is 2,693 km, of which 952 km are 75 bar working pressure pipelines and 1,741 km are 50 bar working pressure pipelines, while total transported volumes are around 3 billion m3 [Plinacro, 2018]. There are two connections with international gas transportation systems (Rogatec on Slovenian border and Drávászerdahely at Hungarian border). The main activity of transmission system is transportation and storage of natural gas throughout the country.

Storage system operator is an energy subject that performs energy activity of gas storage. Croatia currently has only one natural gas storage facility (PSP Okoli) managed by the company Podzemno skladište plina d.o.o. (storage system operator), which is owned by

Plinacro d.o.o.. Since the gas production is constant throughout the year and the gas consumption varies in summer and winter period, the technological processes in the underground gas storage take place in two cycles – injection cycle (April to October) and withdrawal cycle (October to April).



Source: Plinacro Ltd.

Fig. 2. The natural gas transmission system of the Republic of Croatia

There are 35 distribution system operators in Croatia which distribute gas (physically transport gas through a pipeline network) to each consumer's home or business facility. 13 companies operate exclusively in the energy activity of gas distribution, while 23 companies are organized as vertically integrated legal entities that, along with gas distribution, act as gas suppliers on gas market as well. Some of them are state-owned while majority are private companies. The length of the distribution network in Croatia is 19,153 km [HERA 2018].

According to the Gas market law [Official Gazette, No. 18/18], gas market operator is the energy subject that organizes gas market and is responsible for the management of the trading platform. For the Croatian gas market operator is designated Croatian Energy Market Operator d.o.o. [HROTE].

LNG terminal operator is responsible for operation, maintenance and development of the LNG terminal. The license for this activity has the company LNG Hrvatska d.o.o., which was issued in 2017 for a period of 3 years. The LNG terminal construction project is currently underway.

Gas supply represents a purchase or an order of the certain amount of gas that will be later transported through distribution system. Therefore, gas suppliers are in direct contact with final consumers and are exposed to original demand (or retail-level demand). All other upstream supply chain member deal with derived demands. The fact that other upstream supply chain members usually don't have direct data about original demand is one of root reasons for developing phenomenon like bullwhip effect.

Natural gas trade covers the purchase and sale of gas, excluding gas sales to the final customer [Gas market law, Official Gazette, No. 18/18]. The gas trading license currently holds 8 companies.

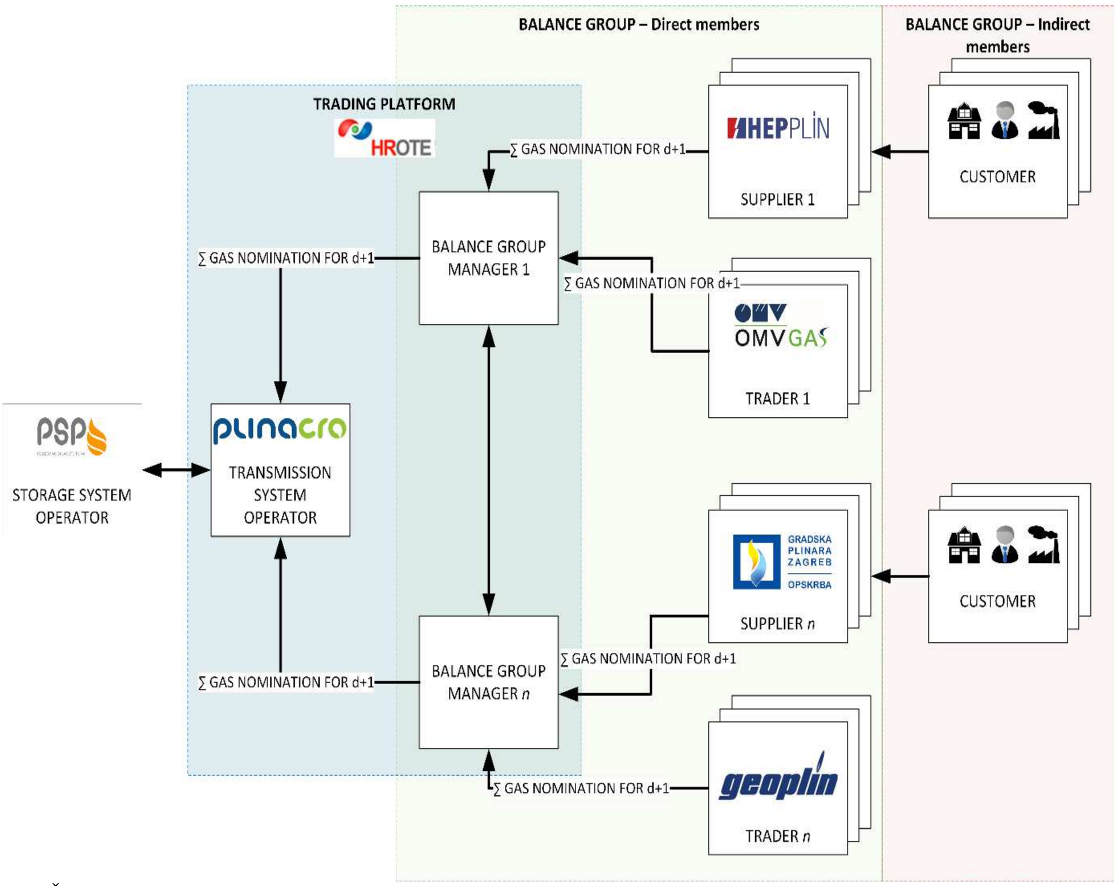
Within the scope of gas supply, customers are divided into two groups:

- households – the supply of households can be performed as a market service (by free choice of gas suppliers and negotiating terms and prices) or as a public service (under the prescribed general conditions and at a regulated price),
- commercial customers – for the supply of commercial customers the market principles are applied, that is, free contracting of mutual relations. This type of customers can be divided into those that are directly connected to the transmission system (large industrial consumers) and those connected to the distribution system.

The specificity of natural gas supply chain (both in Croatia and in most of other countries in the world) is that final consumer demand (original demand) is always entirely fulfilled. Exceptions occur extremely rarely in case of serious geopolitical international conflict, wars or natural disasters. This is due to way of functioning of natural gas transmission system where gas final consumers are actually physically connected with gas producers, and where the pipeline system functions not only as transportation mode, but also as a warehouse / storage with huge capacity.

MEASURING BULLWHIP EFFECTS IN NATURAL GAS SUPPLY CHAIN

For this research, flow of communication in form of orders and/or nominations (order announcements) is even more important than physical flow. Order flow in natural gas supply chain of Croatia is presented at Figure 3.



Source: Šebalj, D., Mesarić, J. & Dujak, D., 2018

Fig. 3. Order flow of natural gas supply chain

Suppliers act a role of retailers towards final consumers (either households or industry) – they sell gas to them and, more or less precisely, measure their consumption of natural gas. Based on historical consumption data and other variables (e.g. weather forecast, seasonality character, other industry or regional specifics) they are making their own predictions and send them as daily nominations (for the following day on hourly level) to the so called balanced group manager – one of suppliers who represents a group of connected suppliers that are buying and withdrawing gas from the same transmission system operator. Balanced group manager collects all nominations from the members of his balance group and sends the total nomination to the transmission system operator, via trading platform.

As the transmission system (i.e. pipeline system) of natural gas in Croatia has to be balanced, it is important to insert same amount of gas into transmission system as the amount that is spend / withdrawn from it. And this is main role of nominations that represent main direction for inserting gas into the system. Nominations are just predictions and they are usually more or less wrong - errors are happening. If there was more gas inserted into the transmission system than it was spent / withdrawn – positive imbalance occurs. In opposite case, negative imbalance of the transmission system follows. Obviously, system needs to be balanced again with additional amount of gas or some not spend gas has to be stored (this amount is called "balancing energy"), and cost of this balancing has to be paid by gas suppliers who were making nominations. The more accurate the nominations are, the lower is the supplier's cost.

METHODOLOGY AND RESEARCH RESULTS

For the purposes of this research authors use data for 2017 year of one of main natural gas supplier in Croatia (natural gas supplier "X") to calculate BEratio and check if there is a bullwhip effect occurring on this natural gas supplier level. For calculating bullwhip effect purposes we used a formula that indicates distortion of information flow as a ratio of variance of orders and variance of demand (due to data availability). Orders are presented with nominations that are send regularly (daily) to transmission system operator, and demand is actual natural gas consumption (because whole demand is satisfied). All data are coming from one measuring-reduction station of supplier "X" that has the largest gas flow (the largest households' consumption) and all data are expressed in kilowatt hours (kwh) of natural gas.

Figure 4 represents the differences between orders and actual consumption during January 2017 (daily level distortion). January is traditionally a month with highest natural gas consumption in Croatia, and it can be seen from figure 4 that differences between nominations and consumption sometimes reach even 22% (like on 10th January). But, than BEratio was calculated:

$$BEratio_{monthly} = \frac{Variance[Orders]}{Variance\ [Demand]} = \frac{46112687894{,}09}{182127159591{,}65} = 0{,}25319$$

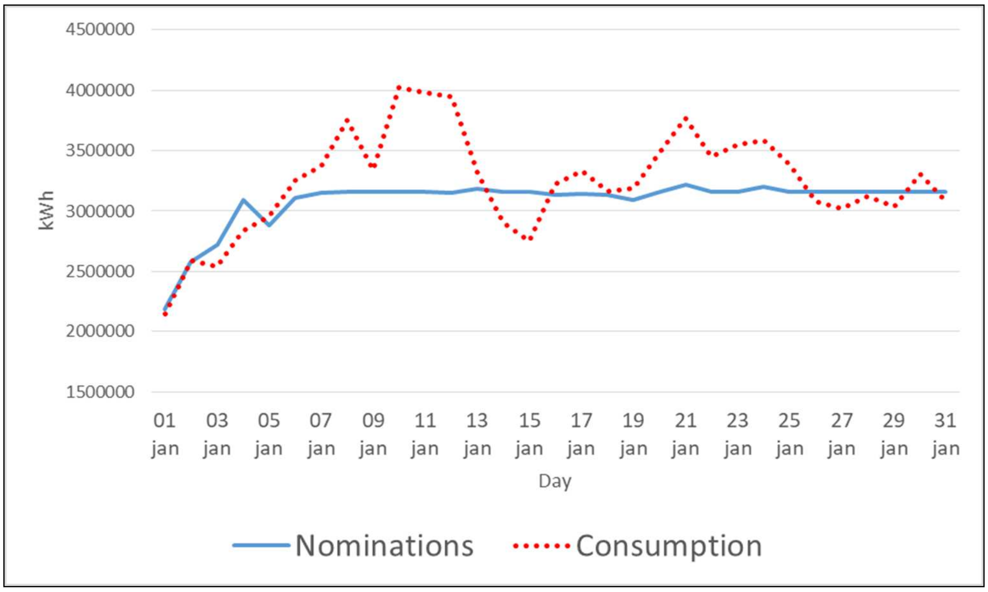
As BEratio is only 0,25319 it can be conclude that on monthly level in January, there is no bullwhip effect at supplier "X".

If the whole year 2017 is analysed (monthly level distortion), it can be seen that the differences between orders and consumption are not significant (see Figure 5). From this figure it can be seen that those differences, especially in summer months, are not so significant – the biggest is around 5% in January. In this case, total nominations are only 2% lower than consumption.

Based on monthly orders and demand data, a BEratio for the whole year 2017 was calculated:

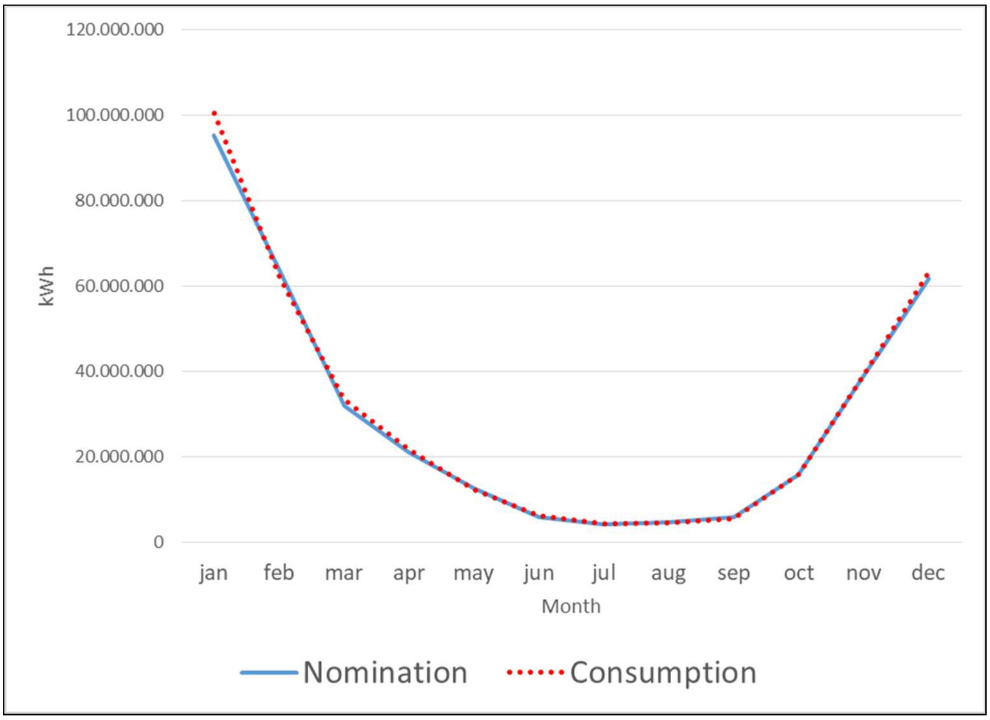
$$BEratio_{yearly} = \frac{Variance[Orders]}{Variance\ [Demand]} = \frac{873972324885971}{932231778637331} = 0{,}937505$$

In this case, BEratio value is much higher and close to 1, but still not higher than 1. Although it can be stated that there is no bullwhip effect at supplier "X" at yearly level, it can be noticed that BEratio value is increasing on longer periods of analysis.



Source: Authors' calculation based on internal data of supplier "X"

Fig. 4. Difference between nominations and actual consumption on a monthly basis



Source: Authors' calculation based on internal data of supplier "X"

Fig. 5. Difference between nominations and actual consumption on a yearly basis

DISCUSSION AND CONCLUSION

Natural gas supply chain is huge and complex system with enormous amount of gas flowing through its transmission system every day. As this system is functioning on balancing principle that penalize differences between nominated quantities (orders) and real consumption, accuracy in forecasting needs for gas for next day accounts for significant share of companies costs. As one of rear studies which analyse specifics of only natural gas supply chain, this research have shown functioning of natural gas supply chain with special emphasis on relationship and communication between lower part members of natural gas supply chain - gas end consumers, suppliers and wholesalers. Research results confirm Azhar's [2013] claim that on lower level of supply chain there is no bullwhip effect or its value is really small – this is the case for natural gas supply chain as well. Even though differences between orders and nominations are noticed in all analysed periods, on the last downstream level of natural gas supply chain there is no bullwhip effect. However, research has shown considerably higher level of BEratio on yearly level (0,937505) then BEratio on monthly level (0,25319). One of the reasons of such low level of BEratio is really short lead time in natural gas supply chain which is enabled with pipeline system of gas delivery, as well as rare changes of consumer prices for gas.

Although, bullwhip is not recorded with this research, differences between orders and demand are noticed (reaching sometimes to even 20%). Recommendations for decreasing this differences and avoiding possible development of bullwhip effect are:

- Organisations should use more information sharing in supply chain with aim of making more accurate forecast and orders (nominations) for gas.
- In future, organisations on different levels of natural gas supply chain should make one joint demand forecast, based on original demand and larger number of other variables collected from more supply chain members. This should be easily feasible especially in supply chain from this research in which in some cases even three levels of natural gas supply chain are vertically integrated by ownership.
- Organisations should use different and forecasting methods with higher accuracy like neural networks, ANFIS, genetic algorithms, grey model or some other mathematical and statistical models [Šebalj et al., 2019].

In further researches, authors plan to measure BEratio on at least one more upstream level in natural gas supply chain, as well as to expand measuring by including larger number of companies on each supply chain level. This way we would be able to conclude about existence and magnitude of bullwhip effect in natural gas supply chain, as well as to discuss about its reasons and ways of avoiding it.

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WYKORZYSTANIE ALGORYTMU HEURYSTYCZNEGO DO ROZWIĄZANIA PROBLEMU SYNCHRONIZACJI DOSTAW CYKLICZNYCH DO CENTRÓW PRZEŁADUNKOWYCH

STRESZCZENIE. Wstęp: W pracy przedstawiono problem synchronizowania dostaw cyklicznych do centrów przeładunkowych. Dostawy realizowane są na stałych trasach: pojazd, obsługujący daną trasę ma dostarczyć towar do centrum przeładunkowego, załadować tam inny towar i przewieźć go do kolejnego punktu trasy lub wykonać pusty przejazd do punktu załadunku. Punktami synchronizacji obsługi tras są centra logistyczne, w których niejednokrotnie towar przywieziony przez jeden pojazd, wyrusza w dalszą drogę innym. Dostawy na każdej trasie realizowane są ze stałą częstotliwością. Trasy dostaw oraz ilości przewożonego towaru są znane. Celem w problemie synchronizacji dostaw cyklicznych jest maksymalizacja liczby synchronizacji przyjazdów i pobytu pojazdów w centrach logistycznych tak, aby możliwe było grupowanie ich obsługi w bloki rozładunkowo-załadunkowe.

Metody: Na podstawie opracowanego wcześniej modelu matematycznego dla problemu synchronizowania dostaw cyklicznych do centrów przeładunkowych został zbudowano algorytm heurystyczny poszukujący rozwiązań poprzez ukierunkowane losowanie. W artykule przedstawiono opracowany algorytm losowego przeszukiwania.

Wyniki: Eksperyment obliczeniowy polegał na rozwiązaniu zestawu zadań synchronizowania dostaw cyklicznych przy pomocy opracowanego algorytmu i porównaniu uzyskanych wyników ze znanymi rozwiązaniami dokładnymi.

Wnioski: Przedstawiony algorytm heurystyczny dla zadania synchronizowania dostaw cyklicznych pozwala na uzyskanie rozwiązań zbliżonych do wyników otrzymanych przy zastosowaniu modelu programowania matematycznego. Zaletą zastosowanego algorytmu jest znaczne skrócenie czasu poszukiwania rozwiązania, co może mieć znaczenie dla praktycznego wykorzystania zaproponowanej metody.

Słowa kluczowe: harmonogramowanie dostaw cyklicznych, programowanie całkowitoliczbowe mieszane, optymalizacja, synchronizacja, algorytmy heurystyczne

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