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LOGISTICS CAPABILITIES IN ACHIEVING THE FIRM'S COMPETITIVE POSITION AND MARKET SUCCESS

Abstract

Firms are constantly looking for ways to build and strengthen their competitiveness. The most important dimensions of the firm's competitiveness are the firm's competitive position as well as the firm's market success. An important role among the most significant factors affecting the firm's competitiveness is assigned to the firm's capabilities, including logistics capabilities. The aim of the article is to present the possibilities of the influence of the firm's logistics capabilities on the firm's competitive position as well as the firm's achievement of market success. In particular, the following issues are presented in the article: (1) the nature of the firm's capabilities, including dynamic capabilities perceived as its strategic capabilities; (2) the firm's competitiveness and its basic characteristics; (3) the firm's competitive advantage with its main dimensions concerning the competitive position and market success; (4) logistics capabilities perceived as the firm's strategic capabilities affecting the firm's competitive position and achievement of market success in light of the research.

Keywords: logistics, capabilities, competitive position, market success

JEL: L10, L19, M10, M19

Introduction

During last years the growing importance of logistics perceived as a concept of management of the flow of materials, goods and information can be noticed. As a result, the potentials of a firm's success related to the area of logistics, frequently referred to as logistics potentials of success, are one of the most significant factors influencing the firm's success in the broad meaning of the word. The most important symptoms of such success are the expected market outcomes (customer satisfaction, customer loyalty, market share) and economic outcomes (profit, profitability, return on invested capital) achieved by the firm. In turn, these outcomes are the basis for building and strengthening the firm's long-term competitiveness including: (1) a competitive advantage, (2) a competitive position, and (3) market success, while the last two are the most significant dimensions (symptoms) of the firm's competitive advantage (Blaik et al., 2013; Matwiejczuk, 2014).

One of the most important potentials of success related to the area of logistics are the logistics capabilities. The aim of the article is to present the possibilities of the influence of the firm's logistics capabilities on the competitive position as well as the firm's achievement of market success. Logistics capabilities are one of the key and dynamic capabilities of a firm, affecting the building and upgrading of business models, as well as the formulation and development of the firm's effective and efficient strategies. Such models and strategies determine the building and strengthening of the firm's competitiveness in the broad sense of the word, including creation of its competitive advantage and competitive position, as well as the achievement of the firm's market success.

1. Nature of the capabilities of a firm and their basic characteristics

The process of building the firm's competitiveness is associated with strategic management in the broad sense of the word, in particular, with a most significant – especially in recent years – stream, referred to as "resource-based strategic management". Within the resource-based strategic management stream the key role in shaping and strengthening the firm's competitiveness is assigned to the so-called potentials of success, including – *inter alia* – the firm's capabilities.

The term "capabilities" was introduced into business management by Ansoff (1965). In general, capabilities are a "bundle" (composition) of various skills and abilities needed for the implementation of activities and/or tasks (Prockl, 2007). The basic feature that is the most important characteristic of the firm's capabilities is their orientation towards achieving the expected outcomes. These outcomes may be reached thanks to purposeful and coordinated methods and ways of active involvement of the firm's resources (composition of resources) in the achieving the set goals.

The firm's capabilities are supposed to have four basic characteristics.

Firstly, the capabilities should enable the firm's quick, effective and efficient response to dynamic changes occurring in the environment, especially in the market and competitive environment, as well as within the firm itself.

Secondly, the capabilities should enable holistic management of the firm and its relations with other firms, taking into account the complexity of the relationships between the firm's individual management subsystems (decision subsystems, components of management concepts, management functions, functional areas, etc.) as well as between the firm and other entities within the entire supply chain (suppliers, distributors, customers, competitors, etc.).

Thirdly, the capabilities should enable achievement of the expected level of performance, assessed both from the market perspective (from the perspective of the value and benefits for customers), as well as from the economic perspective (from the perspective of the value and benefits for the firm).

Fourthly and finally, the capabilities should include management of the firm's multidimensional (holistic) relations with various stakeholder groups, enabling creation of value for all entities in the supply chain.

2. Dynamic capabilities as strategic capabilities of a firm

A crucial role within the process of building of the firm's competitiveness, including – in particular – achieving the intended competitive position and market success, is assigned to the so-called dynamic capabilities of the firm. The firm's possession of resources is not a sufficient condition for obtaining the desired competitive advantage or taking the intended competitive position on the market. It is also necessary to develop the firm's appropriate capabilities, and in particular, the firm's dynamic capabilities.

Particular attention within concept of dynamic capabilities is paid to the strategic importance of the firm's capabilities as "integrating mechanisms" concerning compositions of various resources at the firm's disposal (Teece et al., 1997; Eisenhardt, Martin, 2000). The integration of resources (compositions of resources) and capabilities (compositions of capabilities) enables the simultaneous use of these two types of success potentials in achieving the expected market and economic outcomes by firms. Such outcomes are the basis for creation of the firm's competitive advantage, as well as achieving the intended competitive position and market success.

Dynamic capabilities primarily concern the integration, shaping and reconfiguration of resources as well as the processes of their acquisition and utilization by firms (Teece et al., 1997; Eisenhardt, Martin, 2000). They enable active adaptation of firms to the market requirements as well as to the changes taking place within the firm's environment, being also the basis for shaping the firm's long-term competitiveness. In this sense the firm's dynamic capabilities can be perceived as the firm's strategic capabilities.

Dynamic capabilities as the firm's strategic capabilities include three groups of the so-called "dynamic sub-capabilities":

– adaptative capabilities;
– absorptive capabilities;
– innovative capabilities (Wang, Ahmed, 2007).

The adaptative capabilities include several individual abilities concerning the firm's adaptation to changes taking place in the environment. They apply – first of all – to the adaptation of resources to the market and customer requirements, as well as to processes and activities performed by competitors. In particular, the adaptative capabilities are related to adaptation of products and services to the changing customer needs, responding to new directions and symptoms of market development, including changes taking place in the competitive environment, as well as recognizing and seizing the emerging market opportunities.

On the other hand, the absorptive capabilities mainly include the abilities that allow assessing the value of knowledge, in particular, the so-called market knowledge perceived as a key resource of firms and supply chains, as well as the abilities that allow acquiring and using this knowledge, related to the creation of the firm's competitiveness and its competitive advantage. The absorptive capabilities comprise the abilities in the field of identifying the key areas of market knowledge (customers, products, services, competitors, suppliers, distributors, etc.) as well as the abilities to use the market knowledge in the development of new products and services, taking into account the needs of customers.

Finally, the innovative capabilities concern the abilities of the firm and supply chains in the area of development of new: (1) products and services; (2) production methods and techniques; (3) ways of providing services; (4) customer service standards; or (5) organizational forms and markets. Such innovative capabilities are the key factors influencing the creation of the firm's competitive advantage related to the so-called "long-term competitive benefits", both for firms as well as for entire supply chains.

The above dynamic sub-capabilities can be a basis for a "road map" allowing the development of logistics capabilities which play a significant role in achieving the competitive position and market success by a firm. Then, such capabilities may be referred to as the strategic logistics capabilities of a firm.

3. The firm's competitiveness and its basic characteristics

The concept of competitiveness refers to the activities conducted by firms to gain the desired competitive advantage and to achieve the intended market and competitive position, as well as market success. According to Stankiewicz (2002), the competitiveness of a firm may be described as the firm's ability to efficiently and effectively achieve its goals within the so-called "market arena of competition". As Skawińska (2002) points out, the concept of the competitiveness comes from the "general" competition, and therefore, it is an important part of the "competition area". That is why the competitiveness is sometimes interpreted as the organization's ability to compete.

The firm's competitiveness can be presented as a system consisting of four basic components constituting specific subsystems, including:

– the potential of competitiveness, which comprises all the tangible and intangible assets, necessary for the firm's performance on the market arena of competition;
– a competitive advantage, defined as a result of using the firm's competitive potential, taking into account the conditions of the environment, which enables effective and efficient development of an attractive market offer as well as competition tools;
– competition tools, which can be defined as instruments created and developed by the firm in order to acquire contractors for the presented or planned (future) offer;
– the competitive position, understood as the firm's result of competition in a given sector, considered in relation to the results achieved by competitors (Stankiewicz, 2002).

Taking into account the firm's aspirations to achieve the intended market position, and – as a result – the intended competitive position, two major types of the firm's competitiveness can be distinguished:
– basic competitiveness;
– key competitiveness (Faulkner, Bowman, 1996).

The first of the major types of competitiveness, i.e., the basic competitiveness, includes processes and systems that enable the firm to achieve a leader position within the sector. In general, this type of competitiveness is associated with the capabilities of the firm and the supply chains concerning an increase in the value of products and services perceived from the customer's perspective.

The basic competitiveness comprises two detailed types of competitiveness: (1) operational competitiveness and (2) systemic competitiveness. The operational competitiveness is related to the specific capabilities of firms and supply chains, important from the point of view of their market activities and concerning – for example – technology, distribution, logistics, or controlling methods and tools. In turn, the systemic competitiveness refers to the capabilities concerning the creation and providing value added to customers, enriching this value as well as implementing innovative solutions in relation to the market offer.

The second of the major types of competitiveness, i.e., the key competitiveness, is identified with the capabilities of firms and supply chains, which are the determinants of creating a lasting, long-term competitive advantage. Various potentials of success play an important role in shaping and developing the firm's key competitiveness, including the dynamic capabilities, and also capabilities related to logistics.

4. Competitive advantage within resource-based strategic management stream

The competitive advantage is one of the central issues in strategic management, in particular, within the "sub-area" referred to as the resource-based strategic management stream (Matwiejczuk, 2014).

As Cannon (1996) emphasizes, the firm's striving to acquire and then maintain a competitive advantage is one of the most important determinants of its market activity. As Foss (1996) writes, the central place within the resource-based strategic management stream is occupied by the notion of a competitive advantage. In the process of building and strengthening the competitive advantage, the key role is assigned to the firm's competences, resulting from the integration and coordination of its resources and capabilities.

Godziszewski (2006) emphasizes that the competitive advantage is something that lies inside the firm, and which is also related to what the firm can do and how it can do it. According to the author, the external expression of a competitive advantage is the firm's market offer, thanks to which – if it has a greater value in the eyes of customers than the market offer of the competitors – the firm can achieve a competitive advantage. As a result, such a competitive advantage indicates its close relationships with the firm's resources as well as the capabilities related to the use of these resources.

In the opinion of Romanowska (2006), the resource-based concept best explains the process of creating competitive advantages. As the author emphasizes, in the context of classic management concepts, the search for ways to create a competitive advantage is mainly related to material resources, i.e. capital, location, access to raw materials. In contrast, in modern management concepts, a greater role is attributed to non-material resources, in particular to people and their knowledge, as well as to the intellectual values contained in patents, documentation and databases.

According to Barney (1991), in the context of a resource-based approach, the competitive advantage of a firm exists when the firm possesses and uses the capabilities to implement a value creation strategy that is not implemented by any competitor at the same time. The condition for the implementation of such a strategy is not only the firm's possession of the resources that are unique compared to the resources of competitors, but also the possession of the appropriate capabilities that enable the effective and efficient use of resources.

As pointed out by Teece et al. (2000), the basis for creating a competitive advantage of a firm in the context of the resource-based strategic management stream are organisational and managerial processes that determine the development of the capabilities and competences affecting the market and the competitive position of a firm. The highest importance is attributed to the development of the firm's strategic capabilities, including – in particular – the most significant features and dimensions of such capabilities, which are particularly difficult to copy by competitors.

The competitive advantage of a firm has two main dimensions: (1) the firm's competitive position and (2) the firm's market success.

5. Competitive position and market success as the main dimensions of the firm's competitive advantage

The competitive position of a firm may be understood – in simplest terms – as the firm's market position compared to its competitor(s). According to Stankiewicz (2002), the firm's competitive position may be perceived from the following three perspectives:

– as a symptom of the firm's competitive potentials seen *ex ante*, which are an important part of the firm's strengths understood as its key success factors;
– as a measure of the competitive advantage achieved by the firm, i.e., as a result of competition occurring as an effect of applying a specific competition strategy;
– as a source, symptom and measure of the firm's competitiveness, i.e., as a result of mutual relations among the potential of the firm's competitiveness, competition processes and competition results.

The notion of the competitive position of a firm should be perceived primarily as the final effect (result) of the competitive advantage possessed by the firm. The firm's competitive advantage resulting from achieving the expected market and economic outcomes may lead to the achievement of the desired competitive position on the market. In this sense the competitive position is a significant dimension of the firm's competitive advantage.

Apart from the firm's competitive position, a significant dimension of the firm's competitive advantage is its market success. However, the firm's market success factors cannot be perceived as similar or even the same as the key factors of the firm's success. Therefore, the firm's "overall" success should not be identified with its market success. The firm's market success, including the firm's market offer (i.e. products and services) is influenced by the customer preferences and expectations, related to making specific, individual decisions regarding the customer's purchase of products and services (Matwiejczuk, 2014).

The place of the firm's market success among the most important dimensions of the firm's competitive advantage results mainly from the fact that the attitudes and preferences of customers on competitive markets may be of great importance in creating this advantage. One may notice the performance outcomes of firms and businesses for which the most significant criterion of assessment and verification of the market offer are the purchasing decisions of customers. Customers often do not see the firm's intangible assets, so – as a consequence – intangible resources, capabilities and/or competences that are perceived as key success factors from the firm's perspective do not have to be perceived in a similar way from the customer's perspective.

6. Logistics capabilities as strategic capabilities of a firm affecting the firm's competitive position and market success in light of research

The issue of building competitiveness and a competitive advantage, as well as achieving the intended competitive position and market success by a firm is present not only within the contemporary streams of strategic management, but it is also a significant subject of research and analysis regarding individual functional areas of a firm, including – *inter alia* – logistics. The research conducted in relation to these areas is primarily aimed at assessing the contribution that a given area – in this case logistics – can make in the process of shaping the firm's competitiveness in the broad sense of the word, including the firm's achievement of a competitive position and its market success.

The capabilities within logistics, shortly called logistics capabilities, are one of the most typical groups of the firm's capabilities perceived from the functional perspective. Apart from logistics capabilities, the firm's capabilities can also include other types of functional capabilities, e.g. marketing capabilities or capabilities related to quality management.

Logistics capabilities can be developed both in the "real sphere" and in the "regulatory sphere". The "real sphere" capabilities are associated in particular with such logistics processes as transport, warehousing, storage, handling, packaging, etc. On the other hand, the "regulatory sphere" capabilities mainly concern information and decision processes related to coordinating the flows of materials, goods and information as well as management of these flows within both the firm and the entire supply chain.

An interesting concept of "embedding" logistics capabilities within the structure of the potentials and determinants of success conditioning the building of long-term competitiveness has been proposed by Mentzer et al. (2004). This concept is based on the assumption that the basis for achieving multidimensional outcomes by firms is the active involvement and use of their logistics resources and logistics capabilities in building competitiveness in the broad sense of the word, including creation of a lasting, long-term competitive advantage. The use of these resources and capabilities translates into changes in the system and subsystems of business management, and leads to the achievement of the expected market outcomes (customer satisfaction, customer loyalty, market share) and economic outcomes (profit, profitability, return on invested capital) of a firm.

Mentzer et al. (2004) indicate three groups of logistics capabilities that can be perceived as the strategic capabilities of a firm:

– capabilities concerning creation of the firm's competitive advantage based on customer needs and preferences, referred to as demand-oriented capabilities;
– capabilities concerning creation of the firm's competitive advantage based on costs, referred to as supply-oriented capabilities;
– capabilities concerning information flow management.

The first group of logistics capabilities, i.e., the "demand-oriented capabilities" are primarily related to customer orientation. These capabilities are also referred to as customer-centric capabilities, the capabilities for customer value adding, or customer integration. This group of capabilities allows acquiring customers and satisfying or even exceeding their expectations by offering them a unique value. Apart from the customer orientation, these logistics capabilities are characterized by multidimensionality (e.g., customer service capabilities or logistics quality shaping capabilities) and long-term perspective (e.g., pre-sales, sales and after-sales service capabilities), significantly affecting the building of the firm's long-term competitiveness (including its competitive advantage, competitive position and market success) based on customer needs and preferences.

The second group of logistics capabilities, i.e. "supply-oriented capabilities" involve the total cost minimization, which is a premise for an increase in logistics systems, processes and performance of activities. These capabilities enable defining methods for solving specific customer problems by implementing such solutions as just-in-time (JiT) deliveries, quick response (QR) to customer needs, or vendor managed inventories (VMI). These logistics capabilities relate to the optimization of all activities that make up the logistics processes implemented within the supply chains, leading to minimization of total costs, and – as a consequence – building the firm's long-term competitiveness based on costs.

Finally, the third group of logistics capabilities, i.e. "capabilities concerning information flow management" include capabilities within the area of information technology, as well as the exchange and sharing of information. These capabilities can contribute primarily to the "balancing" between demand and supply within the following supply chain nodes, and thus to improvement of goods exchange processes. Information technology, often playing a key role in the development of logistics capabilities, determines to a large extent the effectiveness and efficiency of information flows, both within the firm as well as the entire supply chain. The information flow management capabilities are usually performed together with the capabilities concerning the management of flows of goods and materials.

Interesting research related to the assessment of the possibility of using the logistics capabilities in achieving the firm's success and competitive advantage was also carried out by Morash et al. (1996)[1].

The results of their research have indicated, *inter alia*, that the analysis of the firm's logistics capabilities may lead to recognition of such capabilities that have strategic importance in achieving the expected market and economic outcomes. One of the fundamental tasks of the firm within highly competitive markets may concern the development of the so-called strategic capabilities of a firm, conditioning the achievement of a competitive advantage, a competitive position and market success. On the one hand, such strategic capabilities allow the formulation of a strategy for an active and effective use of the firm's resources, and on the other hand, these capabilities are the basis for the development of competences that enable the firm to gain a competitive advantage on the market.

Strategic logistics capabilities related to the research conducted by Morash et al. (1996) have been divided into two main groups:

- logistics capabilities related to demand (demand-oriented/customer-oriented logistics capabilities), i.e. capabilities perceived through the customer's lens, concerning customer needs, wants, preferences, expectations, etc.;
- logistics capabilities related to supply (supply-oriented/operations-oriented logistics capabilities), i.e. capabilities perceived through the firm's lens, concerning products and services offered by the firm.

Logistics capabilities perceived from the perspective of demand enable offering the required level of logistics service, primarily by recognizing customer preferences and expectations, ensuring the speed and reliability of deliveries, and – as a consequence – creating solutions for an efficient and effective response to customer needs (solving customer problems). The firm's focus on the development of this group of logistics capabilities may contribute not only to a more transparent presentation of the logistics offer to customers (who can then become familiar with it and thus make a more informed choice), but also to building long-term customer relations based on mutual trust and loyalty.

The condition for ensuring the required level of logistics service is the development of the firm's adequate logistics capabilities perceived from the perspective of supply. These capabilities are mainly related to designing and ensuring

[1] The research was conducted using the telephone interview method, based on questionnaires previously sent by e-mail. The research was attended by 65 managers employed at the highest levels of business management in furniture industry firms with annual gross sales amounting to more than USD 10 million. The modified (extended) Likert scale, covering grades ranging from 1 (the smallest importance of a given capability in achieving the firm's success) to 7 (the biggest importance of a given capability in achieving the firm's success), was used to assess the importance of individual logistics capabilities in achieving success by the firm. The basic symptoms of success adopted the authors of the research were ROA, ROI and ROE, taking into account both their absolute values and trends of changes in the values of these indicators (Morash et al., 1996).

the efficient and effective functioning of distribution systems, adjusted to market (customer) expectations and taking into account the solutions implemented by competitors. It requires, *inter alia*, choosing a proper distribution strategy, which may not only lead to meeting the needs and expectations of customers, but also to obtaining measureable benefits by the firm.

The most significant results of the research carried out by Morash et al. (1996) are presented in Table 1.

Table 1. The importance of strategic logistics capabilities in reaching market success by the firm

Strategic logistics capabilities	Importance of logistics capabilities in reaching the market success by the firm (1–7 point scale)*
Demand-oriented logistics capabilities	
Delivery reliability	6.34
Post-sales customer service	6.13
Responsiveness to target market	6.02
Delivery speed	5.88
Pre-sales customer service	5.62
Supply-oriented logistics capabilities	
Widespread distribution coverage	5.47
Selective distribution coverage	4.87
Low total cost distribution	4.61

* Mean based on the importance of logistics capabilities rated from 1 – least important to 7 – most important with a mid-point of 4.
Source: (own elaboration based on: Morash et al., 1996, pp. 7–9)

The results of the research conducted by Morash et al. (1996) indicate that strategic logistics capabilities can significantly influence the firm's success and competitive advantage. It applies in particular to the demand-oriented logistics capabilities where the most important capability – according to the surveyed managers – is the reliability of deliveries (average rating – 6.34), followed by post-sales customer service (6.13), effective response to customer needs (target market) (6.02), delivery speed (5.88) and pre-sales customer service (5.62). The surveyed managers assigned less importance in achieving success by the firm to supply-oriented logistics capabilities: widespread distribution coverage (average rating 5.47), selective distribution coverage (4.87) and low total cost distribution (4.61) (Morash et al., 1996). The above studies also confirmed that proper identification of the logistics capabilities and the possibility of their impact on achieving success and a competitive advantage by a firm may significantly contribute to the perception of such logistics capabilities as the strategic firm's (business) capabilities, affecting the firm's competitive position and market success.

Conclusion and further research

Shaping and strengthening the competitiveness of a firm is one of the most important issues of contemporary strategic management, including in particular its stream referred to as the resource-based strategic management. The key importance within this stream is assigned to the so-called potentials of the firm's success, comprising resources, capabilities and competences. These potentials may concern various functional areas of a firm, including logistics. Within this area they are called "logistics potentials of success", which – *inter alia* – include logistics capabilities.

Logistics capabilities play an important role in the process of building the firm's competitiveness. In particular, these capabilities are important factors influencing the firm's achievement of expected market and economic outcomes, which are the basis for creating the firm's lasting, long-term competitive advantage. The basic dimensions of such an advantage are the competitive position and market success.

The article presented the possibilities of the influence of the firm's logistics capabilities on achieving the intended competitive position and market success. The directions of further research should focus first and foremost on identification of detailed logistics capabilities that can play a significant role in building and strengthening the firm's competitiveness in the broad sense of the word as well as the competitiveness of entire supply chains.

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THE STRATEGY OF PKP S.A. AS AN INSTRUMENT OF POLISH RAILWAY TRANSPORT DEVELOPMENT

Abstract

The author of the article discusses the principles of the Strategy of PKP S.A. for the years 2016–2020 and the main areas of business activity of PKP S.A. and the PKP Group which derive the Strategy, for example, property management, innovation, cargo logistics and implementing objectives of the national transport policy. The author indicates the necessity to rationalize the PKP Group management through creating a structure that would operate as a holding company. The article concludes that implementation of the Strategy will ensure proper preparation of the Polish railway transport for the upcoming challenges. Macroeconomic trends clearly indicate the necessity to develop multimodality of passenger and freight transport, and the PKP Group takes them into account. The article pays particular attention to the concept of the Physical Internet in railway transport logistics by presenting the key objectives and benefits of the idea of the Physical Internet in railway transport based on the author's own research and on analysis of the available external research sources[1].

Keywords: Physical Internet, multimodal transport, modular containers, railways, freight, Poland, strategy, sustainable transport

JEL: F23, L92, O52, O53, R11, R12, R41, R42

Introduction

The Strategy of PKP S.A.[2] for the years 2016–2020 (with a perspective up to 2023) determines the directions of development for PKP S.A. as well as companies

[1] The article uses elements of the presentation at INNOTRANS Fair 2018 (Antonowicz, 2018).

[2] PKP S.A. is the company's proper name and it will be used in this article in the full form, note that S.A. in Polish stands for a joint-stock company.

in the PKP Group. The strategy has been based on the knowledge and experience from the preceding years. It also takes into consideration the regulatory environment and the dynamically changing market environment. The tasks presented in the Strategy derive from the analysis conducted previously and address the actual and future potential inefficiencies within the business areas of PKP S.A. as well as in the entire PKP Group. The performance of tasks within the specified timeframe assumed in the Strategy is aimed at improving and developing the Polish railway infrastructure. This will allow improving the competitiveness of this transport sector and therefore meeting the expectations of benefits to the society and the economy. The Strategy contemplates specific activities and tools to ensure long-term development of the company's economic activities as well as to support the continuous growth in general. Logistics, as part of the Strategy, is understood as a tool to restore the proper position of railways within the flow of domestic and international cargo streams.

This article presents the principles of the Strategy of PKP S.A. and the main areas of business activity of PKP S.A. and the PKP Group which derive from it. Particular attention is paid to the challenges related to increasing the efficiency of logistics processes in freight transport and the idea of the Physical Internet serving this purpose. The article defines the concept of the Physical Internet in cargo logistics and the potential benefits of its implementation in the PKP Group based on the author's own research and other available sources.

1. Starting point for the Strategy of PKP S.A.

Experiences of the past 15 years identify the aspirations and challenges for the activity of PKP S.A. and companies in the PKP Group. Today's shape of the PKP Group is mainly determined by changes which were implemented through the Act on commercialization and restructuring of "Polskie Koleje Państwowe" [Polish National Railways] state-owned company of 2000. The PKP Group management system is disintegrated and does not support the coordination of operations of each economic entity. Although the operation of those companies is based on the commercial law and in accordance with formal requirements, it does not ensure reaching the social and economic objectives of Polish railways, which could be met only by a providing proper level of integrity between the companies of the PKP Group.

PKP S.A. is one of the largest property owners in Poland. The Company's assets constitute both facilities related to transport and passenger service functions (railway stations) as well as commercial properties. In order to obtain a long-running benefit, a strategic objective for PKP S.A. is management of items of property having both transport and logistics potential while cooperating with various external partners.

A necessary direction of the PKP Group's activities is also further improvement of the quality of freight and passenger services. A significant development opportunity for railway transport is transport multimodality, meaning a combination of more than just one transport sector for the transport of freight and passengers. A key component of multimodality and the *sine qua non* condition for its success are nodal infrastructure facilities which could ensure freight and passenger transfer between different transport modes. Those facilities are most importantly logistic centres and handling terminals, including freight transport as well as railway stations acting as multimodal transfer hubs for passengers.

The continuously changing trends within mobility create new challenges for railway stations. An increase in the demand for alternative methods of travelling can be observed. Passengers willingly use new services such as car sharing, car rental and city bike systems. All those phenomena inspire constant improvement of the quality of service at railway stations and cause improved integration of stations with the surroundings. Railway stations should encourage the use of the public transport while providing the necessary comfort and enabling an effective transfer between different modes of transport.

2. Basic areas of the Strategy of PKP S.A.

The structure of the Strategy of PKP S.A. covers domains, strategic objectives and tasks. The methodological assumptions of the Strategy implementation are based on the Balanced Scorecard (BSC) concept, in accordance with which appropriate indicators have been assigned to strategic objectives and tasks. The Mission of the PKP Group and PKP S.A. described by the Strategy is "creation and development of national railways understood as a basic component of the national logistics system and moreover as a part of the European railways system that ensures the highest possible quality of passenger and cargo transport and logistics services achieved while respecting the rules of sustainable growth and the economic operating efficiency under the open market economy" (*The Strategy of PKP S.A.*, 2018).

The strategy indicates the following areas of business activities of the PKP Group and PKP S.A.:

1. The area of economic and administrative tasks that results from the continuation of the former obligations of PKP as a state-owned company. The area includes the supervisory activities of PKP S.A. over the entire PKP Group, aimed at meeting the business objectives thereof. The strategy of PKP S.A. defines the key business objectives of subsidiaries which will be subject to assessment by the corporate authorities of the PKP Group.
2. The business area related to PKP S.A. asset management. This area indicates objectives and tasks related to improving rationality in the field of management of the property owned by PKP S.A. The objectives are a long-term asset management strategy and maximization of profits from business operations through active development of the portfolio of asset management forms with the use of both the Company's own and external capital.
3. The area of creating innovative transport and logistics products available on national and foreign markets, using the economic potential of companies, both belonging to and outside of the PKP Group. Creating new areas of business operations within the PKP Group will provide additional benefits that will ensure long-term financing for the Polish railway infrastructure development. The PKP Group is interested in implementing sharing economy and innovative

services based on this idea (e.g., car-sharing, bike-sharing, co-working) as it is a significant trend in the segment of passenger services. A valid objective is also ensuring a service standard compliant with the demands of railway station users, including the operation of customer service points "InfoDworzec", standardization of crisis response procedures, provision of aid for persons with reduced mobility and further adjustment of railway stations to their needs. The IDS concept developed by PKP S.A. – the acronym IDS (Innowacyjny Dworzec Systemowy) is translated as an "innovative modular railway station" – takes into account issues of safety, ergonomics, user convenience, digitization as well as energy saving technologies at railway stations, which lower the operational costs of those facilities.

4. The area of creating business activity within cargo logistics. In order to create conditions for such activity, it is recommended to establish an entity that would act as a logistics integrator connecting the logistics system participants, i.e. clients, various transport sector carriers and handling infrastructure owners, which would make it possible to shape a new, non-standard offer of comprehensive door-to-door logistics services provided under the PKP brand. The integrator would make it possible to shape a new, non-standard transport and logistics services supply chain offer. Its objective would be to act as a logistics platform operating based on "stock exchange" rules where every party interested in moving goods or materials would have the opportunity of choosing the preferred method of transport and handling (supply chain configuration).
5. The area of implementing the objectives of the national transport policy within the railway transport, including multimodal transport. A perfect example of implementing the objectives of this area is the PKP Group's project "Wspólny bilet" [Joint Ticket]. The initiative of a joint ticket is an important step towards ensuring a friendly railway transport offer. In light of the implementation of the national transport policy a priority task for PKP S.A. is improving the technical and functional condition of railway stations. The operation of railway stations is not only a business matter for the railways, but also a matter of accomplishing a public mission. As a part of the adopted comprehensive investment programme (PID – Program Inwestycji Dworcowych [Railway Station Investment Programme]) the company will reconstruct or build approximately 200 facilities until the end of the current European Union financing perspective. Those investments will mostly be financed by European funds with the usage of government and company own funds and one of its main goals is to adapt the new and existing infrastructure to the needs of persons with reduced mobility and reducing inconveniences related to transport, meaning that it should minimize the time and effort of passengers associated with the journey. The answer is to build transport and transfer centres (multimodal hubs) to allow a quick, convenient and economically justified, from the passenger's perspective, change of the transport mode which would ensure comfort, safety and provide additional services at the same time.

In the context of freight transport multimodality, the Strategy of PKP S.A. indicates the possibility to use well-located properties in order to develop logistics infrastructure facilities, such as logistics parks, handling terminals, warehouses, sidings and storage and handling points. The directions defined by the Strategy of PKP S.A. in the area of logistics reflect the assumptions elaborated by PKP S.A. together with the PKP Group companies brought together in the Intermodal Transport Development Plan with a timeframe perspective until 2030. A wide scope of initiatives related to organizing the intermodal logistics chain, financing, investment technology, transport technology, legal solutions as well as innovations, has been adopted as a part of that Plan.

Other significant tasks being a part of the previously described area include coordination of implementation of the European Union legislation within the PKP Group (Directive 2012/34 and the Fourth Railway Package), in particular, interoperability and railway safety. The area also encompasses the participation of the PKP Group in activities related to the investments of Centralny Port Komunikacyjny (CPK) [Solidarity Transport Hub], a High-Speed Rail (HSR) system and the rolling stock development.

A strategic objective is rationalization of the PKP Group management systems through creating a structure that would operate as a holding company, which would serve both implementing business objectives of the railway transport as well as objectives of the national transport policy. Creating a holding structure, in which PKP S.A. would perform the role of a dominant entity will allow an effective implementation of the objectives and tasks of the Strategy of PKP S.A., defined in the preceding areas. It is necessary to implement proper management tools at every level of the process, considering the autonomy of each company in the PKP Group. The role of PKP S.A. as the parent company will be coordination of the Group's activity including but not limited to strategic management, finances, legislation and adjustment to the European Union standards as well as economic cohesion.

The rationalization of the PKP Group management also covers the implementation of projects related to improving the coherence of financial information, including transfer prices, and implementing an IT tool that would improve the Group's reporting processes. PKP S.A. coordinates the project of digitalization of the PKP Group, which will allow an improved use of IT tools within the Group through integrating ICT solutions as well as technology standardization. It is also crucial for the companies to join and use the European Technology Platform on Logistics.

3. Strategic challenge for rail transport in the area of logistics

The idea of the Physical Internet (PI) is worth considering to improve the effectiveness and efficiency of transport and logistics processes. The processes of the flow of goods in time and space (transport and logistics), their efficiency and reliability affect the efficiency of business processes and determine the ability to timely and appropriately meet the needs of individual and institutional clients using those services via railway transport.

The Physical Internet is a global system of closely related logistics networks, based on efficiency and reliability. It is based on the use of linked interoperable logistics assets which use unified collaboration protocols, intelligent interfaces and a standardized modular transport unit[3].

Modern transport chains are long and complex, e.g. rail transport chains of the New Silk Road. Some of the fundamental problems that the idea of the Physical Internet can reduce or eliminate include unused space, transport inefficiencies in processes as a result of the lack of integration of systems and the lack of intelligent interfaces (Pękala, 2019).

Figure 1 shows the idea and basic objectives of the Physical Internet.

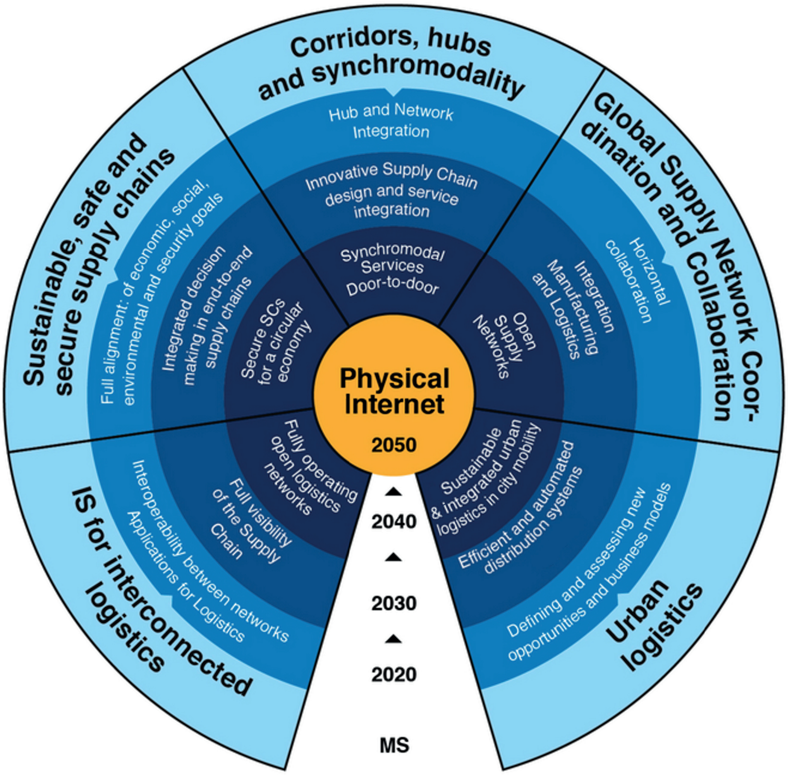

Figure 1. Idea and basic objectives of Physical Internet
Source: (ALICE, 2019)

The basic objectives are:

- more than a twofold increase in the efficiency of logistics (taking into account the benefits of the redirection of the already sent shipments);
- improvement of the reliability of the flow of goods achieved through fast, automated supply chains based on complex information about the difficulties and dangers;
- better use of human resources, hardware and infrastructure;

[3] Own elaboration using the definition proposed by B. Montreuil (creator of the concept) (Montreuil et al., 2014).

– significant reduction of greenhouse gas emission in land transport (PI projects support the EU Horizon 2020 Programme);
– increase in innovative logistics solutions.

"As it appears from research conducted in the U.S., the Physical Internet proposes a system in which the global logistics supply chains are connected by an open intermodal system (road, railway, shipping-barges and ships) that uses standard, modular, reusable containers, identification and coordination of routes in real time by shared logistics centres" (Maxmania, 2012). Producers, shipments senders, transport operators operate independently, using shared logistic networks, which increase the load of vehicles, railcars, boats, and reduce empty mileage of vehicles.

The pillars of the Physical Internet are shown in Figure 2.

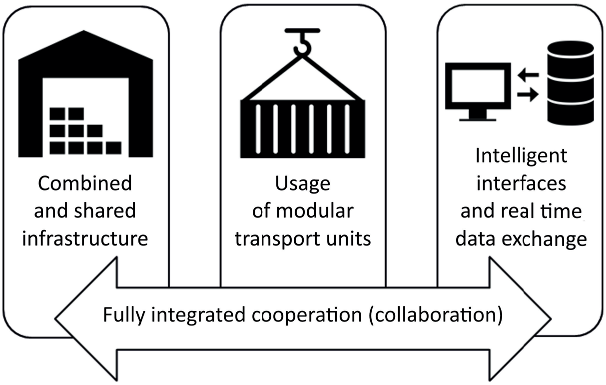

Figure 2. Pillars of Physical Internet
Source: (own elaboration based on: Zdziarska, Hachuła, 2015)

Therefore, the aim of most of the logistics activities in the PKP Group are potential sources of benefits of constructing a global logistics system based on the concept of the Physical Internet:
– a significant increase in the intermodal transport volume obtained by standardization and usage of modular transport units (intermodal is the most prospective segment of rail services);
– generating a huge pool of orders for railway transport as a result of suggesting senders of shipments to plan the decision process via a computer system that takes into account a variety of multimodal options.

For the achievement of these benefits, first and last mile railroad freight terminals, managed within the idea of the Physical Internet, should have adjacent warehouses and a grading plant and increased length of the railway loading track which would enhance capabilities to simultaneously manage and handle the transhipment point of many trucks.

Figure 3 shows a sample layout of a terminal for intermodal rail-road transport.

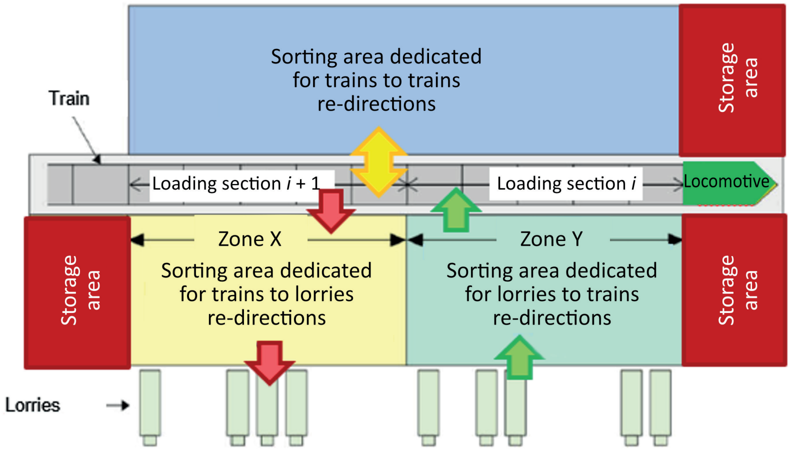

Figure 3. Exemplary layout of a rail-road terminal in the Physical Internet concept
Source: (own elaboration based on: Chargui et al., 2018, slide 4)

This idea can be implemented on condition that the clarity of the collaboration rules with various stakeholders is improved in order to acquire goods for common supply chains, integration and implementation of investment processes and business, development of competence and deployment of the latest solutions and techniques to optimize logistics processes, promotion of multi-modal services and organic forms of transport.

Conclusions

Implementing the Strategy of PKP S.A. will ensure proper preparation of the Polish railway transport for the upcoming challenges. Macroeconomic trends clearly indicate the necessity to develop multimodality of passenger and freight transport. At the same time it is reasonable to take into consideration the fact of continuous globalization and consolidation processes in Europe as well as all over the world, which justifies the need of creating a powerful and integrated railway infrastructure that would operate as a holding company. In terms of cargo logistics, Poland must use the great advantage of its geographical location at the crossing of European corridors: East-West and North-South. When analysing logistics in rail freight transport, the use of the idea of the Physical Internet means introduction of new principles for carriage of cargo, new principles and methods of packing and manipulation of static electricity, the flow of information in standardized protocols in real time and the need to integrate and cooperate links in the entire transport chain. Supporting those main objectives will increase the efficiency of transport and logistics processes and will have a positive effect on the railway transport. Multimodality of passenger transport should be built through railway station investments, which would lead to improved availability and connection of different transport sectors.

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PKP CARGO S.A., Poland

DEVELOPING THE LOGISTICS OPERATOR FUNCTION IN PKP CARGO GROUP STRATEGY

Abstract

The aim of this article is to present the possibilities of developing logistics services by the PKP CARGO S.A. Group which is the largest rail freight operator in Poland and one of the largest in Europe. PKP CARGO S.A. wishes to enhance its market position, and one of the strategic goals of the company is to take up the function of a logistics operator. The company is predisposed to play this role due to its position in the market and the opportunities for its development. Moreover, it is the economy and the changing freight structure as well as the EU policy in the field of sustainable transport that are conducive to developing the function of a logistics partner.

Nevertheless, PKP CARGO is operating in specific business, legal, infrastructural and rolling-stock conditions. This environment is not easy, in certain situations it is even a hindrance, an obstacle to the development of logistics services, nonetheless, the company can see wide prospects for such business. Moreover, analysis of the European market shows that rail operators on these markets have been developing in the direction of a logistics partner.

Keywords: railway, freight transport, intermodal transport, logistics, logistics operator, third party logistics partner

JEL: L920

Introduction

Every purposeful activity, each economic process requires logistics support whereby adequate resources will be provided for a given process in the right quantity, to the right place, at the right time and at the right price.

The welfare of the society depends to a large extent on the condition of the economy and its competitiveness. In the era of globalization, it is more and more often not only enterprises, but whole sectors of the economy and the state that compete with one another. This competitiveness depends on the system efficiency in a given country, the availability of resources, human resources in particular, the legal system friendliness for business and the transport system efficiency. It is for this reason that the economic situation in freight transport is regarded as a barometer of the economic situation in the whole economy and there is a feedback here whereby an increase in the freight transport pinpoints economic development, and economic development triggers an increase in the freight transport.

Nowadays, trying to find competitive advantages in the market, PKP CARGO has to head towards the role of a logistics operator. Why is it just the role of a logistics operator that is growing in importance in today's economy? Explanations can be found in the literature on the subject indicating the competition and customer requirements that drive the demand for logistics services. It is therefore that "enterprises determined to meet the growing customer requirements and expectations, being at the same time focused on cost optimization, stimulated by economic considerations, decide to commission logistics services to carry out modern business processes to specialized logistics enterprises called 3PL (Third Party Logistics Provider)" (Wasielewska-Marszałkowska, 2017, p. 126).

It should be remembered that the function of a logistics operator in this approach is very broad-scoped, as it integrates transport, transhipping, storage, packaging, marking, handling of returned shipments and waste collection, customs and other services, depending on the needs of customers. There are several factors at the core of the integrating function of logistics which are described by, *inter alia*, Chaberek who claims that the functions of logistics include but are not limited to "better planning of investments to better handle the flow of materials and products" and the "integration processes lead to unifying the objectives of distribution, production and procurement activities whereby suboptimization of activities can be avoided" (Chaberek, 2002, p. 33). Furthermore, the professor indicates that by integration of logistics processes "the activities performed can be better controlled; risk can be reduced by limiting anticipatory activities (such as manufacturing whole ranges of product varieties in anticipation of the future demand) to be replaced by the concept of delayed final picking (until customer needs are known)" (Chaberek, 2002, p. 33). What is more, this market segment is a source of innovation. Kempny (2001) pointed out that logistics would be affected by the changing customer service strategies and changes in the organizational structure of enterprises. Many of such analyses were later confirmed in the following years, when the logistics sector underwent many changes and experienced intensive development.

One of such trends is also the development of the "Third Party Logistics Partner", which is associated with massive changes in the world economy as well as in the Polish economy. Generally speaking, it can said that the 3PL is a response to the changes taking place in modern supply chains and nobody is questioning any longer the need for logistics companies to develop and take over new functions (Chaberek, Trzuskawska-Grzesińska, 2011). This trend results also from the fact that outsourced services have become a very important cost reduction measure in the enterprise, which can be clearly seen in logistics. The fact that many enterprises resign from maintaining their own transport or storage operations may serve as an example here. One of the reasons why this is happening is that owing to the operation of logistics companies there are no problems with shipping even large quantities of goods to any region of Poland, Europe or the world at any time. PKP CARGO can see this trend, therefore, the aim of this article is to show the development of the function of a logistics operator in the PKP CARGO Group strategy.

1. The role of a logistics operator in the strategy of PKP CARGO

The rapid growth of intermodal transport in Poland over the last five years is impressive. This has resulted primarily from the economic growth in Poland which implies greater activity of enterprises. It is also their needs, i.e. "door-to-door" services and containerization of deliveries that create additional market demand for intermodal transport as an important part of the logistics process. Poland is part of the global economy, our plants and factories have business relations with enterprises in Europe, Asia, North America and other continents, and these relations and exchange are characterized by the fact that freight is carried primarily in containers. The use of logistics services is a must for many enterprises as they do not have their own resources to deliver freight to a customer located hundreds or even thousands kilometres away. Goods destined for other European countries are transported via our country which unfolds opportunities for logistics operators to extend their business. The trend of containerization of cargo will intensify in the forthcoming years in both road and railway transport.

These factors have had an impact on the PKP CARGO Group Strategy for 2019–2023 with a view to 2038, which was adopted in late 2018. This document sets out the goal to be attained by the PKP CARGO Group, namely, reach the position of a Central European leader in rail transport by way of gaining a dominant position in the "Three Seas" region and on the New Silk Road. This can be achieved by implementing a comprehensive logistics service on the rail freight market and intermodal services which would give the position of the first choice supplier.

The concept of integration, intermodality and interoperability is strongly emphasized as early as at the strategy definition stage. Moreover, the highlighted component are comprehensive logistics services laying out the directions for the company's development in the forthcoming years in line with the market trend. This obviously does not mean any departure from the basic transport mode offered by the company, namely, bulk goods, principally coal and aggregates. This market will be very important for PKP CARGO for many years to come, nonetheless, the importance of the logistics partner will be certainly growing.

The transformation of PKP CARGO towards a logistics operator will not be possible without implementing the process of the company's digitization and computerization which is strongly highlighted in the new strategy. It is important for the quality of services to provide the customer with online information on the cargo location and the expected delivery time. PKP CARGO wants to launch a service called "Customer Portal", where the customer will be able to access the system 24 hours a day and 7 days a week and check the location of their container(s).

In practice such a system becomes a standard in the world, the timeliness of intact cargo deliveries is a determinant of the market success of enterprises operating in a complex logistics chain comprising dozens, hundreds, and often as many as thousands of entities. Manufacturers, assemblers, distributors have a detailed schedule of deliveries of parts, subassemblies or finished products, prepared for many weeks, months ahead, which is to guarantee continuous manufacture and constant availability of goods for customers and consumers. The customer wants to have control over the cargo shipped or awaited and this is not going to be provided by telephone or email contact with the logistics operator.

In previous years, the development of the logistics operator function at PKP CARGO was neglected, which, on the one hand, means that it is necessary to catch up with the West, however, on the other hand, the company may now skip some stages of development, entering higher levels instantly. An example of the practical implementation of the task to transform PKP CARGO into a logistics operator is opening a terminal company which will be integrating the operations of 27 different terminals within the PKP CARGO Group. Such coordination will bring great benefits, as PKP CARGO will be able to prepare a better offer for customers. Following the solutions applied in Germany, France and the Netherlands, it will be possible to use terminals to optimize transhipment, transport and warehousing processes. This concerns, for example, "transferring" goods between terminals to fill trains with goods where there are fewer shipments at a given time, thus limiting empty runs.

Another example of capitalizing on the Western experience is the organization of transport. Jointly with the Italian carrier Mercitalia Rail, PKP CARGO intends to launch a shuttle train service between the Treviso terminal on the Adriatic, the Czech Republic and Poland. A regular rail connection is a condition for acquiring large clients, and the benefits that can be gained from this are shown on the example of a regular railway connection between the port of Hamburg and Berlin.

The function of a logistics operator is supposed to be a tool for the PKP CARGO Group to win a leading position on the market of the Three Seas countries and on the EU section of the New Silk Road. Foreign acquisitions or opening offices abroad would be needed to take over as many of such shipments as possible. PKP CARGO plans to open such an office in China to handle cargo shipped from the Middle Kingdom to Europe, both by sea, air and land, and ship containers with goods from Poland and Europe to China.

The company has also high hopes related to the plans of the Ministry of Maritime Economy and Inland Navigation to develop the inland waterway transport. This is primarily related to the Oder river, and the role of rivers in logistics is very well illustrated on the example of Germany and the Netherlands, where river ports are conductive to the development of the trade exchange and the transport of goods also by rail and road. The largest river port in the world is operated on the Rhine in Duisburg. In 2018 the port handled containers with a volume of over 4 million TEUs – which is more than that was transhipped by all the Polish seaports within the same period. Duisburg works closely with the port of Hamburg, while the Dutch use river ports for handling freight delivered to ports in Rotterdam and Amsterdam. Already at the present time the role of PKP CARGO in this European system is important enough for the company to work with the port of Duisburg in the development of logistics services.

2. Place of PKP CARGO on the Polish intermodal market

A considerable increase in the rail intermodal transport has been observed in Poland for several years now – it is worth a dozen or so percent per year. It is higher than the growth of the entire railway market the transport structure of which continues to be predominated by coal, aggregates, ores and other bulk commodities, nonetheless, the share of the intermodal transport is also steadily growing.

Table 1. Intermodal transport in rail transport structure

Million tons / Year	2003	2005	2010	2015	2017	2018
Total rail transport	241.5	269.4	235.5	224.8	239.9	250.2
Intermodal transport	2.3	2.2	4.4	10.4	14.7	17.0
Intermodal share	0.94%	0.81%	1.87%	4.62%	6.12%	6.80%

Source: (The Office of Rail Transport, 2017)

In 2018, the mass of intermodal shipments was 17 million tonnes, i.e. it was higher by 15.6% than in 2017. And in the period 2015–2018, this increase amounted to almost 70%. The transport performance indicators are also sharply growing: where it was 6.2 billion tkm in 2018, i.e. by 0.8 billion tkm more than in 2017 (14.8%). It should be also noted that although intermodal shipments accounted for 6.8% of the railway market in the previous year in terms of mass, it was as much as over 10% in terms of transport performance.

In 2018 the railway carriers could pride themselves on a record result of unit loads handled with over 1.2 million units (increase by 16.4% compared to 2017). This translated into almost 1.9 million TEUs (more by 13.6% compared to 2017).

This trend has also been noticed by carriers, as the number of companies operating in the intermodal railway transport is growing year by year. While there were six enterprises operating in this area in 2007, there were as many as twenty of them in 2018.

The market leader is incessantly PKP CARGO, both in terms of the mass of transported cargo and in terms of transport performance: the company carries more than 46% of the cargo mass while the five other carriers control 41% of the market. Thus, we can talk about a certain concentration as six companies carry more than 87% of freight while the fourteen next operators – 13% only. A similar division can also be observed in other European countries, where the leading player controls at least about 50% of the intermodal transport. In terms of the transport performance the situation is very similar, while the position of PKP CARGO is even stronger – the company controls 52% of the market.

Attention should be also paid to the strong position of foreign operators on the Polish market. Captrain is the Polish branch of Captrain Deutschland controlled by the French railways SNCF. DB Cargo Polska is a part of German-based DB Cargo. Poland is an attractive location for Western operators, as international transport is predominated by intermodal freight transport – almost 70%, of which 30%, 25% and 15% are accounted for by imports exports and transit, respectively, while domestic transport covers only 30% of the market. For this reason, the average freight transport distance in the intermodal sector is around 360–370 km.

Increasing competition can be observed in the market. Enterprises are trying to acquire the largest possible share in the market by improving the quality of services offered and offering prices which would be attractive to customers. Strong competition is the reason why PKP CARGO – so as not only to maintain, but also to strengthen its leading position – has to improve the processes wherefore the company strives to develop the role of a logistics operator.

The increasingly growing volumes in railway intermodal freight transport should not be surprising to anyone, mainly due to the fact that we can notice increasing mass of freight carried in containers around the world. Containers make it easier to carry out logistics processes and standardize production. The railways also take advantage of the popularity of Polish ports, where a rapid development of transhipments has been seen for years, and Gdańsk has reached the position of the largest maritime container terminal on the Baltic Sea. The ports expect to increase container transhipments, and furthermore, we can count on increasing transport volumes on the New Silk Road and in the North-South Corridor. China forecasts that the number of trains crossing the NSR will exceed 10,000 per year before 2030 (there were more than 6,000 trains in 2018). Most of these trains are supposed to cross Poland.

It should be noted that the development of the intermodal sector on the Polish railways is in line with the idea of sustainable transport. Therefore, we are heading in the right direction so that the railway should take over as much as possible of the goods transported by lorries now, although we have to be aware that Poland still has a number of restrictions, which are somewhat hindering this trend. If the freight transport structure is to change, these conditions have to be changed as well.

3. Sustainable transport as an opportunity for the development of rail transport

3.1. Introduction

The main goal of economic activity is to ensure sustainable development that would take into account human activity while respecting the environmental principles. Therefore, the international community, and especially the European Union countries are supporting solutions with the least adverse impact on the natural environment. In this respect, the EU is promoting low-carbon modes of transport wherein the rail transport is included. For this reason, it is important to fully calculate the cost of transport operations taking into account external costs (alternative costs interchangeably) as an element of social costs (Bąk, 2009).

When implementing a responsible policy, firstly it is necessary to create comparable conditions for competing between rail and road transport, and secondly, rail should be preferred by reason of lower external costs in terms of social and environmental costs. From this perspective, one of the elements of improving the competitiveness of rail transport is its intermodality.

Table 2. Freight transport structure in Poland

Million tons / Year	2017	2016	2015	2014	2013	2012	2011	2010
Total transport	2 053.2	1 836.7	1 803.8	1 840.0	1 848.3	1 844.1	1 912.2	1 795.6
Rail transport	239.5	222.5	224.3	227.8	232.6	230.9	248.6	234.5
Share of rail transport	11.66%	12.10%	12.43%	12.38%	12.58%	12.52%	13.00%	13.05%

Source: (The Central Office of Statistics, www.stat.gov.pl)

An analysis of freight transport shows a falling share of rail transport in the total transport from 14% in 2010 down to 12.1% in 2017. A decrease by almost 2% points is very large and shows the problem of railway competitiveness in relation to other modes of transport, road transport in particular. This unfavourable trend for the railways has been seen for many years, and there were periods when this decline was even deeper and, for example, in 2005, the share of rail transport in the entire market was 19.0%.

The main objective of the Community Transport Policy of the EU is to ensure free and fair competition. Such "healthy" competition is intended to lead in a straight line to the efficiency of the transport industry. A basic measure to attain this objective is structural harmonization (balancing/unification of the conditions of competition). Most of all, identical legal environment and economic conditions of operation have to be provided to all modes of transport. If any sector enjoys preferences or amenities that are not available to other sectors, then it has a competitive advantage at the onset. In the case of rail and road transport this means most of all equal access to the infrastructure. There is no such equality at the moment, as the cost of transporting a tonne of cargo is definitely in favour of the road transport. Under these conditions, it is very difficult, if not impossible, to implement a sustainable transport model in Poland, as the basic indicator for most companies is the price which is the determinant for them to choose the transport service provider. And as long as rail transport is relatively more expensive than road transport, the rail transport growth will be lower than the road transport.

Attention should be also paid to the market conditions and the rolling stock organization. These are obviously only the most important factors, since their list is much longer, and includes, but is not limited to, the level of technological and scientific development of the country and the scale of digitization of the economy.

3.2. External conditions

According to The Office of Rail Transport (2017) the track system in Poland is 19,291.3 km long. Most of the rail routes are electrified lines (11,864.3 km). An important problem which causes a limited capacity of the tracks is the fact that only 8,740 km of them are two-way lines of which 90% are electrified. In the case of monorail routes, the electrification level is only 62%, so the need to replace locomotives limits the throughput still to a larger extent. The average density of railway routes in Poland is 6.17 km/100 km^2, the highest being in the Silesian Voivodeship (15.8 km).

Although we are among countries with the longest railway network, nonetheless, at the same time its saturation places us within the European average, as for example in Belgium, there are almost 12 km of railway lines on 100 km^2, and almost 11 km in Germany. The Hungarians, Austrians and Italians have a denser railway network than us, as well.

As can be seen, the saturation of the railway network in Poland is not high. A positive fact is that the technical condition of the infrastructure is improving owing to the investments of PKP PLK. Although passenger trains can still travel at speeds of up to 80 km/h on more than 40% of the lines, however, there are gradually more routes, where trains can travel at speeds of up to 120 km/h (43%) and 120 km/h to 160 km/h (14.8%). We also have short sections of routes with speeds above 160 km/h (1%).

As far as freight transport is concerned an important parameter of the railway network is the permissible axle load. At the present time, an axle load of more than 221 kN is allowed on almost 58% of the lines. Nonetheless, still almost as much as 25% of the network is suited for train sets with an axle load smaller than 200 kN. Hence, carriers can dispatch less loaded trains to these sections, which increases the operating costs and lowers the competitiveness of the railway industry.

The current condition of the railway network in Poland can unfortunately be a factor hampering the pace of development of intermodal transport. All the more due to the fact that railways lose much of their competitiveness by reason of the low commercial speed of freight trains, which is slightly over 22 km/h on average and unfortunately it has a decreasing tendency, which also applies to intermodal trains (speeds of less than 30 km/h). The situation is bad compared to the Western countries, where trains run twice as fast on average. Moreover, e.g. in the Netherlands or Germany, intermodal trains can travel at average speeds exceeding 70 km/h as separate routes have been set for some of such trains.

The challenge is the poor condition of the infrastructure and the organization of repairs and investments translating into problems with transport by rail, particularly in view of the constantly improving quality of Polish roads, where it is not only the growing network of motorways and expressways, but also an increasingly better standard of regional, district and municipality roads that may serve as an example here. In several years' time, when the implementation of the National Railway Program is completed, the commercial speed is supposed to exceed 40 km/h, however, until that time railway carriers have to deal with this problem on their own which affects the timely delivery of freight, thus affecting the competitiveness of railways.

A very important issue in the state policy is to ensure comparable conditions of competition between sectors, and the tool to achieve this purpose are the rates of access to the infrastructure. In Poland, the fees paid by road carriers are lower than charges imposed on operators on the rail market. Moreover, charges for access to the rail track infrastructure for carriers are higher than the cost of purchasing traction energy and fuels.

Discussion on the prospects and directions of the development of rail freight transport has been held in the public space for over two decades. One of the main strategic problems surrounding this debate is whether rail transport, compared to road transport, should be competitive or substitutable. The author is closer to the thesis advocating a substitutive nature of transport modes with respect to each other. Obviously the best verifier will be the market, however, for this to happen, comparable operating conditions for rail and road transport should be created.

It is not only the condition of the track system that influences the prospects for the development of rail intermodal transport. The network of terminals and logistics centres in Poland is also poorly developed. There are around 30 state-of-the-art land terminals which can handle trains up to 750 m long. According to experts, there should be at least about 100 such facilities operating. Then, we will achieve a similar saturation with terminals as in the economically developed western countries (1.5–2.5 terminals per 1000 km of railway lines). Another issue is a more balanced distribution of such terminals country-wide, as at the moment, most of these facilities are located in central Poland, and in Silesia and Wielkopolska (Greater Poland) regions.

Another challenge is to extend railway border crossings to handle trains travelling between China and the EU. The most attractive corridor goes through Małaszewicze and it is in the interest of Poland to increase its capacity which is the objective of the investment program implemented by PKP CARGO Małaszewicze Logistics Centre. At the same time, it is necessary to improve the procedures related to customs control and services of warehouses, so that trains should be leaving the Polish-Belarusian border crossing faster.

In the Polish conditions a major factor for the intermodal sector to be successful is the accessibility to the Baltic ports by rail. Most of containers in domestic and international transport are carried to and from the ports in Gdańsk, Gdynia, Szczecin and Świnoujście. Ports are expanding their container wharfs, nevertheless, railway lines running from the inland to the coast are not upgraded at a sufficient pace. Despite that fact PKP PLK announced an ambitious investment programme, which was supposed to improve the accessibility of railways to ports, however, bidding procedures for these works had to be cancelled as the submitted bids significantly exceeded the investment budget. Fortunately, the case is not lost, as the government passed a resolution to increase the funds for this programme by PLN 3.2 billion.

The rail freight transport in Poland is mostly based on the transport of bulk goods, primarily coal and aggregates. It is therefore that these two sectors have the greatest impact on the railway freight, and the demand for services presented by mines, power plants and construction companies to the largest degree determines the revenues generated by carriers. Which does not mean that this market is not changing.

In 2018, the transport of such freight as hard coal, metal ores, mining and quarrying products, accounted for 64.9% of the mass and 53.6% of the transport performance. Hard coal had the largest share in the market in terms of mass – 40.8% (90.6 million tonnes). Nevertheless, at the same time it should be noted that the volume of transport by rail is declining. In the years 2007–2015 it decreased by more than 37.0% (53.9 million tonnes). This is caused by, *inter alia*, a change in the structure of the demand for energy raw materials, and the factor that has the greatest impact on the transport of coal is the level of electricity generated by coal-fired power plants. And although hard coal is our main energy raw material, the technological progress, implementation of more economical methods of production is the reason why the demand for Polish "black gold" is declining. Smaller quantities of coal are also purchased by municipal heating plants and individual customers.

The transport of aggregate is supposed to grow owing to large infrastructural investments included in the current financial perspective of the EU, and in the future, this segment will be fuelled by the construction of the Central Transport Hub and the 1,600 km of new railway lines needed to serve it.

In the next few years, the market growth in the intermodal segment of at least a dozen or so percent per annum is expected. What is more, the pace should be maintained or decline slightly in the long run (15–20 years) as intermodal transport will be consistently increasing its share in the rail transport – a similar process was seen some years ago in the West and now it is also happening in Poland.

The plans of PKP CARGO are not unique in the market, since actions leading to the creation of specialized logistics operators on the basis of railway undertakings were implemented in many European countries a long time ago.

It is best seen on the example of Germany-based DB Schenker, belonging to the Deutsche Bahn German railways. Currently, it is one of the world's largest logistics operators, with road and rail fleets, also using inland waterways, sea navigation and aircraft in its operations. The concern also has warehouses and logistics centres with an area of 8 million m^2 in about 750 locations around the world. Nonetheless, the company also uses foreign resources, moreover, it integrates logistics operations of various entities unrelated to the German railways.

At this point it should be emphasized that this structure has been built for decades as it was as early as in 1931 that DB bought the shipping company DB Schenker and has been developing it under their wings ever since. During this time DB Schenker has worked up to the role of a logistics partner for many companies from different regions of the world, providing cargo handling at all stages "from the first to the last mile", and performing a number of other services, including the recycling of packaging and post-sales activities.

It is also the Austrian Railways (ÖBB) that have had their logistics company since 2005 when they established a subsidiary, Rail Cargo Group (RCG). RCG is a conglomerate of freight forwarding and cargo handling companies which also provide technical services. RCG has gradually expanded their business operations to include Hungary, the Czech Republic, Slovakia, Turkey, Greece and Italy. The Rail

Cargo Group provides logistics services for goods received mainly at the Adriatic ports (Trieste, Venice, Koper, Rijeka) also trying to develop connections between China and Austria via Ukraine and Slovakia. Another direction of RCG's expansion is the Baltic Sea owing to the launch of a direct Wels–Luebeck container route.

The Austrian Railways are engaged in the development of a logistics base for RCG – warehouses, storage yards are located at the most important points of the country and an example of such a project is the Vienna South main railway freight station with an area of 55 hectares. It is located at a strategic point at the intersection of trade routes linking rail and road transport lines.

Logistics functions are developed by French state railways SNCF. Their daughter company, SNCF Logistics (formerly known as SNCF Geodis) is responsible for the transport of goods and full logistics. The functions have been strictly divided between subsidiaries within the company. And thus, for example, Fret SNCF is the company responsible for rail freight in France, and Captrain organizes freight transport by rail abroad (in Poland Captrain is ranked second – following PKP CARGO – in the intermodal transport segment). Other companies of SNCF Logistics take on the task of organizing operation of terminals or transport on short distances using mainly vans and trucks.

The logistics operator is the Lineas railway group operating mainly in Belgium, the Netherlands and northern France, which was established on the basis of the National Railway Company of Belgium SNCB/NMBS. The company specializes in intermodal transport operating mainly on routes connecting inland terminals with the ports of Ghent, Antwerp and Rotterdam. And although Lineas is not a large operator compared with other logistics companies, it is becoming increasingly powerful on its regional market. Thus, as can be seen, the logistics sector creates opportunities for both large and smaller operators. PKP CARGO has the potential and market opportunities to be in the former group.

Poland is located at the intersection of the most important east to west and south to north trade routes. This gives us natural competitive advantages over other countries, but it does not guarantee success. The key factors in this context are the above mentioned infrastructure conditions, nonetheless, a major challenge is also to improve the container train handling organization as well as the development of a specialized rolling stock depot.

Some of our terminals require investments in the purchase of facilities and equipment as their handling capacities are approaching the limits. It is also necessary to invest in digitization, which is a tool for monitoring the transported goods, so that customers should be informed in real time where and in what condition their shipments are. This system is also supposed to protect shipments against theft, damage of freight, and to quicken the circulation of documents and containers. If these objectives are to be accomplished, it would be required that a comprehensive IT system in which all the intermodal market operators are be included is prepared and implemented.

Railway carriers surely are concerned about rolling stock shortages. A rapid development of intermodal transport is the reason why the demand for platforms for transporting containers and locomotives to pull such sets is growing. In the latter case, it is necessary to buy, lease or rent also multi-system vehicles, so that international connections could be made without the need to replace the locomotive at the border crossing of another country. Carriers operating on the Polish market carry out such projects, being one of their priorities and take advantage of the EU co-financing when making such purchases.

Projects carried out by the PKP CARGO Group can serve as an example. One of the tasks concerns the purchase of 936 intermodal platforms that will be used in domestic transport. The investment amounts to more than PLN 451.5 million, of which the EU subsidy exceeds PLN 183 million. Another project of PKP CARGO concerns the purchase of 220 platforms and five multi-system locomotives for operating international trains in the European North-South transport corridor. The investment will cost PLN 227.6 million (PLN 92.4 million coming as support from the EU budget).

Other companies also see the need to invest in intermodal transport. Two locomotives and over 320 platforms will be purchased by Lotos Kolej, which will cost PLN 183 million (74.3 million is an EU subsidy). And Rail Capital Partners will purchase 12 locomotives for intermodal transport, which will be equipped with an in-vehicle exhaust module, so that they can also operate on non-electrified sidings. In this case, the purchaser of locomotives will not be the user, locomotives will be leased to carriers. This case shows that intermodal transport is considered as the future of railways and profitable operations. This is confirmed by the market, as the margins achieved by carriers on container transports are higher than e.g. in transport of bulk goods.

The market tells carriers what type of rolling stock to buy. Approximately 97% of intermodal transport is accounted for chiefly by 20′ and 40′ containers. On the other hand, semi-trailers and trailers as well as swap bodies account for over 2% of the market only. This is the reason why platforms for carrying containers with shipments most frequently shipped are and will be predominantly purchased by shippers.

Container transport could be improved if the regulatory environment were more favourable. A primary issue is to eliminate bureaucratic barriers which are blocking at the moment e.g. border crossing by trains. All the time we have a situation where the road transport is privileged, even in the form of charges for using the infrastructure. Despite the fact that there are preferential rates for access to rail tracks in the case of intermodal transport, the financial burdens of road carriers are still relatively lower. Moreover, railway carriers are exposed to much more severe financial sanctions for exceeding the axle load limit than road transport operators. Furthermore, the state should promote rail transport as a greener and cheaper mode of transport than transport of containers by trucks. When there are fewer containers on roads the level of safety of road users will also increase.

Intermodal transport is a great opportunity for the Polish railways. Its share in the transport structure will surely be growing, and in the long run, the situation in Poland will be similar to the markets of developed Western countries, where the intermodal transport accounts for more than 50% of the entire transport (it is more than 70% in some countries). Nevertheless, further development of this sector depends on whether the railways will be well-prepared in terms of organization and technical capacity to receive this stream of freight. Therefore, the investments that are needed include, but are not limited to, the railway network, construction of terminals and logistics centres, larger capacity at border crossings, as well as implementation of organizational and legal solutions that will shorten the bureaucratic issues related to trains with containers and increase the level of services offered to customers. If the intermodal transport is not growing, it will be impossible to implement the EU recommendations where in the transport plan it is assumed that 30% of freight will be carried by trains by 2030 and that this indicator will exceed 50% by 2050.

Conclusion

As the analysis of the company's operations shows, PKP CARGO has a great potential and capacities to develop the role of a logistics operator and the company has already taken up the first steps to this end. This segment is also playing an increasingly important role in the business structure of PKP CARGO, which is related to the rapidly growing intermodal transport sector in Poland. The prospects for the development of this market are promising mainly due to an increase in transhipments in the ports of Poland and countries of the Three Seas region and due to the fact that a high growth rate of rail freight traffic is supposed to be maintained on the New Silk Road in the forthcoming years.

At the same time, it should be noted that PKP CARGO does not wait passively for the development of events, but it reorganizes its operations, increases its flexibility and takes advantage of the opportunity of integrating various modes of transport. As far as storage and transhipments are concerned, all the terminals of PKP CARGO should be merged into one company operating in Poland and Europe. However, this is only a part of the strategy, as a specialized company will have to be established to organize the logistics process. Using internal and external resources, this company will prepare the best offer for customers to deliver their freight to the right place, in the right quantity, at the right time and at the right price. At the same time, this indicator does not necessarily have to mean the "lowest price" as PKP CARGO is also facing demanding tasks when the most important issue for the customer is prompt and safe delivery of freight wherefore they are willing to pay more for the service.

Focusing on the development of logistics is a well-thought-out strategy of PKP CARGO as the Group's future cannot be mass cargo handling in a long time perspective. Taking up the function of a logistics operator will make it possible for PKP CARGO to earn a higher added value than if the company should remain with the carrier's function only. It can be said that this is a natural path of development for the company and its subsidiaries.

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DRAFT TO IMPLEMENT A LOGISTICS INFORMATION SYSTEM FOR CORPORATE MANAGEMENT USING MULTI-CRITERIA DECISION MAKING METHODS

Abstract

This manuscript is focused on describing and analyzing certain logistics processes and activities in a chosen light manufacture, warehouse and distribution enterprise, and subsequently a proposal for implementing a suitable logistics information system for corporate management providing interconnection among all the logistics activities of such an enterprise. The first two chapters outline the basic concepts related to the issue of logistics processes, electronic information systems as well as a brief description of the analyzed enterprise. The following chapters consist of the most important parts of this research study. An advanced logistics information system is specified and thereafter implemented on the basis of a predefined set of criteria and by implementing certain opted methods included into the Operations Research, particularly the multi-criteria decision making problems. Specifically, the Scoring Method is utilized, and subsequently the results obtained are compared using the Saaty quantitative pairwise comparison method.

Keywords: corporate management, logistics information system, multi-criteria decision making, Scoring method, Saaty quantitative pairwise comparison method

JEL: M15, L63, L86, L96

Introduction

Nowadays, virtually no field of business can work and develop its activities without a proper information system. Apparently, a transport or logistics enterprise is no exception, due to the fact that accurate information and sufficient data should be transmitted in a timely manner for successful operation of all logistics processes.

Thus, it can be stated that logistics is one of the fields where the information flow is based on the material and financial flow (Bazhenov et al., 2019). Not such a long time ago information was exchanged and kept in the paper form. Compared to this, automated and electronic information flows are much faster, more accurate, and allow much more information to be transmitted and transferred at once (Krásenský, 2010; Grischuk, Gunicheva, 2017).

Electronic logistics information systems enable the collection, processing, analysis, distribution, retention and evaluation of data necessary to ensure the continuity of functional logistics processes. Generally, a logistics information system (hereinafter referred to as LIS) is defined as interconnected hardware and software systems designed to support the logistics components; e.g., coordination of logistics activities, material flow, and inventory replenishment; i.e. a subset of an organization's entire information system, and is focused on the particular issues associated with logistics decision making (Odero et al., 2017; Liu, Lin, 2019).

To put it simply, an LIS may cover all fields of the following logistics activities and is made up of individual information systems/components (see Figure 1):

- Material Codification;
- Asset Management;
- Value-added Logistics Services;
- Organization Management;
- Personnel Management;
- Warehouse Management;
- Supply Management;
- Distribution Management;
- Handling and Transport Equipment Operation and Maintenance;
- Transportation Management;
- Consignment Tracking;
- Facilities Management;
- Acquisition Management;
- Surplus Management;
- Material Resources Management;
- Logistics Support for Operations;
- Crisis Management Support;
- Standardization Management (Sýkorová, Čverhová, 2011; Lorenc et al., 2016; Eschenfelder et al., 2019).

The information systems that belong to the LIS have a modular structure, having at the same time a variety of techniques that allow evaluation of data. Such a type of structure allows individual information systems to retain their special features, as well.

The LIS allows not only evaluating the actual data, but also creating the planning data. The information systems provide easy-to-use planning functions which are also supported by a forecasting function. The planning functionality of the information systems and the component sales and operations planning have been combined and enhanced to make one central planning and forecasting tool/component.

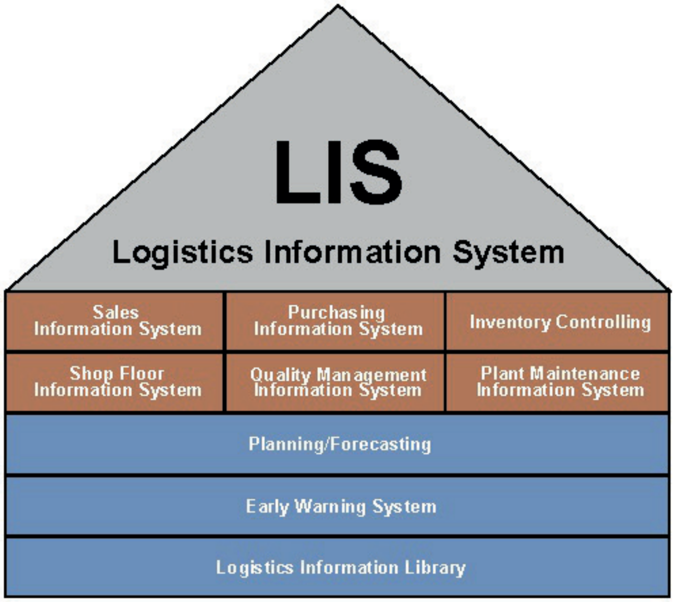

Figure 1. An overview of individual components of a Logistics Information System
Source: (own elaboration based on: Eschenfelder et al., 2019)

The Early Warning System is integrated in all of the information systems and is based on the key figures of the information system. The Early Warning System supports the decision making process by allowing the customer to target and monitor weak areas in logistics. It searches for exceptional situations and helps in the early detection and correction of undesirable situations.

The Logistics Information Library is a further component of the specific LIS. The Logistics Information Library makes it possible to access key figures in the LIS by using simple search strategies. In addition, the Logistics Information Library allows cataloging the key figures.

With the constant need to meet the ever-increasing customer demands and needs, the LISs are being advanced, more sophisticated and optimized, as well as interconnected among suppliers, transport operators, logistics providers and customers (Rasouli, 2019; Lizbetin, 2018; Mahmoudsalehi et al., 2019).

Hence, following the outlined topic within the introduction chapter, the research problem and the main objective of the manuscript may be formulated. It lies in designing an approach methodology in terms of searching for an appropriate logistics information system for corporate management of a particular enterprise when applying the specific multi-criteria decision making methods (in particular, the Scoring Method and the Saaty quantitative pairwise comparison method).

1. Description of the examined enterprise

In cooperation with the chosen enterprise, Alpha, a suitable corporate management logistics information system may be implemented based on the corporate requirements. Since it represents a relatively small enterprise with assembly, warehouse and distribution operations as well as assistance services including immobile or damaged vehicle towing, removing obstacles in connection with road transport, and displacement of heavy or oversized loads; i.e. it may be referred to as a complex 3PL (Third Party Logistics) provider, however, not able to develop its own software, it has decided to purchase a comprehensive advanced logistics information system. This enterprise Alpha is a contractual partner of the Road and Motorway Directorate for interventions on the South Bohemian motorway D3 and has been contracted exclusivity to remove road obstacles in the South Bohemian Region (Ližbetinová et al., 2019; Singh et al., 2018).

With the continuous growth and development of the enterprise and the expansion of the employee base, there are also higher demands on the accuracy of information and the speed of its transmission (transfer). Recently, the enterprise manager (and the owner at the same time) was able to provide most of the corporate logistics processes in-house (on his own), however, nowadays, these processes are divided among several corporate departments. Thus, the need to have an overview, such as the order status, the movement of all vehicles and their crews and the subsequent invoicing regarding the financial indicators, has arisen (Kubasakova et al., 2015). The corporate manager is also aware of the need for the customer relationship management (CRM) which cannot be done without an accurate customer database with an overview of orders.

2. Data and research methods

Based on the enterprise's requirements, specific relevant criteria were identified in terms of implementing the corporate management logistics information system, which must interconnect all the key activities and processes, as well as the information system itself. By linking all the data, the LIS must provide the owner and other competent persons with comprehensive relevant techno-economic information.

2.1. Overview of individual criteria and variants

On the basis of aforementioned, the examined enterprise management determined the basic set of criteria as follows:

- an option to export invoicing data and materials;
- recording vehicle activities and operations;
- working with a larger number of contract partner price lists;
- archiving photographic documentation for a specific order;
- system openness to all corporate departments;
- vehicle tracking by a GPS locator and storing the history;

– an option to interconnect the system with a mobile application.

Due to the abovementioned identified parameters (criteria), four relevant companies dealing with the development of information systems were taken into consideration from the point of view of the decision making process (Chovancova, Klapita, 2017).

In the case of this research study, those companies are named LIS-A, LIS-B, LIS-C and LIS-D. All those companies are focused, *inter alia*, on the development of information systems, and precisely, the management logistics information system interconnecting corporate economic activities with transport (logistics) and it is the customer part that matters for the enterprise.

2.2. Multi-criteria decision making

Individual methods and techniques of multi-criteria decision making issues (including methods of determination of the criteria weights as well as methods of multi-criteria evaluation of alternatives) differ, *inter alia*, in whether they give ordinal or cardinal information about the ranking of individual variants (or the importance/preference of individual criteria) and whether they need ordinal or cardinal information about individual variants by each criterion (Golini et al., 2018; Mirkouei et al., 2017).

First of all, the Scoring Method is applied for the purpose of the evaluation procedures of this research study. As a result, this method gives cardinal information about the preferences of individual criteria (Rezaei et al., 2018). The criteria and their weights were determined in cooperation with the investigated enterprise management, the enterprise's clients as well as based on the opinion of several external experts in the particular issues. They evaluated the individual criteria and rated them by points in the range of 1–5 (see Table 1).

Thus, a rating scale of variants depending on each determined criterion was drawn up as shown in Table 1.

Table 1. Rating scale of variants by each criterion

Numerical evaluation	Corresponding assessment
1	Not allowing, not included
2	Allowing with difficulty, or the implementation is unsatisfactory
3	Allowing with problems, features are not ideal
4	Allowing a function with less reservations
5	Allowing, absolutely satisfactory

Source: (own elaboration)

Based on the following procedure, a criterion matrix (Nadoushani et al., 2017) may be compiled (see Table 2). The method procedure consists in several follow-up steps:

– each variant is evaluated by the determined criteria – *sij*;
– for the quantification of information by the each criterion, a scale of 1–5 is used so that the best rating is 5;

– the total evaluation of each variant is then calculated as the sum of the partial values (see Equation 1):

$$s_i = \sum_{j=1}^{k} s_{ij}, \quad i, j = 1, 2, \ldots, \mathrm{k}, \tag{1}$$

where:
s_i is the total score of variants (variant preference index);
s_{ij} are the elements of the criterion matrix;
– subsequently, all the variants are ranked in a descending order by *si* and the best (compromise) option can be determined.

If multiple options are demanded, the required number of variants with the highest *si* values is selected. The procedure may also be extended by the weighting criteria, the *si* values are then calculated as normalized sums (Maznah et al., 2011; Hwang, Yoon, 1981).

As for the second technique, the Saaty method is applied. This is a method of a quantitative pairwise comparison of individual criteria. Generally, for the evaluation of paired comparison of criteria, a 9 point scale is utilized. For more detailed evaluation of criteria pairs, it is possible to use intermediate values as well (2, 4, 6, 8) (Lin, 2019; Hu, Sheng, 2014; Saaty, 2013):
1 – equal criteria *i* and *j*;
3 – slightly preferred criterion *i* above *j*;
5 – strongly preferred criterion *i* above *j*;
7 – very strongly preferred criterion *i* above *j*;
9 – absolutely preferred criterion *i* above *j*.

The evaluation process using the Saaty method (Saaty, 2013) is based on the fact that the researcher (expert / decision maker) compares each pair of criteria and inputs the value of preferences of *i*-th in relation to the *j*-th criterion into the Saaty matrix $S = (s_{ij}, i,j = 1, 2, \ldots, k)$. In case that the *j*-th criterion is preferred above the *i*-th criterion, inverse values are entered into the Saaty matrix ($s_{ij} = 1/3$ for low preference, $s_{ij} = 1/5$ for strong preference, etc.) (Hu, Sheng, 2014).

In the Saaty matrix, $s_{ji} = {}^{1}/_{s_{ij}}$, and furthermore ($s_{ij} \approx {}^{v_i}/_{v_j}$ represents the approximate ratio of the criterion weight *i* and *j*).

This already indicates the basic characteristics of the Saaty matrix. Saaty (2013) designed several numerically very simple ways by which individual weights *vi* can be estimated. The vectors of their values are denoted as $v_i = (v_1, v_2, \ldots, v_k)$. The most common method to be applied to calculate the weights is referred to as a normalized geometric mean of a line in a Saaty matrix. The Saaty method can be used not only to determine the preferences between the criteria, but also among individual variants by analyzing the original assignment, which is called an Analytic Hierarchy Process (hereinafter referred to as the AHP method) (Hruška et al., 2014).

To calculate the geometric mean of each row of matrix *S* (Equation 2) (Hruška et al., 2014):

$$g_i = \sqrt[k]{\prod_{j=1}^{k} s_{ij}}, \ldots i, j = 1, 2, \ldots, k, \tag{2}$$

where:
g_i is the geometric mean;
s_{ij} are elements of the Saaty matrix;

$\prod$ is the product of the values of the Saaty matrix elements.

Normalization of the geometric mean (Equation 3) (Hruška et al., 2014):

$$v_i = \frac{g_i}{\sum_{i=1}^{k} g_i}, \ldots i, j = 1, 2, \ldots, k, \tag{3}$$

where:
v_i is the normalized geometric mean;
g_i is the geometric mean;
$\sum$ is the sum of geometric mean values.

3. Obtained results

In regard to the Scoring Method, to obtain the desired results, a criterion matrix for individual logistics information systems needs to be compiled based on the evaluation values by each criterion using a rating scale and a decision matrix. Then, the sum of the individual variant values by each criterion according to Equation 1 and the resulting order of individual logistics systems can be determined. The resulting evaluation of variants is summarized in Table 2.

Table 2. Criterion matrix and the resulting evaluation of variants by the Scoring Method

Criterion	Variant			
	LIS-A	LIS-B	LIS-C	LIS-D
C_1 – export of invoicing data and materials	4	5	3	5
C_2 – recording vehicle activities and operations	5	5	5	5
C_3 – working with a larger number of contract partner price lists	2	3	1	4
C_4 – archiving photo-documentation for a particular order	1	1	1	3
C_5 – system openness to all corporate departments	5	5	5	4
C_6 – vehicle tracking by GPS locator and storing the history	3	4	4	4
C_7 – interconnecting the system with a mobile application	1	5	1	5
The resulting $\sum$ values	21	28	20	31
Weighted mean = result values $\sum$ / number of criteria	3	4	2.857	4.286
Variant rankings	3	2	4	1

Source: (own elaboration)

As for the Saaty method, the obtained criteria pair values (assigned by the corporate management, the enterprise's clients as well as based on the opinion of several external experts) were used to calculate the weights of individual LIS parameters (see Table 3). The sum of all the weight values must be equal to 1.

Table 3. The resulting Saaty matrix

Criterion	C_1	C_2	C_3	C_4	C_5	C_6	C_7	g_i	v_i
C_1	1	1/5	3	5	1	1/3	1	1.000	0.101
C_2	5	1	7	9	3	1	1	2.661	0.269
C_3	1/3	1/7	1	3	1	1/7	1/5	0.456	0.046
C_4	1/5	1/9	1/3	1	1/3	1/9	1/7	0.235	0.024
C_5	1	1/3	1	3	1	1/5	1/5	0.631	0.064
C_6	3	1	7	9	5	1	3	3.113	0.315
C_7	1	1	5	7	5	1/3	1	1.788	0.181
								$\sum = 9.884$	$\sum = 1.000$

Source: (own elaboration)

Assigning the judgment of decision makers (experts, clients and corporate management) to each of the criteria represents the first step of the AHP method. Subsequently, according to the general AHP procedure, a comparison of individual variants by individual criteria needs to be performed (Hruška et al., 2014; Triantaphyllou, Mann, 1995).

And again, experts, enterprise clients and corporate management were asked to specify preferences among individual variants by each criterion. Each of the experts set a level of significance for each pair of the LIS by the corresponding criterion (Jurkovi , Sosedová, 2013). And a product of the sub-matrices of all decision-makers was established for each matrix evaluation element (Podvezko, 2009), and subsequently the mean was calculated.

All comparisons of the LIS by each criterion are summarized in the following tables (Tables 4–10).

Table 4. A comparison matrix of the variants by C_1

C_1	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1/3	3	1/3
LIS-B	3	1	5	1
LIS-C	1/3	1/5	1	1/5
LIS-D	3	1	5	1
v_i	0.151	0.391	0.067	0.391

Source: (own elaboration)

Table 5. A comparison matrix of the variants by C_2

C_2	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1	1	1
LIS-B	1	1	1	1
LIS-C	1	1	1	1
LIS-D	1	1	1	1
v_i	0.250	0.250	0.250	0.250

Source: (own elaboration)

Table 6. A comparison matrix of the variants by C_3

C_3	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1/3	3	1/5
LIS-B	3	1	5	1/3
LIS-C	1/3	1/5	1	1/7
LIS-D	5	3	7	1
v_i	0.118	0.263	0.055	0.564

Source: (own elaboration)

Table 7. A comparison matrix of the variants by C_4

C_4	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1	1	1/5
LIS-B	1	1	1	1/5
LIS-C	1	1	1	1/5
LIS-D	5	5	5	1
v_i	0.125	0.125	0.125	0.625

Source: (own elaboration)

Table 8. A comparison matrix of the variants by C_5

C_5	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1	1	3
LIS-B	1	1	1	3
LIS-C	1	1	1	3
LIS-D	1/3	1/3	1/3	1
v_i	0.300	0.300	0.300	0.100

Source: (own elaboration)

Table 9. A comparison matrix of the variants by C_6

C_6	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1/3	1/3	1/3
LIS-B	3	1	1	1
LIS-C	3	1	1	1
LIS-D	3	1	1	1
v_i	0.100	0.300	0.300	0.300

Source: (own elaboration)

Table 10. A comparison matrix of the variants by C_7

C_7	LIS-A	LIS-B	LIS-C	LIS-D
LIS-A	1	1/9	1	1/9
LIS-B	9	1	9	1
LIS-C	1	1/9	1	1/9
LIS-D	9	1	9	1
v_i	0.050	0.450	0.050	0.450

Source: (own elaboration)

In total, seven criteria were specified, and the weight was calculated for each of them. This weight must be subdivided among the variants. The weights of each criterion as well as the variant depending on these criteria were calculated (see Tables 4–10). The total values of each variant by individual criteria multiplied by the weight of the corresponding criterion had to be counted to determine the overall variant rankings. Subsequently, the variants were sorted in the descending order whereby the final variant's ranking (i.e. final evaluation of variants) was defined (see Table 11).

Table 11. The resulting evaluation of the variants by the Saaty method

Variant	Criterion							Total values	Variant rankings
	1	2	3	4	5	6	7		
LIS-A	0.151	0.250	0.118	0.125	0.300	0.100	0.050	0.1507	4
LIS-B	0.391	0.250	0.263	0.125	0.300	0.300	0.450	0.3170	2
LIS-C	0.067	0.250	0.055	0.125	0.300	0.300	0.050	0.2023	3
LIS-D	0.391	0.250	0.564	0.625	0.100	0.300	0.450	0.3300	1
Criteria weights	0.101	0.269	0.046	0.024	0.064	0.315	0.181	–	–

Source: (own elaboration)

4. Discussion of the results

The selection of the appropriate method depends on the point of view of the decision maker (investigator) interested in the given subject. Proposing a suitable logistics information system for corporate management can be viewed as a decision making problem in which the final decision is influenced by a group of external factors. For the purpose of addressing MCDM problems, the methods of multi-criteria analysis are used which therefore can be used even while deciding about the appropriate LIS selection. There are many different methods of multi-criteria decision analysis which can help in such an issue. Nevertheless, in practice, many of these methods cannot be applied as they do not allow processing all the intricacies intended in this manuscript. Another significant problem field for the application of certain methods consists in the fact that we do not know the details of LIS customers and users, which we could have analyzed.

The final decision summarized in Table 2 (applying the Scoring Method) shows that the best possible value within the ranking is achieved by the LIS-D system, the LIS-B system is ranked second in the row, the third place is assigned to the LIS-A system and the LIS-C system scores the least points, thus taking the last place in the ranking.

On the other hand, when using the Saaty quantitative pairwise comparison method (or the Analytic Hierarchy Process method), although the greatest calculated value is obtained by the LIS-D system as well, which is thus ranked first, and also the LIS-B variant is ranked second, nevertheless, the third place is assigned to the LIS-C variant and the LIS-A system scores the least points, and thus for a change, it is ranked on the last position. Either way, if the enterprise chooses to procure the LIS-D system, it will obtain an appropriate system to support its processes to ensure all the economic and logistics activities.

Each of the methods implemented appears to be relatively easy to handle and apply to the complex and difficult task of selecting a suitable LIS for corporate management. Furthermore, a number of criteria have a lesser or greater impact on the final decision in this regard. It was necessary to apply such a method that would allow the decision maker to judge the relationship significance (preference) between the two criteria compared. In addition to that, the Saaty method allows a detailed division of these preferences.

Conclusions

Analyses of a variety of logistics processes (in various countries) resulted in the necessity to implement a management logistics information system into enterprises, since currently, still huge amounts of paper work are performed, and information is often transmitted orally or in writing. Therefore, depending on the size, focus and possibilities of enterprises, it is recommended to consider the possibility to create specific software in terms of streamlining various operations and processes, and especially to implement a special tailor-made advanced logistics information system.

Applying the Scoring Method as well as the Saaty quantitative pairwise comparison method, the LIS-D logistics information system for all the assessed criteria achieved excellent evaluations, i.e. almost a full score. In addition, it provides additional interesting feature options, e.g. saving records of call to customers. It is important to emphasize that this represents an information system created directly for enterprise aiding services, and therefore, apparently, it perfectly suits its implementation in the examined enterprise.

The outcomes of this research study have confirmed that both methods for determining the criteria weights represent effective techniques to be applied for purposes of multi-criteria decision making problems in terms of seeking a suitable logistics information system. In addition, the Saaty (AHP) method allows a reduction in the number of the criteria that are taken into account when searching for solutions.

Nonetheless, these are only recommendations according to the above-described methods of calculation, defined criteria and specification of their weights. Furthermore, individual criteria pair preferences differ from one decision maker to another; therefore, the outcome depends on who is making the decision and what their objectives and preferences are. The final decisions and forms of such a methodology will depend on a number of factors and evaluation details by the decision makers concerned.

In the future, in addition to the above, the addressed issue would need to be examined more comprehensively. It is recommended to focus in particular on:

1. Designing a concept of telematics interconnection of on-line information related to multiple logistics activities (their optimal deployment, proper capacity

utilization with respect to material flows, entry prices – fuel, toll, shipping cost, warehousing cost and also with respect to the environment, etc.). By corresponding HW and SW, the basic idea is to support the creation of a platform for the telematics flow of processes inside and outside enterprises. To do this, it is necessary to know the outlook directions for the logistics market development, its participants and customer requirements in terms of the services provided.

2. In terms of the economic advantage/disadvantage of the proposed application of the new LIS, it would be appropriate to address its economic aspect as well. However, due to the complexity of the issue and the limited range of the manuscript, it is not possible to focus on this area. Since there is no universal approach to assess the economic effectiveness of the LIS implementation within enterprises, it also would be reasonable to address this issue as well.

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A STUDY ON THE POSSIBILITIES OF REDUCING THE SAFETY STOCK BY MODELLING AND ANALYSING THE STOCK REPLENISHMENT PROCESS

Abstract

The paper describes the course of study on the stock replenishment process in a production company. The study has proven that improvement in the information exchange between the Producer and the Supplier of raw materials brings business-related benefits. The example shown concerns the reduction of stock of a selected material, replenished as part of a system based on the reorder point. The automation of activities related to information processing has shortened the duration of certain stages of stock replenishment, which, on the basis of basic dependencies within the replenishment system, has allowed reducing the safety stock kept to ensure production continuity in conditions of uncertain demand. It was possible to introduce changes in the replenishment process (both on the Producer's and the Supplier's part) owing to a profound analysis of the process itself. The example presented applies the BPMN 2.0 standard and the iGrafx tool.

Keywords: stock, safety stock, process, BPMN, optimisation, process analysis
JEL: O330

Introduction

Despite the development of alternative concepts of managing flows of goods, stock management under conditions of random changes of demand still remains an important issue. The task gets even more challenging when, in addition to random demand variability, there are also changes (often of a random nature) of the replenishment lead time. It is also important to properly identify all time components of the total replenishment lead time. In many cases it is the purchaser, not the supplier, that is responsible for some of them (order preparation, transportation, reception of goods). All these subprocesses have their own "times" and time deviations.

Thus, it is important to develop a model for calculation of basic parameters controlling a given replenishments system (e.g. the reorder point model), where all the identified lead time components (mean values and standard deviations) are included. In order to make use of the model most efficiently one has to look for all possibilities leading to potential process improvements by reducing some of the lead time components and their variabilities. Business Process Modelling was used for the purpose of the research reported in this paper.

The main research goal was to investigate what impact the application of business process modelling may have on the stock replenishment process and one of its key performance indicators – the safety stock level. The research was conducted in an industrial environment.

1. Methodology and theory

The considerations presented below refer to stock replenishment based on the reorder point (Figure 1), where the stock replenishment cycle should commence at the moment of achieving (or dropping below) the so-called reorder point (level) B.

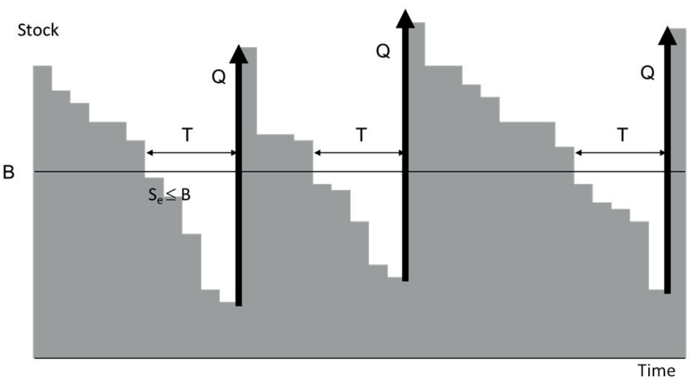

Figure 1. General stock replenishment rules in a system based on reorder point
Source: (own elaboration)

In general, the reorder point B may be calculated as follows:

$$B = \overline{D} \cdot \overline{T} + \sum \overline{x_i} + \sqrt{Ss_D^2 + Ss_T^2 + \sum Ss_{xi}^2} \qquad (1)$$

In the foregoing formula:
$\overline{D}$ – the average demand in a specific unit of time;
$\overline{T}$ – the mean time of the stock replenishment cycle;
$\overline{x}_i$ – the mean values of other factors, related to:
– shortages in the quantity or quality of a delivery;

– placing orders when the economic stock level S_e is significantly lower than level B, which, consequently, is related to:
  - increased demand in a nominal replenishment cycle, resulting from the actual stock control cycle or the order placing cycle[1];
  - with the nature of demand distribution.

Ss_D – safety stock resulting from random demand variability:

$$Ss_D = \omega_D(\alpha SL) \cdot \sigma_D \cdot \sqrt{\overline{T}}, \qquad (2)$$

where $\omega D(\alpha SL)$ is a safety coefficient corresponding to the adopted service level – the probability to serve demand in a stock replenishment cycle (Tempelmeier, 2000), for the distribution to which demand applies. It is the standard distribution that usually applies to fast-rotating goods, while it is Poisson's distribution or exponential distribution that applies to slow-rotating goods.

Ss_T – safety stock resulting from the replenishment cycle time variability:

$$Ss_T = \omega_T(\alpha SL) \cdot \overline{D} \cdot \sigma_T, \qquad (3)$$

where $\omega \mathrm{T}(\alpha SL)$ is a safety coefficient corresponding to the adopted service level (the probability to serve demand in a stock replenishment cycle), for the distribution to which the replenishment cycle time applies – in practice, it is not standard distribution but, for example, triangular distribution.

Ss_{xi} – safety stock resulting from other above listed factors. This part of the safety stock may generally be presented as:

$$Ss_x = \omega_x(\alpha SL) \cdot \sigma_x, \qquad (4)$$

where $\omega x(\alpha SL)$ is a safety coefficient corresponding to the adopted service level (the probability to serve demand in a stock replenishment cycle), for the distribution to which the analysed factor applies. It may be standard distribution, but in certain situations a different distribution (e.g. rectangular) may apply (Krzyżaniak, 2015, 2017).

The constituents of the above listed safety stock depend on factors that may be minimised or even eliminated as a result of process analyses.

The main area for potential changes discussed in the present article is the shortening of the stock replenishment cycle time and its variability. Attention should be drawn to the fact that the cycle replenishment duration is a sum of the number of partial stages.

Most of them are the supplier's responsibilities, except for a few, where the responsibility rests with the ordering party. Figure 2 shows an example of such a structure of time (T).

A process analysis was conducted by the authors to verify the impact of the proposed solutions. Process maps, created on the basis of process interviews, were made to ensure the proper quality and readability. The maps were prepared in accordance

[1] For example, placing orders at a specific time of day (e.g. in the evening) requires taking into account the expected demand volume in the period from meeting the order conditions ($S_e \leq B$) to the actual commencement of the stock replenishment cycle. Failure to meet this organisational condition may, in certain situations, result in lower availability of service.

with the BPMN 2.0. standard – currently the most popular tool for describing business and production processes (Briol, 2010). The maps were later complemented with lead times of individual activities, waiting times between activities, the number of employees involved in the process and schedules of operation to ensure the proper quality and readability. Process models were developed as a result. The models underwent simulations with the use of specialist software (iGrafx) (Ragin-Skorecka, Nowak, 2016).

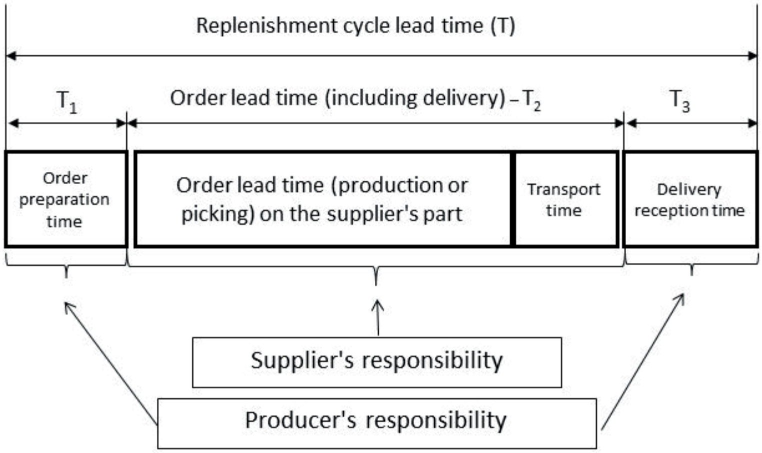

Figure 2. Structure of stock replenishment cycle time (T) for the discussed example
Source: (own elaboration)

2. Results and discussion

The example assumes that direct transport to the Producer's headquarters is the Supplier's responsibility. The total stock replenishment cycle time (T) is the sum:

$$T = T_1 + T_2 + T_3,$$

where:
T_1 – the time spent on preparing and releasing the order;
T_2 – the time required for the supplier to complete the order (including delivery);
T_3 – the time spent on delivery reception (unloading, inspection in terms of quantity and quality, transport to the warehouse and making an entry on the delivery reception in the IT system).

Considering the processes of order preparation and delivery reception (i.e. the issues for which the producer is responsible), it should be noted that they form a set of operations carried out simultaneously, which have separate lead times (including possible deviations), which is the subject of the process analysis described below.

The adopted assumptions allow presenting the safety stock as follows:

$$Ss = \sqrt{\omega_D(\alpha SL) \cdot \sigma_D^2 \cdot (\overline{T}_1 + \overline{T}_2 + \overline{T}_3) + \overline{D} \cdot \left\{ \sum_{i=1}^{i=3} [\omega_{T_i}(\alpha SL)]^2 \cdot \sigma_{T_i}^2 \right\}}, \quad (6)$$

where:

$\overline{D}$, σ_D – the average demand and its standard deviation in a specific unit of time;

$\overline{T}_{1,2,3}$, $\sigma_{T_{1,2,3}}$ – the mean times T_1, T_2 and T_3, according to the formula (5), including their standard deviations;

$\omega_D(\alpha SL)$ – safety coefficient corresponding to the service level, for the observed demand distribution;

$\omega_{T_i}(\alpha SL)$ – safety coefficients corresponding to an adopted service level, for observed distribution of times T_1, T_2 and T_3.

It was initially assumed that, from the Producer's perspective, a process analysis should, above all, cover times T_1 and T_3, both with reference to the mean value and the standard deviation, as well as, in certain situations, the features characteristic for the distribution frequency of these times. On the other hand, at the stage of implementing improvements shown by the process analysis, time savings were found in T_2 (the time spent by the Supplier on formal services related to the order), as well. The savings are a result of the information exchange automation achieved due to the integration of IT systems. T_3 remains unchanged and is not taken into consideration as a source of possible improvements in the present publication. The potential for improved efficiency was determined by comparing two models of stock replenishment processes: the current process (AS IS), presenting the current course of executing orders for raw materials necessary to maintain current production, and the target model (TO BE), providing a new stock replenishment method.

It should be borne in mind that, both for the AS IS and TO BE models, the positive course of executing the researched process only was assumed – the appropriate business roles (Decision-Maker and Manager) always approve the order and the dispatch of goods.

On the basis of the information obtained from warehouse or production employees, an employee responsible for the purchase of raw materials prepares the order (activity: order preparation), which is then verified and approved by a Decision-Maker (activity: order acceptance). The order is sent by the employee responsible for the purchase of raw materials to the Supplier (activity: order placement). The Supplier's Customer Service Department analyses the order (activity: order analysis) and passes it to the manager for review and acceptance (activity: acceptance). The next activity is the picking and release of goods (activities: picking and release) in compliance with the Delivery Note document. The goods (raw material to be used in production) supplied together with the Delivery Note are received by the Producer's target warehouse, which marks the end of the analysed process – the current stock is replenished.

The process model presented below (Figure 3) displays a potential for optimisation – the activities which may be eliminated or the duration of which may be shortened by introducing certain improvements, presented on the target process model (Ragin-Skorecka, Nowak, 2017).

The target process model (TO BE) presented in Figure 4 shows an improved method of ordering raw materials required for current production.

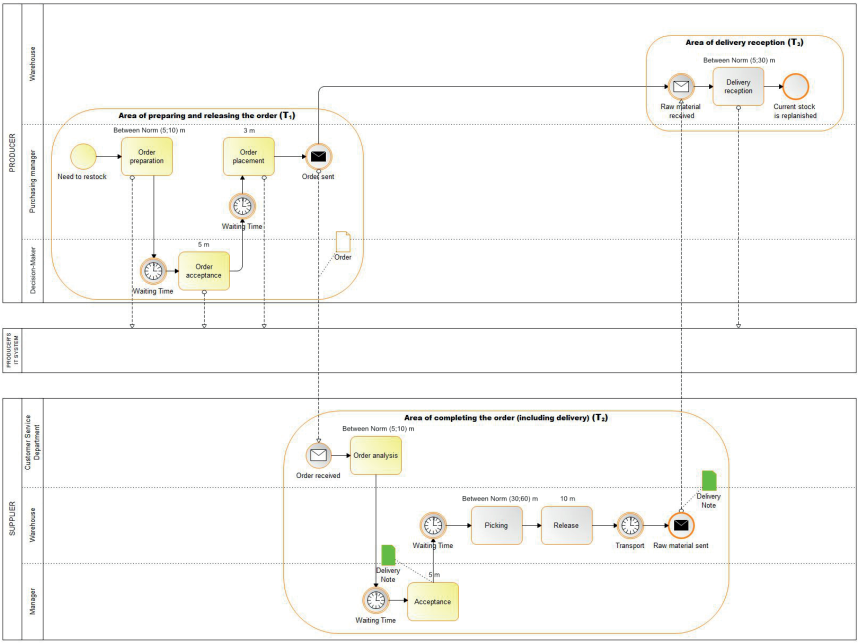

Figure 3. Stock replenishment process map, current status – AS IS
Source: (own elaboration based on own research conducted by the Institute of Logistics and Warehousing, Software used: iGrafx Process 2011 for Enterprise Modelling)

Course of the target process (TO BE):

Due to the automation of activities related to information processing when stock drops to a level at which information urging the Producer to replenish the stock is sent, the Producer's IT system initiates an order directly in the Supplier's IT system. The integration is supported by a data bus (Integrator) serving as a medium for exchanging messages between them. The data bus should operate based on EDM (Enterprise Data Management) or ETL (Extract, Transform and Load) solutions (Christodoulou, Scherer, 2016). The Supplier's system generates a Delivery Note document and orders the picking directly in the warehouse. At the same time, it sends an Order Confirmation to the Producer's IT system. Then, similarly as in the case of the AS IS model, goods are picked and released, and finally received by the Producer.

The volume of orders which are subject to such automation should remain within the limits set out in framework agreements concluded between the Producer and the Supplier. The basis of such agreements may be the data concerning the planned order volume, delivery times and delivery frequencies. Appropriate planning of the terms of framework cooperation is crucial because individual orders will be executed automatically without the need of their approval by decision makers representing the Producer or the Supplier.

The following assumptions were adopted for the current process (AS IS):
- the number of orders per day – 1 order/day;
- the amount of resources as part of individual business roles – 1 resource in each business role;
- the time of work: 8 hours/day, 5 days/week, 22 days/month;
- the process observation time – 1 year.

$\overline{D} = 71, \sigma_D = 20$
$T_1 = 255.53$ [min] $T_2 = 607.56$ [min] $T_3 = 22.68$ [min]
$\sigma T_1 = 0.85$ [min] $\sigma T_2 = 5.1$ [min] $\sigma T_3 = 2.5$ [min]
$\omega_D(\alpha SL) = 1.64$
$\omega_{T_i}(\alpha SL) = 1.64$

The following assumptions were adopted for the target process (TO BE):
- the number of orders per day – 1 order/day;
- the amount of resources as part of individual business roles – 1 resource in each business role;
- the time of work: 8 hours/day, 5 days/week, 22 days/month;
- the process observation time – 1 year.

$\overline{D} = 71, \sigma_D = 20$
$T_1 = 0.0$ [min] $T_2 = 355.02$ [min] $T_3 = 22.68$ [min]
$\sigma T_1 = 0.0$ [min] $\sigma T_2 = 4.99$ [min] $\sigma T_3 = 2.5$ [min]
$\omega_D(\alpha SL) = 1.64$
$\omega_{T_i}(\alpha SL) = 1.64$

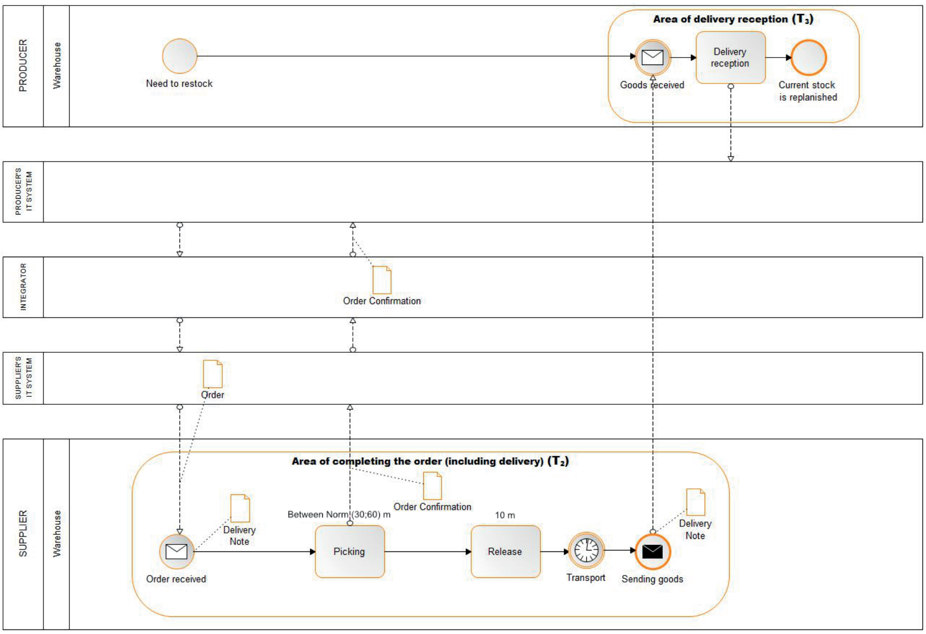

Figure 4. Stock replenishment process map, target status – TO BE
Source: (own elaboration based on own research conducted by the Institute of Logistics and Warehousing, Software used: iGrafx Process 2011 for Enterprise Modelling)

Results of comparative process simulations for AS IS and TO BE models:

With the purpose of comparing the efficiency of both processes, the simulation results were compared, focusing on the mean service time and the mean use of resources, which were considered key indicators for studying the efficiency of changes in the process (see Table 1).

Table 1. The degree to which resources were used for the execution of tasks assigned to individual business roles in analysed processes

Business roles	AS IS	TO BE
Stock / Producer/ Purchasing manager	2.18%	0%
Stock/Producer/Decision-Maker	3.11%	0%
Stock / Supplier / Customer Service	4.69%	0%
Stock/Supplier/Manager	3.11%	0%
Stock/Supplier/Warehouse	34.19%	34.33%
Stock/Producer/Warehouse	14.10%	14.15%

Source: (own elaboration based on own research conducted by the Institute of Logistics and Warehousing)

Use of resources – part of work (in %), in which a resource (business role) is involved in a specific process (Figure 5).

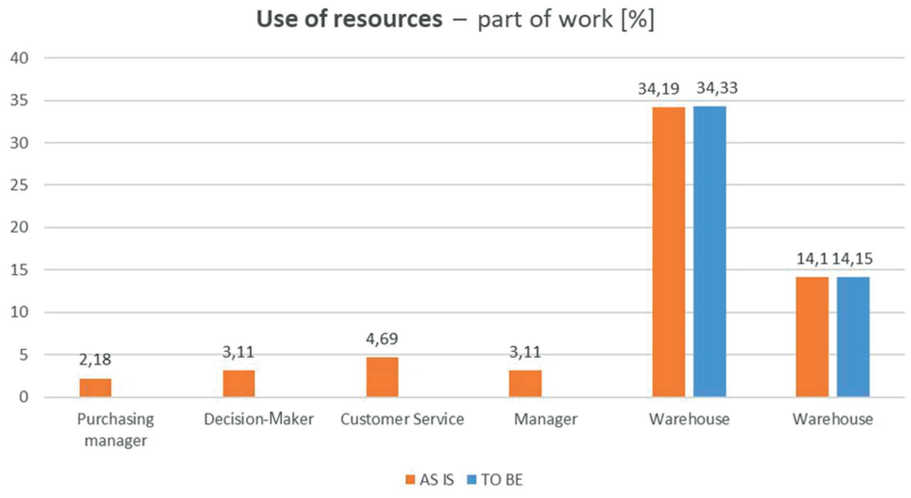

Figure 5. A graphic illustration of the degree to which resources were used for the execution of tasks assigned to individual business roles in analysed processes
Source: (own elaboration based on own research conducted by the Institute of Logistics and Warehousing)

Mean service time = T – mean time necessary to serve one instance of stock replenishment (Figure 6).

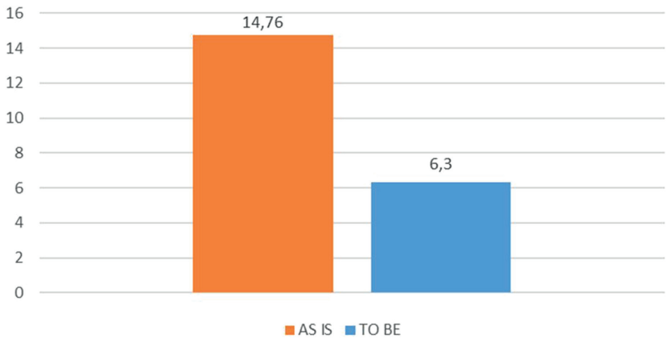

Figure 6. Mean service time in hours
Source: (own elaboration based on research conducted by the Institute of Logistics and Warehousing)

Conclusions

The operational result of the change was the shortening of the complete stock replenishment process lead time from almost 15 hours to approximately 6 hours. It is therefore possible to perform full stock replenishment on one shift. Furthermore, the operational availability of business roles responsible for accepting orders (decision-maker, manager) and roles handling the formal service of orders (purchasing manager, customer service representative) was increased for other processes carried out by enterprises. It was possible to achieve by reducing their activities in the analysed stock replenishment process.

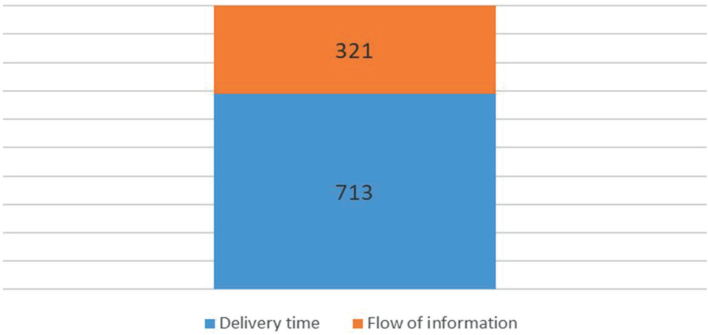

Figure 7. Structure of safety stock
Source: (own elaboration based on own research conducted by the Institute of Logistics and Warehousing)

Stock maintained to ensure production continuity (safety stock) will also be significantly reduced (by 31%) (Figure 8). It is a measurable economic effect of the change, which has directly influenced the decrease in the costs of maintaining the stock of raw materials to be used in production. The initial safety stock (1033 pcs) may be divided into stock securing the flow of raw materials (713 pcs) and the stock securing information flow, which accompanies the stock replenishment process (321 pcs) (Figure 7) – following the automation of the information flow between the producer and the supplier, this part of the stock does not need to be kept.

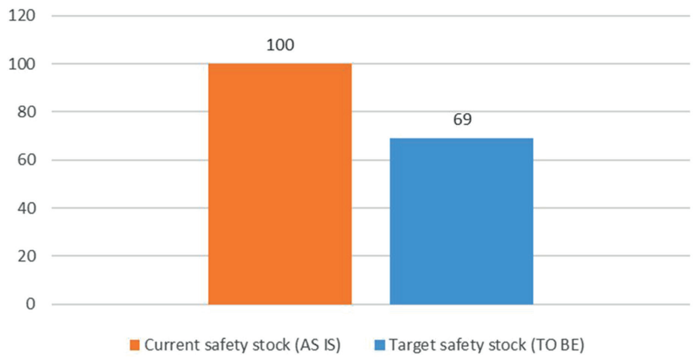

Figure 8. Projected change in safety stock, in %, after target model (TO BE) implementation
Source: (own elaboration based on own research conducted by the Institute of Logistics and Warehousing)

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SPACE LOGISTICS – CURRENT STATUS AND PERSPECTIVES

Abstract

Space exploration has been going on for decades. Although humanity has not been able to reach further than the Moon, and the only human activity in space is currently taking place in the low Earth's orbit, technological and organizational innovations that accompanied the previous projects have contributed to significant changes in the space sector and the global economy. These changes are also visible in logistics activities, especially in transport. In this article, the author reviews the current achievements in the field of space logistics, presents its definition, principles and functions, and indicates the specifics of processes, resources and the infrastructure. Due to the reviewing nature of the paper, the author's main goal is to identify a new research problem in logistics and initiate a scientific discussion on space logistics, especially in the Polish logistics environment. The important goal of the paper is also the promotion of this topic on the basis of business practice, pointing to the space sector, as a place for the development of Polish enterprises and organizations, including logistics operators or research centers. The main method used in the work on the paper is a critical, systematic analysis of the literature of the subject and resulting from the author's interests, the observation of the global space sector. An important premise for addressing the topic is the search for an original research problem using knowledge, interests and intuition. The most important conclusion resulting from the considerations undertaken in the paper is to establish that space logistics, as a result of technological breakthroughs dedicated mainly to the perspective of manned interplanetary missions, is a field that is facing extremely rapid growth, which in turn determines the growing expectations towards the scientific community. Logistics in space considered so far as an "abstract" theme should meet with greater interest of Polish scientists. This article is an introduction to an in-depth research on the subject of setting up and managing orbital and interplanetary supply chains.

Keywords: space logistics, International Space Station, interplanetary supply chain

JEL: M0, L990, O310, F530

Introduction – premises for taking up the topic

The main reason for taking up the topic was the author's interest and the related need to popularize a futurological vision of the development of logistics in space. An important premise for addressing the topic is the search for an original research problem using knowledge, interests and intuition.

The groundbreaking events related to space exploration that have occurred over the past few years have also worked as an incentive to generate a scientific discussion on the identified issues. The most important one, from the point of view of developing logistics in space, can be the successful return of the Falcon 9 rocket. The rocket manufactured by the American company SpaceX in April 2016 was used to move Dragon spaceship to the orbit, which carried supplies and an inflatable BEAM module for the International Space Station (ISS). A component of the rocket landed successfully on a special sea platform for the first time and could be used in subsequent missions. The introduction of a "recyclable" launch rocket into the space transport system is a harbinger of significant cost reductions, thus contributing to the growing demand for transport services from both government and private entities operating in the space sector.

Widely presented projects of manned missions to the Moon and to Mars as well as the effective implementation of unmanned research expeditions, in which Polish scientists and engineers had a significant share, were also important for the topic. In the author's opinion, at this stage of the life cycle of the space sector (the stage of dynamic growth), it is not only Polish engineers or constructors but also the cooperating Polish logistics specialists that have a chance to appear as significant participants in the planned expeditions.

The ancillary (support) function is included in the idea of logistics, not differently for space projects. As the history of the conquest of space shows, the importance of logistics for its effectiveness is growing. This is associated not only with a visible large share of logistics costs and the impact of logistics on the efficiency and safety of moving in space. The importance of logistics is growing mainly due to the opportunities offered by innovative logistics systems, adapted to the extremely difficult natural conditions prevailing in space, using the laws of physics to reduce the costs of flows and adopting terrestrial concepts to the very non-standard needs of space missions.

1. Space in logistics literature

Logistics is a key element determining the effectiveness of space projects (Coogan, 1987). Until now, these projects have been coordinated mainly by government agencies of these countries, which are perceived as the source of a global economic and political advantage in space. These are: NASA – National Aeronautics and Space Administration, Russian ROSKOSMOS – Russian Federal Space Agency, European ESA – European Space Agency (which includes 20 space agencies in European countries, including the Polish Space Agency), Chinese CNSA – China National Space Administration and Japanese JAXA (Japan Aerospace Exploration Agency), and recently also Indian ISRO – Indian Space Research Organization. Of these, it is only American, Russian and Chinese agencies that have a sufficient financial and organizational potential to take up a comprehensive activity in space, with the possibility of sending manned missions. So far, the largest budgets for space programs have been allocated by NASA, but it should be emphasized that the majority of initiatives dedicated to space exploration are undertaken in international cooperation, over political divisions. The aforementioned balance of power, state and scale of rivalry and international cooperation, as well as the very history of human expansion into space, have shaped the map of scientific and research achievements, including theoretical ones (see NASA website).

Notwithstanding the fact that space exploration is undertaken more or less independently by many countries in the world, the United States are leading the way in initiating and coordinating the majority of cosmic ventures. It is not surprising then that American literature is the richest and most accessible source of knowledge in the field of operational activities, including logistics operations undertaken for the needs of human activities in space. Rich achievements are also a consequence of a very fruitful cooperation of the American government agency with scientific units that has existed since the beginning of NASA. The review made by the author in scientific databases dedicated to logistics reveals that the most important are the papers written by MIT researchers – the Massachusetts Institute of Technology in cooperation with representatives of NASA (see NASA Online Directives Information System) and publications of the American Institute of Aeronautics and Astronautics (AIAA) – the world's largest technical society dedicated to the global aerospace profession (https://www.aiaa.org/about). Intense scientific activities in preparing publications in the field of space logistics is also visible at American astronomical universities, such as, e.g. the Embry-Riddle Aeronautical University, which has been organizing a conference on space conquest (Space Conference) since 1962, giving high priority to logistics (https://commons.erau.edu/space-congress-proceedings/) and training in areas related to operational activities in space (Bachelor of Science in Spaceflight Operations) (see Embry-Riddle Aeronautical University website).

An important source of knowledge about the state and perspectives of the development of cosmic logistics are publications available on the websites of space agencies, especially NASA and ESA. Many years of theoretical and practical achievements of employees of both organizations and the openness to share knowledge allow obtaining very reliable knowledge in this field.

In the Polish logistics literature, as well as in publications on astronomy or space physics, the subject of logistics activities in space is not really discussed. Individual publications are in the achievements of military academies (Borek, 2016), whereas the base of popular science sources is very rich. Magazines, such as *Astronomy* and *Urania*, have relatively many articles dealing with the logistics aspects of space exploration in their tables of contents. Interestingly, some information concerning logistics, in particular with regard to transport, appears in publications of scientists from other fields than logistics, such as, for example, law or tourism (Kułaga, 2007; Muweis, 2017; Różycki, Kruczek, 2017).

In the author's opinion, an important source of knowledge about space logistics may be the Polish Space Agency, established in 2014, as a member of the ESA. Notwithstanding a short period of operation, the agency is very actively pursuing the scientific goals of its activity. Currently (2019) the available publications are related to the subject of astronomy, and in an area close to logistics – GPS systems (polsa.gov.pl).

2. Definition, specifics and functions of space logistics

According to the definition of AIAA (American Institute of Aeronautics and Astronautics) the Space Logistics Technical Committee, space logistics is the theory and practice of driving space system design for operability, and of managing the flow of materiel, services, and information needed throughout the space system lifecycle (Snead, 2004; Goodliff, Paunescu, 2018). In the presented perspective, space logistics refers to activities dedicated to projects and space systems, undertaken both in space and on Earth. The ultimate goal of logistics in space is to maximize the exploration potential derived from vehicle performance, efficiency and effectiveness of processes and infrastructure capabilities.

Nevertheless, referring to the above approach, simplifying it, space logistics can be defined as managing the flows of people, products and information in space. The main purpose of logistics in space understood in such a way is to ensure the safety, efficiency and effectiveness of these flows. The long-term goal to which the described logistics activities contribute is the progress in space exploration.

Logistics activities in space pose a much greater challenge than those undertaken, even in the most difficult conditions, on Earth. Two main differences are significant here compared to terrestrial analogs. First, the physics of rocket propulsion provides only a minute fraction of the launch mass (typically well below 1%) for resources and items needed during exploration. This narrow margin forces careful selection of what cargo to bring and makes multi-level packing and packaging a high priority. Second, the dynamics of orbital trajectories significantly constrains the transportation schedule and duration. If a critical item fails during an exploration, it may take weeks or months to deliver a replacement with no alternatives for resupply (Grogan, 2010; Grogan et al., 2011).

The conditions that prevail in space are very important for logistics operations. Spacecraft are exposed to a range of hazards including intense particle and electromagnetic radiation, dense plasma flows, highly reactive species, and variable neutral gas densities in the low Earth orbit (LEO). Additionally, spacecraft communications and radio navigation must account for the propagation of electromagnetic waves through the ionospheric plasma in the uppermost layer of the Earth's atmosphere (Anderson, Mitchell, 2005).

If we want to look for links with terrestrial logistics, then space logistics in its ideas, principles and features is closer to military than civilian logistics. It results from enormous requirements regarding the safety of undertaken activities, their design-related nature and very high requirements as to the standards of logistics services. An important feature combining cosmic logistics with logistics for military operations, including martial activities are high requirements regarding the level of synchronization and integration of physical and information flows.

Summarizing the above considerations, the specificity of the space logistics against the background of logistics undertaken on the surface of the Earth consists of:

- functioning in extremely difficult conditions of space (Bothmer, Daglis, 2007);
- very large distances between the starting and end points and the impact on the time and manner of moving phenomena in space (Anderson, Mitchell, 2005);
- very high transport costs;
- quantitatively limited means of transport and low capacity;
- very large and uncompromising reliability requirements;
- space logistics defined and characterized in this way fulfills unique functions. Studying reports of government organizations coordinating space exploration projects, including the documentation of space missions, one can find a statement about the key importance of logistics for the success of such expeditions. The strategic participation of logistics manifests itself in its dominating share in the costs of space missions and a significant impact on their effectiveness.

NASA has defined the functions of space logistics through the prism of the life cycle of the space system known as: Life Cycle Logistics Support (LCLS) (NASA, 2012). LCLS comprises the planning, development, implementation, and management of a comprehensive, affordable, and effective systems support strategy. LCLS encompasses the entire life cycle including acquisition (concept studies, concept and technology development, preliminary design and technology completion, final design and fabrication), final production, support (system assembly, integration and test, launch, operations and sustainment), and closeout.

The principal objectives of LCLS are:

- Ensure Life Cycle Cost (LCC) is considered along with key design and performance parameters[1];
- influence product design so that the system can affordably attain required operational availability;
- design, develop, and implement a cost-effective support system;
- maintain and improve availability, improve affordability, and minimize the logistics footprint.

[1] In the case of a system such as a space vehicle that is used multiple times or is in continuous operation for an extended period, the majority of the system's life cycle costs (typically 60–70%) can be attributed directly to operations and support costs, while in the case of a system such as a launch vehicle the majority of life cycle costs may be in design and production (NASA, 2012).

3. Systems of space logistics

The areas of the use of logistics in space are related to the directions and objectives of space projects. Currently, logistics activities support mainly the transportation and servicing of telecommunication and research equipment (satellites, probes, telescopes) and the service of the International Space Station (ISS). However, in the future, on the basis of the observation of the plans of major space agencies, as well as private companies interested in space, the use of logistics will expand to support unmanned and manned interplanetary missions and to support space sectors such as space mining, space tourism and waste management activities. Each of the mentioned areas of logistics in space requires an individual, "tailor-made" logistics support system. These systems differ in the goals and scale of logistics activities, the degree of their complexity and recurrence, as well as, and perhaps above all, the cost of maintenance.

Current and future cosmic logistics systems include:

– a system of transport and service of objects on a low and geostationary orbit of the Earth (e.g., satellites, telescopes);
– a space objects service system: purchasing, transporting people, redistribution and servicing (e.g., International Space Station (ISS), objects of the space tourism sector, space mining and ecologistics);
– a system for interplanetary unmanned missions (e.g. probes);
– a system for manned interplanetary crew missions (e.g. planned expeditions to the Moon or Mars).

Each of these systems uses specific processes, resources and logistics infrastructure. These elements do not differ from their earthly counterparts in terms of type. Therefore, all major logistics processes are carried out in space systems such as locating, transporting, storing, controlling stocks, managing information. These processes use appropriate means of transport (rockets and spacecraft), storage facilities (logistics modules, ground storage centers), information and IT systems (control and control centers), and are organized according to appropriate concepts or methods. And thus, for example, the satellites and orbiting systems around the Earth use terrestrial devices to monitor and control satellites, equipment to exploit the capabilities of satellites in orbit (terminals), carrier vehicles that carry satellites into orbit and take-off systems. The planning and implementation of logistics activities is of key importance for the efficiency of the functioning of the discussed system. It also affects its costs, and thus the profitability of public and private investments in the satellite system (the cost of putting into use and maintaining one satellite ranges from several hundred million to one billion dollars) (Breidenbach, 2011).

In addition to operating a satellite system, the highest logistics activity in space is recorded in the service of the International Space Station. This, by far the most important and expensive space project (project and construction cost of about $ 10 billion), is also the most complex organizational space exploration program ever undertaken. Thus, it is an excellent testing ground for innovative logistics solutions.

The main ISS coordinators are the space agencies of the United States, Russia, Europe, Japan and Canada. The ISS Program of the International Space Station brings together international flight crews, a fleet of carrier rockets, equipment and infrastructure for takeoffs deployed around the world, operations, training, engineering and development. Communication networks and the international research community are a key element of the program.

The assembly of the ISS was by far the most ambitious project of man in space. Station elements delivered from different countries and continents were assembled in space, and merged with each other only after reaching the orbit.

Space station support is even more complicated than other space flights because it is an international program. Each partner has a basic responsibility to manage and run the provided equipment. The construction, assembly and operation of the International Space Station requires the support of facilities on Earth managed by all international partner agencies and countries involved in the program. These include the construction of objects, take-off and processing support facilities, mission support facilities, equipment for the research and development of technologies and communication devices. Such a complex project requires perfect coordination, integration and synchronization of coordination, integration and synchronization activities.

Supply missions to the International Space Station (ISS) are still the most complicated logistics operations. The need to maintain a balance between the security of astronauts, maximizing the effects of scientific research and the effectiveness of logistics operations means that although it seems to be a simple process on the surface of the Earth, it is actually highly diverse and labor intensive, requiring reliable management of goals and changing priorities.

The specifics in the ISS supplies are primarily:
- limited capacity of logistics and crew modules;
- limited size of the admission area (docking compartments);
- low frequency of deliveries associated with very high costs;
- high versatility of supply vehicles that can be used for other purposes in the ISS, e.g. as a residential module, tugboat leveling the orbit of the station and a vehicle for transporting waste from the ISS to Earth (Rarick, 2016; NASA, 2015).

The ISS has been supplied over the years using various spacecraft, including those constructed and built by international partners, i.e. government space organizations cooperating within the ISS project, as well as private partners. The ISS has served several spacecraft belonging to countries leading in the station project, but from the point of view of the development of space logistics, the ISS involvement of the spaceship DRAGON owned by SpaceX is extremely important (Rarick, 2016).

We read in the guide to the ISS that SpaceX missions are launched on Falcon 9 from Launch Complex 40 at the Cape Canaveral Air Force Station, Florida. The first stage is powered by nine SpaceX Merlin engines, and the second stage is also a single SpaceX Merlin engine. The spacecraft that launches on Falcon 9 is called the Dragon. The Dragon spacecraft is an automated logistical resupply vehicle designed to rendezvous with the ISS and is grappled and berthed using the Space Station Remote Manipulator System (SSRMS). The Dragon has a capsule section for delivering pressurized cargo, and another section called the "trunk" is used to deliver unpressurized cargo to the ISS. Once the mission is complete, the Dragon unberths from the ISS. The trunk is jettisoned and destroyed during reentry into the atmosphere, whereas the Dragon capsule, with its valuable pressurized return cargo, reenters the Earth's atmosphere and lands in the ocean with the use of parachutes. The Dragon capsule is recovered by SpaceX and it is transported back to their facility for return cargo processing (NASA, 2015).

The participation of a private company in space programs has become a milestone in increasing the efficiency of cosmic logistics. The NASA programs focused on the development of public-private partnerships, including Commercial Orbital Transportation Services (COTS) or Commercial Resupply Services (CRS). Commercial Orbital Transportation Services was a NASA program to coordinate the delivery of crew and cargo to the International Space Station by private companies. The program was announced on January 18, 2006 and successfully flew all cargo demonstration flights by September 2013. COTS are related but separate from the Commercial Resupply Services (CRS) program. COTS relate to the development of vehicles, CRS to the actual deliveries (NASA, 2014, 2018).

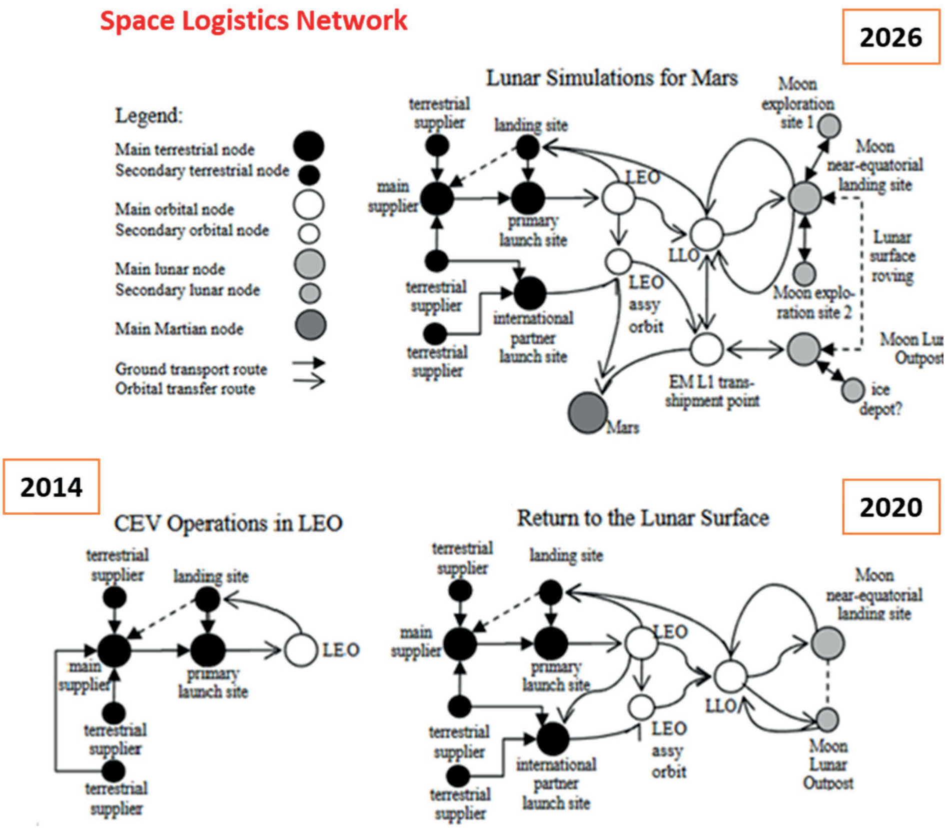
The support for telecommunications or ISS systems have provided a starting point for developing further more advanced space projects. These are definitely manned interplanetary missions, to the Moon and to Mars (Shull et al., 2006). Researchers from NASA and MIT have been preparing for new challenges for many years. At the inception of the Exploration Systems Research and Technology study entitled Interplanetary Supply Chain Management and Logistics Architectures, the investigators determined that there should be a set of studies on terrestrial analogs for space exploration. The decision to undertake projects improving space logistics based on NASA's experience results from a very serious challenge which is a human flight to the Moon and to Mars, and the future of regular traveling on these space routes.

The study, assigned to United Space Alliance LLC in Houston, TX, was to review as many sources of Logistics Lessons Learned as were available, and to attempt to draw some conclusions about the current state of NASA's logistics architecture and any challenges to developing an interplanetary supply chain (see Figure 1).

The overall objective of this project is to develop an integrated capability for guiding the development of an interplanetary supply chain that will be required to enable sustainable space exploration of the Earth-Moon-Mars system and beyond.

The goals of this project are as follows:

– find analogies of terrestrial supply-chains for both high-risk, capital intensive projects, as well as those servicing remote environments. Define and apply criteria as to the applicability of terrestrial SCM models and methods to space logistics;
– build a flexible network-based modeling environment for capturing nodes and arcs of both the ground and space based segments of the future interplanetary supply chain. This network model must capture both energy requirements and time dependencies in the network;



LEO – Low Earth Orbit, LLO – Low Lunar Orbit, EM L1 – the first Earth-Moon Lagrange point

Figure 1. The growing complexity of the NASA logistics network architecture
Source: (own elaboration based on: Evans et al., 2006)

- develop probabilistic supply/demand models by class of supply to predict likely manifests for space exploration with emphasis on small quantity logistics under uncertainty and robust sparing strategies;
- wrap these models into a user friendly and effective simulation and planning tool for NASA and the contractor community. This tool can be used to evaluate competing mission architectures in terms of their supply chain impact and sustainability and will be integrated with the agency's planned simulation-based acquisition strategy;
- carry out trade studies to highlight the implications of major architectural options of the interplanetary supply chain in terms of intermediate buffers, redundant transportation modes and push-pull boundaries. This objective includes modeling a variety of historical and planned future missions and campaign scenarios, including some with refueling and other non-traditional operations;
- actively engage the space logistics community at NASA, the contractors and academia in the challenge of creating a sustainable supply chain for interplanetary

exploration via a series of workshops, short courses as well as model development and validation efforts;
– impact the education of future explorers and engineers by involving students at MIT and affiliated institutions in the interplanetary supply chain problem by developing additional modules and assignments for existing supply chain and logistics courses. Make these educational materials easily accessible to the public (de Weck et al., 2006; de Weck et al., 2007).

The overall objective of this project is to develop an integrated capability for guiding the development of the interplanetary supply chain that will be required to enable sustainable space exploration of the Earth-Moon-Mars system and beyond.

Many research projects are dedicated to the configuration of interplanetary supply chains (Ho, 2015). Apart from technological projects, one of the most interesting projects in the author's opinion is the use of gravity fields and gravity assistance, and Lagrangedo nodes for planning very long space travels. Lagrange nodes represent the libration points (zones of no net gravitational acceleration from the celestial bodies) (Grogan, 2010). Though a current use of Lagrange points for logistics is limited to observational satellites, future missions may use them to maintain fuel or other supply depots.

Scientists from NASA and their scientific partners create maps of gravitational tracts (gravity highways) that allow space vehicles to move almost with minimal fuel consumption. In the future such projects will contribute to the construction of an "interplanetary transport system" that uses, like ships from wind power, the gravitational interaction of planets (Mazarico et al., 2011).

Conclusions

The exploration of space changes our civilization, gives previously unknown perspectives and satisfies the cognitive ambitions of man. Logistics is a very important element of this phenomenon. This pleases but also obliges. On the basis of a review and critical analysis of the literature, including industry reports and materials from governmental space agencies, in the course of the discussion undertaken in the paper, the author is convinced that the practice and the theory of cosmic logistics do not develop at the same pace. And although these differences seem typical of logistics itself, the gap is much more noticeable in the case of its space part. The real practical achievements in the field of space logistics are the result of several decades of cooperation between government organizations and research centers, as well as the ambitions and operativeness of private enterprises. This exceptionally efficient and effective cooperation on the basis of practice confirms that progress is much greater when we combine knowledge and experience on the foundation of a shared vision and mutual trust. According to the author, such a model of cooperation is needed in the theoretical trend of the development of cosmic logistics. Greater involvement of logisticians in Poland in research projects dedicated to space exploration, can support Polish engineering projects in real terms, as well as build the image of Poland in the international scientific space. The author intends to undertake such efforts in the field of configuring interplanetary supply chains.

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IMPLEMENTING INFORMATION SECURITY MANAGEMENT SYSTEMS IN TRANSPORT INDUSTRY ORGANIZATIONS

Abstract

The aim of the publication is to present the concept of information security management systems and new requirements concerning such systems and indicate security areas and their application in the transport industry. Moreover, the effects of implementing the ISO 27001 requirements in the organizational culture in the transport sector enterprises will be outlined.

Keywords: ISO 27001, information security, information security management system

JEL: P4, L1, L9

Introduction

The transport industry is one of the fastest developing areas of economy. Transport companies are increasingly often seeking and implementing system tools to manage their organization. The ISO series systems were implemented partly by reason of the legal requirements stipulating that, for example, the HACCP system (2001) (food safety management) for the transport of food products should be introduced (The Act on Health Conditions…, 2001). Subsequently, suppliers were forced by corporations of large retail chains to have BRC (2015) and IFS (2017) systems in place. It was the market itself and the opportunity of being competitive that forced enterprises in the transport sector to implement the popular quality management system ISO 9001 (Quality Management Systems – Requirements…, 2016). Furthermore, system solutions are implemented more and more frequently, depending on the transport mode. To give an example, ISO 28001 (International Organization for Standardization, 2007) is increasingly often implemented in the road transport to manage the supply chain – which, as claimed by Skojett-Larsen (1999) – is not an easy task in the adaptation to the organizational culture of an enterprise. Another example is the railway sector where the implemented safety systems are the standards EN 50126 (Railway Applications…, 2011) or IRIS (International Railway…, 2005) unifying the rules of security for all organizations participating in the railway transport (Białoń and Pawlik (2014) note that the standard (PN-IEC 60300-3-9) also applies in this area).

As far as management systems are concerned, great interest has been recently shown in the information security management system (ISO 27001). Before that time, interest in the system had been shown by financial, medical and governmental organizations often by reason of the importance of processed data. However, for several years, it has been possible to observe great interest in this system in various industries, including the transport sector. Small and medium-sized transport enterprises have started to see how valuable information is becoming aware that it should be protected. According to the data provided by certification bodies, such as SGS (*Liczba certyfikacji systemów…*, 2017) or TUV SUD (*ISO Survey 2016…*, 2016) a considerable increase in the number of certifications for these systems has been observed recently.

Research on the implementation of information security systems was carried out among transport industry companies. The studies have shown that it is a necessary system for this area of activity, and its implementation significantly affects changes in the organization. These changes mainly concern management methods and tools, competencies and awareness of people in the organization, identifying threats and incidents, and information management.

1. Information security management system concept

The international information security management standard has been defined in the form of the standard: PN-EN ISO/IEC 27001:2017-06 – Information Technology – Security Techniques – Information Security Management Systems – Requirements. An enterprise holding an ISO 27001 certificate (Information Technology…, 2018) is often perceived as a reliable business partner. It should be noted that the ISO 27001 standard "frees" the enterprise from formalized written procedures describing every activity to implement effective actions. These actions should be documented in any manner according to the so-called "Documented information" i.e., for example, instead of a detailed procedure, the enterprise may use an application managing a given area with defined tasks and specific access rights.

The concept of the system is to build a string of actions and sequences to ensure comprehensive management of data in the organization. Similarly to all ISO standards, this system is based on the PDCA Deming circle philosophy.

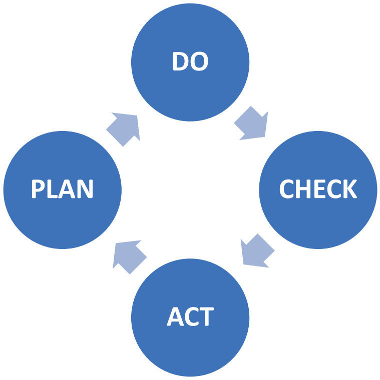

Figure 1. PDCA-Deming circle philosophy
Source: (own elaboration based on: Information Technology…, 2018)

The Deming cycle based on the PLAN-DO-CHECK-ACT principle in an information security management system should be understood as:

1. PLAN – identify and plan actions to attain a goal, which means that you should:
   - define the information security policy;
   - define the scope of the system;
   - identify and assess the risk;
   - establish a risk management plan;
   - define the methods to measure the effectiveness of the applied controls.
2. DO – carry out the planned actions as a trial, which means that you should:
   - implement a risk management plan (apply security controls);
   - implement a training and awareness program;
   - manage the resources;
   - implement procedures and controls.
3. CHECK – check whether the implemented plan was effective, if it brings results and how this process can be improved, which means that you should:
   - check if the procedures are followed:
     - review the effectiveness of the information security management system;
     - review the level of residual and acceptable risk;
     - conduct internal audits;
     - have the information security management system inspected by the management;
     - record the actions and events affecting the information security management system effectiveness.
4. ACT – improve the process that has worked or correct the errors in an unsuccessful process which means that you should:
   - implement and improve the information security management system;
   - implement the identified improvements;
   - register inconsistencies;
   - take corrective actions.

Hence, we can say that the objective of the information security management system is to ensure the selection of adequate and proportionate controls to protect information assets and ensure trust in the stakeholders.

Attention should be also paid to what information is, where it occurs and what ensures its security. The new ISO 9000 standard (Quality Management Systems – Fundamentals…, 2016) defines a document as information and its medium, and the ISO 27001 standard uses the concept of documented information. Such documented information are:

– all IT systems containing a series of data in various applications located on the firm's servers or in cloud solutions;
– all paper documents used in offices and used by customers, suppliers, employees and the outsourcing personnel, e.g. the accounting office;
– information and knowledge "in people's heads" – knowledge about events, figures, contacts, experience, education – this is the documented information that is most difficult to manage.

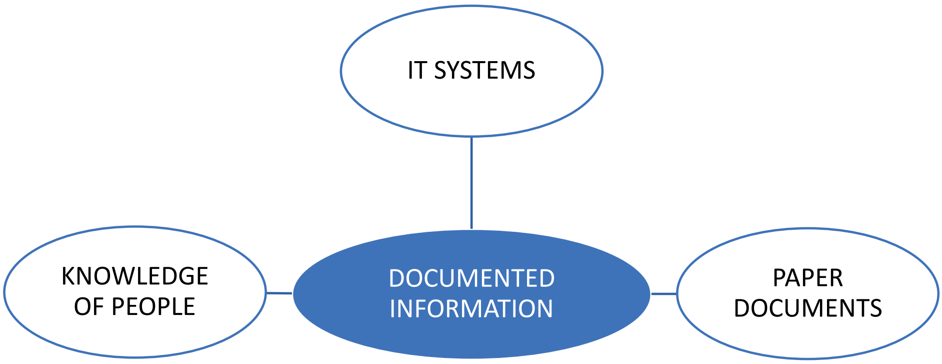

Figure 2. Object components – documented information
Source: (own elaboration)

The notion of the asset must be mentioned in the context of documented information. Information means "assets that unlike other important business assets are necessary for business organization and, in consequence, require an adequate protection (...)" according to PN-ISO/IEC 27000: 2014 (3.2.2) and more precisely "information is significant data" according to PN-EN ISO 9000:2015 (3.7.1). Recapitulating – assets are everything that is of any value for the organization. Hence, the security of documented information – of the assets – has three main attributes: confidentiality, accessibility and integrity. Taking into account the objective, which is to ensure uninterrupted business success and going concern and to minimize the effects, information security consists in applying and managing the adequate security controls, which in turn consists in contemplating a wide range of threats as defined in ISO/IEC 27000:2014 (Information Technology…, 2014).

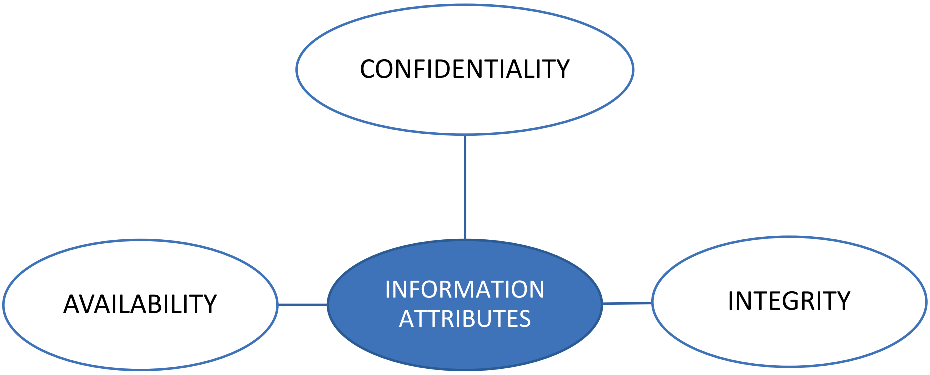

Figure 3. Information attributes
Source: (own elaboration)

To explain, the attributes of information are:

- confidentiality of information – the quality consisting in the fact that information is neither shared with or disclosed to unauthorized persons, entities or processes;
- integrity of information – the quality to ensure the completeness and accuracy of information;
- availability of information – the quality of being available and useful to an authorized entity on demand.

Let us come back to the concept of an information security management system. Once it has been established what information is and what its attributes are, it should be defined what can be done with such data. The task of an organization implementing an information security management system is to define operations or sets of operations performed on the data, including but not limited to collecting, recording, organizing, ordering, storing, adapting or modifying, downloading, browsing, using, disclosing by sending, distributing or otherwise sharing, matching or combining, restricting, deleting or destroying. A premise for an information security management system is that the following rules should be established for the foregoing activities defining: who, what, how, where, when – in respect of ensuring the security of information. And the guidelines on how to effectively protect the system are stipulated in the ISO 27001 standard requirements.

3. Requirements for the information security management system

The requirements for an information security management system are described in detail in PN-EN ISO/IEC 27001:2017-06. Information Technology – Security Techniques – Information Security Management Systems – Requirements. It can be said that this standard consists of two parts, the first part devoted to system solutions and the second part showing the security areas to be applied.

The first part comprises ten chapters which describe the requirements for an information security management system in a systemic manner (like most ISO standards). The requirements are contained, *inter alia*, in clauses related to the scope, normative references, terms and definitions, the context of organization, leadership, planning, support, operational activities, evaluation of performance and improvement. The standard requires that the following actions should be taken: define the scope of the ISMS, define the ISMS policy, develop mechanisms for systematic risk assessment, identify risks, assess risks, identify and assess risk management variants, select objectives and controls, prepare a declaration of application, prepare a plan how to deal with risk, implement controls, define how to measure performance and implement tools for improving the controls, and then repeat these actions regularly as part of risk reassessment.

The above guidelines are supported by the second part of the standard – Annex A, which contains 117 detailed requirements for the application of controls within the information security management system. These requirements apply to:

A.5 Security policy – information security policy document. Review and assessment. The information security policy should be published and provided to all employees of the company. The objective of the policy should be defined and it should be specified how the information will be secured in terms of confidentiality, integrity, accessibility, accountability and lawfulness.

A.6 Organization of information security – information security infrastructure. Information security management forum. Information security coordination. Allocation of information security responsibilities. Authorisation process for information processing facilities. Specialist information security advice. Cooperation between organizations. Independent review of information. Authorisation process for information processing facilities. Cooperation between organizations. Identification of risk related to external parties. Security requirements in agreements with external parties. Security requirements in third party agreements.

A.7 Human resources security – security when defining roles and responsibilities in management of human resources. Conditions of employment. Non-disclosure agreements. User training. Response to security incidents and improper functioning of the system.

A.8 Asset management – inventory of assets. Inventory categories of information assets. Classification guidelines. Information labelling and handling.

A.9 Access control – business requirements for access control. User access management. User responsibilities. Control of access to the system and applications.

A.10 Cryptographic controls – cryptographic security.

A.11 Physical and environmental security – secure areas. Physical security perimeter. Physical entry controls. Securing offices, rooms and facilities. Working in secure areas. Public access, delivery and loading areas. Equipment security. Equipment siting and protection. Supporting utilities. Cabling security. Equipment maintenance. Security of equipment off premises. Secure disposal or re-use of equipment. General controls. Clear desk and clear screen policy. Removal of property.

A.12 Secure operations – operational procedures and responsibilities. Documented operating procedures. Operating change management. Security incident management procedures. Segregation of duties. Separation of development, test and operational facilities. Protection against malicious code. Controls against malicious code. Recording and monitoring of events. Control of operational software. Information systems audit considerations.

A.13 Security of communications – network security management. Transmission of information.

A.14 Systems acquisition, development and maintenance – security requirements of information systems. Security requirements analysis and specification. Security of application services in public networks. Protection of application services. Security in development and support processes. Test data. Test data protection. Input data validation. Control of internal processing message authentication.

A.15. Information security in relations with suppliers – policy of information security in relations with suppliers. Management of services provided by suppliers.

A.16 Information security incident management – responsibilities and procedures. Reporting incidents. Reporting security weaknesses. Assessment of events. Response to incidents. Lessons learned. Collection of evidence.

A.17 Business continuity management – aspects of business continuity management. Business continuity management process. Business continuity and risk assessment. Developing and implementing business continuity plans. Business continuity planning framework. Testing, maintaining and reassessing business continuity plans.

A.18 Compliance – compliance with legal requirements. Intellectual property rights. Securing documents. Data protection and privacy of personal information. Prevention of misuse of information processing facilities. Regulation of cryptographic controls. Collection of evidence. Review of security policy and technical compliance. Compliance with security policies. Technical compliance checking. Information system audit controls and tools. Information system audit controls. Protection of information system audit tools.

Nevertheless, it should be remembered that excluding any requirements included under any clause of the standard is not possible if the organization declares compliance with this international standard. Any exclusion of controls considered as required should be justified and evidence should be provided that the associated risks have been accepted by authorized individuals. If exclusions have been made, the compliance with the standard is declared when such exclusions do not affect the organization's ability to ensure information security and the responsibility for doing so.

4. Effects of implementing an information security management systems in transport sector organizations

At the time of implementation, training and audit works, research was conducted with respect to adapting the requirements of the information security management standard in transport industry enterprises. The following results confirm that the implementation of such a system is not easy, nonetheless, it significantly increases the security of information in the organization.

The information security management system having been implemented in transport companies, the awareness of employees and managers with respect to the identification of legal requirements, application of legal and normative requirements in the organization and awareness as to the consequences of disclosure or loss of data, etc. increased significantly.

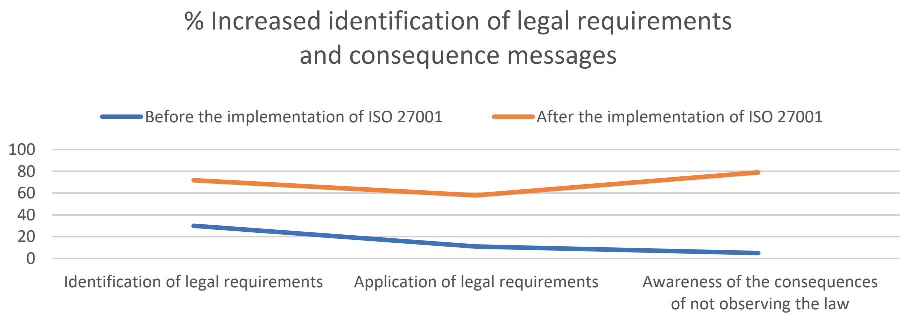

Figure 4. Awareness of legal requirements in organizations before and after implementation of ISO 27001
Source: (own elaboration)

Control over documents and assets having been implemented, the level of documenting transport operations, particularly in respect of documenting the provided information increased significantly and the same applies to the level of documenting actions aimed at controlling the data security system which to a large extent has translated into the employee awareness in respect of the importance and significance of the provided information.

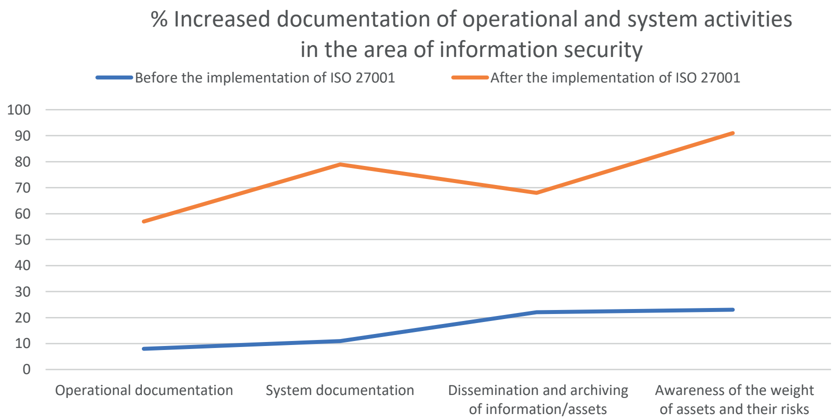

Figure 5. Awareness concerning documenting operational and system activities in the area of information security before and after implementation of ISO 27001
Source: (own elaboration)

Having familiarized themselves with the requirements of the standard, transport entrepreneurs started to pay significant attention to the surrounding risks and established risk identification and documentation methods.

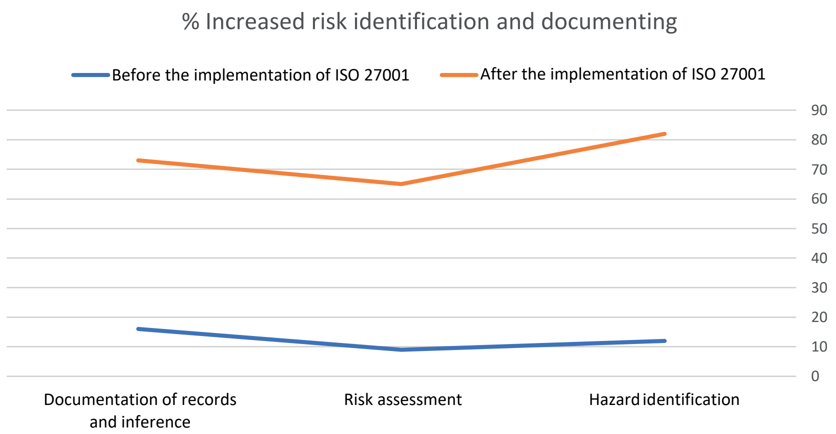

Figure 6. Awareness of risk identification and documentation before and after implementation of ISO 27001
Source: (own elaboration)

Having conducted risk analysis and risk assessment, managers of transport enterprises considerably formalized the rights and responsibilities in respect of information security. Moreover, several time-related and financial outlays were made to build appropriate awareness of employees in respect of information security management system operations.

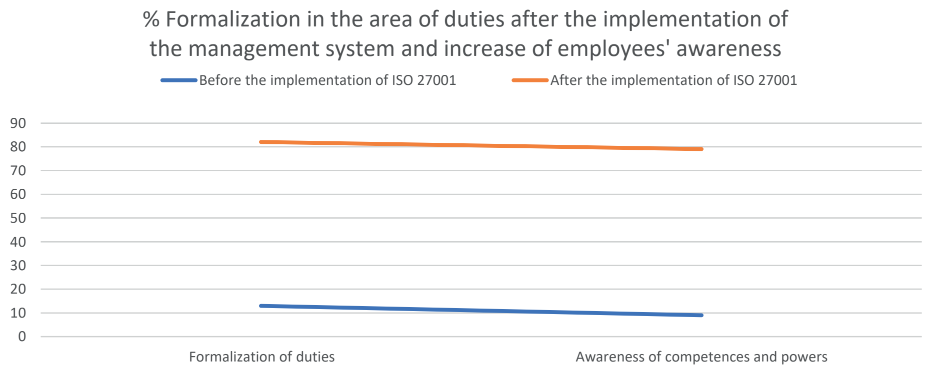

Figure 7. Relation in the area of competence and awareness before and after implementation of ISO 27001
Source: (own elaboration)

When the data control policies had been implemented in transport firms, the identification and recording of data losses or potential data losses increased significantly.

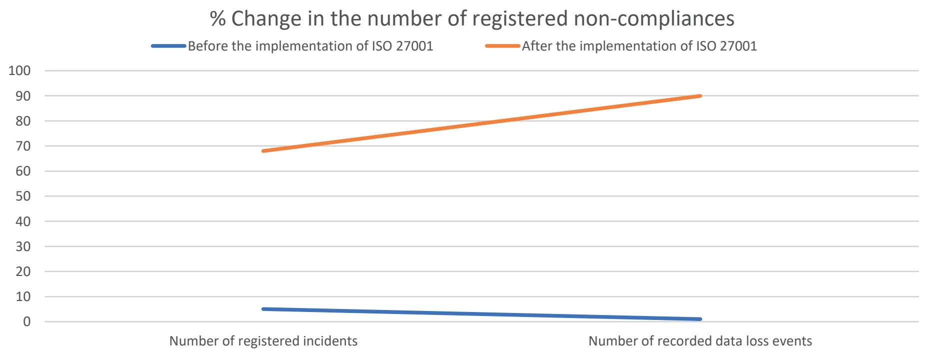

Figure 8. Recording of incidents and data loss events before and after implementation of ISO 27001
Source: (own elaboration)

Before the system was implemented there had been no resource planning activities to secure data in transport companies. It was only when the information security standard requirements had been complied with that planning and predicting financial and other resources to ensure data security started.

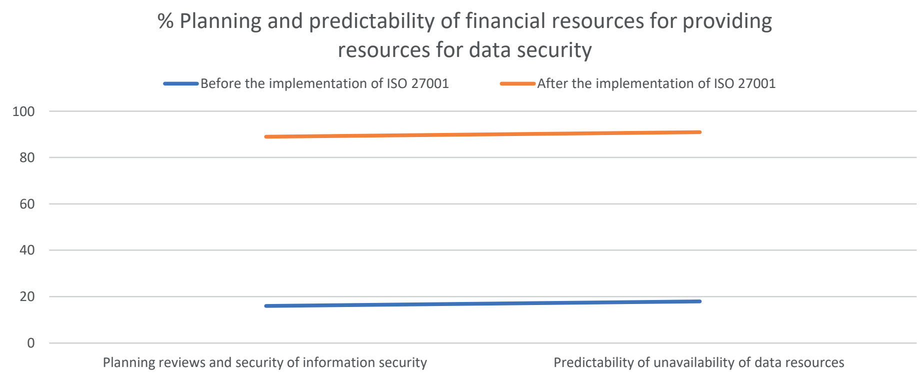

Figure 9. Planning and predicting financial resources for the provision of resources and information security system operation before and after the implementation of ISO 27001
Source: (own elaboration)

Conclusions

Observing the surveyed organizations it can be said that implementing an information security management system changes organizations to a very large extent. The awareness of the importance of data and the willingness to protect it are growing significantly.

Transport enterprises implementing such a system often pinpoint the difficulties in its implementation. The most frequently indicated obstacles include: difficulties in interpreting the requirements of the ISO/IEC 27001:2017 standard, problems in developing a risk assessment model and difficulties in risk management, a vast number of procedures and instructions regulating the data management procedures, the formal system requirements, the expenditures for security which often are not low, high commitment of all the personnel and the specialist knowledge which is lacking in transport enterprises, wherefore it has to be procured and purchased.

Nevertheless, it should be noted that the surveyed enterprises show great appreciation for the implemented system and often emphasize that "it is worth the cost incurred in terms of money and time".

The literature on the subject, the standards supporting ISO 27001 and the practice of transport organizations that have implemented the information security management system show that the implemented system develops the company and strengthens security. Efficient safeguarding of information in the organization by implementing adequate controls prevents information loss. Possible financial and image losses are also reduced by preventing and minimizing the frequency of leakage of confidential information to the outside. Effectively implemented systems prevent breaches of law due to unauthorized use of information and ensure compliance with the legal requirements.

Recapitulating, the aim of implementing and certifying the ISO 27001 system in the transport industry is to give credibility to the organization and improve its image as a secure, reliable and modern business partner, which increases the competitive advantage.

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RISK MANAGEMENT IN SMES

Abstract

Risk management is a process concerning not only large organizations, but also enterprises belonging to the SME sector. When this process is managed effectively, it is possible to eliminate the greatest and most frequent disturbances and also appropriately respond to the occurring changes and use the available opportunities. The activity of the SME sector and the impact of the risk management process on the competitive position of these enterprises increasingly gain significant importance. Therefore, it is worth considering how to help these enterprises to overcome the difficulties which they encounter. The article presents the results of the research conducted on enterprises from the SME sector and operating in the Silesian Voivodeship, using a research survey. The research concerned the application of risk management in these enterprises and the way of documenting it.

Keywords: SMEs, small and medium-sized enterprises, risk management
JEL: D81

Introduction

The contemporary market forces enterprises, especially those from the SME sector, rapidly and flexibly adapt to the changing demand conditions, and also to reduce the costs of manufacture (Saniuk, Saniuk, 2016). The SME sector is characterized by great flexibility in adapting to the market needs. For this reason, it is important to form the proper conditions for the operation and development of the SME sector. It should be remembered that the activity of SMEs is affected by many different macroeconomic and microeconomic factors, which may be both a stimulus and an inhibitor for their development (Fic, Jędrzejczak-Gas, 2005). The significance of this sector is emphasised in the literature, most of all in terms of unemployment reduction. The SME sector is also expected to play a priority role in overcoming the economic slowdown (Soininen et al., 2012).

Risk management is a process concerning not only large organizations, but also enterprises belonging to the SME sector. When this process is managed effectively, it is possible to eliminate the greatest and most frequent disturbances and also appropriately respond to the occurring changes and to use the available opportunities. Both large and small enterprises often face similar problems, with the only difference that a large entrepreneur should develop and implement an entire system supporting the management of the organization, while a small entrepreneur may find it sufficient to adapt the basic elements of methodology and understand the basics of its operation (Spiżyk, 2015). Unfortunately, risk management is practically absent in the SME sector, and in most cases the managers/entrepreneurs do not manage it in a formalized and orderly manner, but usually on an *ad hoc* basis, depending on individual courage, knowledge or skills (Spiżyk, 2015). It is hard to make SME owners aware that risk management can be adapted, with some limitations, to their needs, as SME entrepreneurs benefit from various forms of support (training, consulting) to a limited extent and their activities in this respect are chiefly of an intuitive nature (Safin, 2003). Unfortunately, such situation is not favourable for SMEs, most of which already operate on the global market, competing (often unconsciously) on a daily basis with foreign companies which have been improving both their theoretical knowledge and practical risk management solutions for a long time to limit the negative effects (or use them as a chance that a specific risk will faced by a competitor). Failing to see risk may result in the inability to carry out the planned actions, while on the other hand, exaggerating such risk or being ignorant as to the possibility of controlling it may discourage them from taking up pro-development actions (Stawasz, Ropęga, 2014).

Identification and risk assessment for planned investments is already a standard for many large enterprises, however, in the case of SMEs many decisions are still made on the basis of the owner's intuition or the so-called good practices. The overwhelming number of SME enterprises do not use risk management systems, they do not have clearly defined goals, strategies, structures, which means that these enterprises make decisions in an *ad hoc* and very flexible way, focusing on current operations and staying on the market (Łobejko, 2008). This applies to both the scope of activity and the quality of products and services offered. These companies perceive risk as a negative phenomenon, so they focus on defense and risk minimization. The company's risk management process should include a coherent strategy and a set of procedures tailored to specific recycling activities. It is important that risk is not treated as a threat only, but also as an opportunity, according to the theory of an active approach to risk.

Notwithstanding the wide-ranging international discussion, the issues related to risk management in the organization are discussed in Poland to an insufficient extent, which can be seen particularly in the business practice. Looking at the global practices we realize that risk management has currently become an integral component of business activities undertaken by enterprises (Gorzeń-Mitka, 2011).

The article presents the results of the research conducted in 593 SMEs operating in the Silesian Voivodeship. The research concerned the implementation of risk management in the SME sector and the way of documenting it in these enterprises.

1. The use of risk management in SMEs operating in the Silesian Voivodeship

The literature on the subject highlights the importance of the SME sector (Soininen et al., 2012), which currently plays an important role in developing the national economy. Its development is determined by numerous internal and external factors (Czerwińska-Lubszczyk, Michna, 2013). SMEs often operate in market niches and in markets with a fairly small potential of growth. They are characterized by greater flexibility than large enterprises wherefore they can respond much quicker to changes in the environment, e.g. changing the customer needs (Mikołajczyk, Krawczyk, 2007).

SME classifications are based on quantitative, qualitative and mixed criteria. The quantitative criteria are: the employment size, the balance sheet total, the annual sales, the value of fixed assets (Safin, 2003). Medium-sized enterprises employ fewer than 249 people on a yearly average, and the annual net sales of goods and services and income from financial operations do not exceed the Polish zloty equivalent of 50 million euros. Small enterprises employ fewer than 50 employees, their annual sales do not exceed 10 million euros. On the other hand, microenterprises employ fewer than 10 people, and their annual sales do not exceed 2 million euros (Act on the Freedom of Economic Activity of 2 July 2004).

In Poland, the vast majority, namely, as many as 99.8% of the SMEs are small and medium-sized businesses employing approximately 70.1% of all employees in the market sector and generating approximately 48.5% of the GDP. The smallest enterprises in this group generate almost every third zloty (29.7%). The share of medium-sized enterprises is three times smaller (11.0%) than microenterprises, and the share of small-sized enterprises is almost four times smaller (7.8%) (Zadura-Lichota, Tarnawa, 2014).

The Report on the conditions of the SME sector in Poland (2014) shows that there were over 212 000 active enterprises in 2014 in the Silesian Voivodeship, i.e. almost 5,000 more than in the preceding year. They account for almost 12% of the active business entities in the country compared to the preceding year. In 2014, both small, medium-sized and large companies in the Silesian Voivodeship had a comparable share on the nationwide scale, oscillating around 13%. On the other hand, the share of microenterprises was less than 12% nationwide.

According to the research conducted by the Gdańsk Institute for Market Economics in cooperation with Konrad Adenauer Stiftung (Tarkowski, 2015) the Silesian Voivodeship is the most attractive region for potential investors in Poland. In 2014 (Nowicki, 2014) the Silesian Voivodeship was assessed to be a leader in seven categories in terms of attractiveness understood as the ability to incite investments, in particular, by offering benefits resulting from the location that can be achieved while conducting business activities. The categories included: the availability of transport, the cost of labour, the volume and quality of labour resources, the market sales capacity, the level of development of the economic and social infrastructure, the level of economic development, the level of general safety (Nowicki, 2014; Tarkowski, 2015). It should be highlighted at this point that the Silesian Voivodeship hip also takes the second place in Poland, following the Mazowieckie Voivodeship, in generating the gross domestic product accounting for approx. 2.5% thereof (GUS, 2015).

The presented deliberations prompted the author to research SMEs operating in the Silesian Voivodeship.

2. Scope, objectives, progress and results of quantitative research

Owing to an in-depth analysis of the literature it was possible to prepare a research questionnaire, which was divided into two parts: Part I – Respondent's Particulars and Part II – Risk Management in the Enterprise. The questionnaire contained closed-ended questions where the respondent could offer his/her own answers as well as semi-open-ended and open-ended questions.

The developed research tool was addressed to persons occupying various positions in the organizational hierarchy of the surveyed enterprises. Therefore, questionnaires were completed both by the management staff and employees who were not representatives of the organization's management.

The questionnaires were sent out to 950 small and medium-sized enterprises operating in the Silesian Voivodeship. 650 questionnaires were returned, of which 593 were taken into account.

Having in mind the EU definition of the SME sector categorization, 275, i.e. 46% of all of the surveyed enterprises were classified as medium-sized; 252, i.e. 43% as small enterprises, and 66%, i.e. 11% as microenterprises. The classification of the surveyed enterprises is presented in Table 1 and in Figure 1.

Table 1. Classification of enterprises by employment, annual income and total assets

Description	Number	Aggregate number	Percentage	Aggregate percentage
Categorization of enterprises of the number of employees				
Enterprises with up to 9 employees	66	66	11	11
Enterprises with 10 to 50 employees	252	318	43	54
Enterprises with 51 to 250 employees	275	593	46	100
Categorization of enterprises by annual income				
Enterprises with annual income of up to EUR 2M	66	66	11	11
Enterprises with annual income of EUR 2M to 10M	252	318	43	54
Enterprises with annual income of EUR 10M to 50M	275	593	46	100

Description	Number	Aggregate number	Percentage	Aggregate percentage
Categorization of enterprises by total assets				
Enterprises with total assets of up to EUR 2M	66	66	11	11
Enterprises with total assets of EUR 2M to 10M	252	318	43	54
Enterprises with total assets of EUR 10M to 50M	275	593	46	100

Source: (own elaboration)

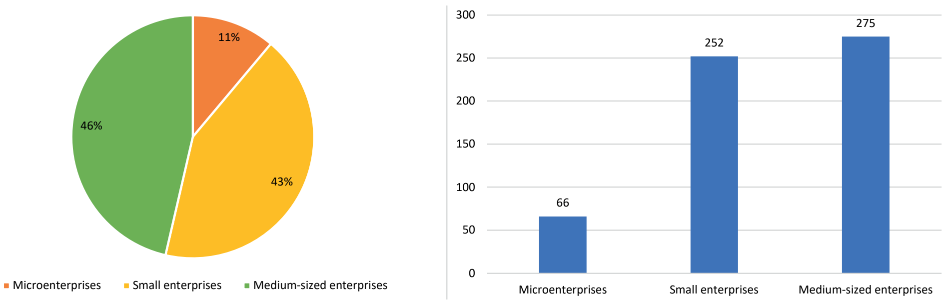

Figure 1. Classification of enterprises by the number of employees and sales
Source: (own elaboration)

550 (93%) of the surveyed enterprises conducted manufacturing activities, 22 (4%) provided services, 13 (2%) were involved with trading activities, and 8 (1%) conducted other business, including, but not limited to manufacturing, commercial activities, services, training, as illustrated in Figure 2.

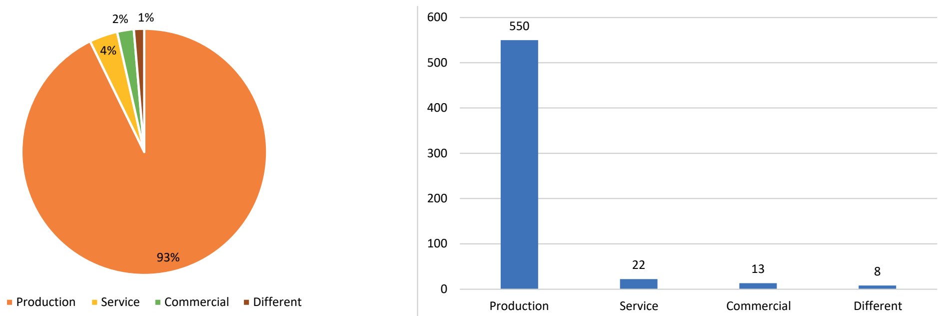

Figure 2. Classification of enterprises by type of business
Source: (own elaboration)

The question whether a risk management system was in place in the enterprise was answered in the negative by the majority, i.e. 419 (71%). 73 (12%) of the surveyed enterprises had on opinion on the subject, 57 (10%) declared that risk management was in place. The results are presented in Figure 3 and in Table 2.

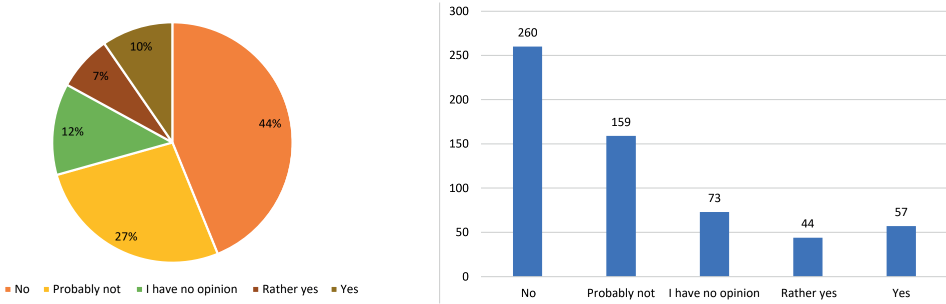

Figure 3. Application of risk management in the surveyed enterprises
Source: (own elaboration)

Table 2. Application of risk management in the surveyed enterprises

Type of enterprise	Is there a risk management system in place in the enterprise?					
	No	Probably not	I have no opinion	Rather yes	Yes	Total
Micro	36	18	8	2	2	66
	55%	27%	12%	3%	3%	100%
Small	110	70	31	17	24	252
	44%	28%	12%	7%	10%	100%
Medium-sized	114	71	34	25	31	275
	41%	26%	12%	9%	11%	100%

Source: (own elaboration)

The majority of the enterprises declaring to use risk management are medium-sized business – 56. These are followed by 41 (17%) of small enterprises and 4 (6%) of microenterprises that have such a system in place.

Bearing in mind the foregoing it can be observed that risk management in the SMEs operating in the Silesian Voivodeship is relatively rare. Risk management is much more often used by medium-sized enterprises than by small and micro businesses. Hence, the reason why risk management in this sector is applied to such a small extent is not the lack of knowledge about this process, but the specificity of such businesses and their limited resources.

In 72 (71%) out of the 101 enterprises declaring to have a risk management system in place it was the managerial staff that was indicated as responsible for this process. In 22 (22%) cases, a dedicated business unit was indicated, and in 7 (7%) cases designated individuals from specific business units were named. The results in this respect are presented in Table 3.

Table 3. Division of responsibility for risk management in SMEs

Type of enterprise	Who is responsible for the risk management process?					
	Managers	Designated business unit	Designated individuals from specific business units	I do not know	Another person	Total
Micro	4	0	0	0	0	4
	100%	0%	0%	0%	0%	100%
Small	29	12	0	0	0	41
	71%	29%	0%	0%	0%	100%
Medium-sized	36	15	5	0	0	56
	64%	27%	9%	0%	0%	100%

Source: (own elaboration)

Moreover, in enterprises declaring to have risk management in place, in answer to the question how the risk management process in an enterprise was documented, 62 (61%) persons said that it was not documented, 22 (22%) persons mentioned a risk analysis sheet, and 17 (17%) persons pointed out to the risk map. The results are presented Table 4.

Table 4. Manner of documenting the risk management process

Type of enterprise	How is the risk management process documented in the enterprise?					
	Not documented	Risk analysis sheet	Risk map	Computer program for risk analysis	Other	Total
Micro	4	0	0	0	0	4
	100%	0%	0%	0%	0%	100%
Small	35	0	6	0	0	41
	85%	0%	15%	0%	0%	100%
Medium-sized	23	22	11	0	0	56
	41%	39%	20%	0%	0%	100%

Source: (own elaboration)

It is hard not to see that the risk management process is documented mostly in medium-sized enterprises, then in small businesses. However, no documentation of the risk management process is prepared in microenterprises. The reason for this may be the usually low financial (or organizational) capacities or too much reliance on one's own intuition (the decision making process is not supported by industry or specialist reports).

On the basis of the obtained results, four basic conclusions can be drawn:

- risk management is not commonly used in the SMEs operating in the Silesian Voivodeship;
- the use of risk management increases with the size of the enterprise;
- it is the managers who are mostly responsible for risk management;

– the risk management process is documented to a greater extent with the increasing size of the enterprise.

It seems that the reason for the scarce use of risk management by SMEs may be the lack of an appropriate practical model. This would constitute a basis for further research in this area.

Conclusions

The importance of the SME sector and the impact of the risk management process on the competitive position of these enterprises increasingly gain significant importance. Therefore, it is worth considering how to help these enterprises to overcome the difficulties which they encounter.

In the economic reality of today, risk management becomes a prerequisite for effective operation of enterprises on the market. Risk management is focused on the entire enterprise and on efficient and effective support of the implementation of the developed strategy and on capturing these signals which indicate the need to modify objectives, financial flows, programmes and results.

The conducted research shows that risk management in SMEs based in the Silesian Voivodeship is relatively rare. Risk management is much more often used by medium-sized enterprises than by small and micro businesses. It can be said that the reason why risk management in this sector is used to such a small extent is not the lack of knowledge about this process, but the specificity of such businesses and their limited resources. The business practice shows that small and medium-sized enterprises have difficulties in implementing and maintaining the risk management process in place.

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WAREHOUSE AND TRANSPORT PROCESSES BASED ON THE EXAMPLE OF A SELECTED ENTERPRISE FROM THE ELECTRICAL INSTALLATION INDUSTRY

Abstract

This article presents the course of warehouse and transport processes on the example of a selected enterprise from the electrical installation industry. The warehouse infrastructure – finished goods warehouse, technical means of manipulation and storage devices were characterized. The analysis of the storage process was performed using a map of processes and indicators for warehouse management, for warehouse and technical performance indicators. The second part of the article deals with the analysis of the transport process. The enterprise's own transport was compared with the possibility of outsourcing this service. The transport process was also analyzed using the mapping and indicator methods. Thus, this article uses such methods as analysis, process mapping and indicators to diagnose the analyzed processes. The article also presents further research directions.

Keywords: warehouse and transport processes, process map, logistic indicators
JEL: L91, M10, O10

Introduction

Both warehousing and transport are important processes in the distribution of products (Dyczkowska, 2014). The movement of products between specific links in the logistics chain always involves the need to hold these products in certain places and for a certain period of time. The organization of all activities related to this process is among the most important components of logistics as it significantly affects the efficiency of flows of goods. This is related to the number and type of operations in the order picking area, i.e. the warehouse capacity which is measured by the number of cargoes received and issued per year. The transport process is generally considered as a key factor in distribution (Bendkowski, Kramarz, 2011). This process which is carried out using means of transport is divided into the following phases: conceptual preparation of movement, preparation of cargo for transport, organization of the process of carriage, the physical movement of cargo, handling of the process in legal and financial terms and cost analysis and transport process evaluation.

Companies performing at least some of the transport-related operations using their own resources usually have a special dedicated unit (a separate department or an organizational unit) for this purpose. The resources of this unit make up the transport base. This base includes not only the means of transport and people responsible for their use, but also all resources for loading, unloading and handling of goods as well as equipment supporting documentation and information processes. The purpose of this article is to analyze the warehouse and transport processes of a selected enterprise from the electrical installation industry.

The warehouse infrastructure – a finished goods warehouse, the technical means of manipulation and storage devices are characterized. The analysis of the storage process was performed using a map of processes and indicators for warehouse management, for the warehouse and technical performance indicators. The second part of the article deals with the analysis of the transport process. The enterprise's own transport was compared with the possibility of outsourcing this service. The transport process was also analyzed using the mapping method as well as the index method (quantitative and qualitative indicators, e.g. transport costs per km or transport reliability). Thus, this article uses such methods as analysis, process mapping and indicators to diagnose the analyzed processes. The process mapping method allows the presentation of subsequent process activities at the assumed level of detail and identification of all resources supplied to the process. Logistic indicators help to control processes. The results of these indicators allow obtaining a picture of the company's condition and introducing changes that improve its functioning (Miłaszewicz, Wengel, 2015). Process indicators support the analysis as they help understand what is happening inside them (Dohn, 2006). As with streamlining and reorganizing processes, if we do not know where we are, we will not get where we want to be. Indicators specify the goals and responsibilities, facilitate focusing on key activities, and are the basis for reasonable judgments.

This article poses the following questions: What characterizes the process of storage and transport of products in the electrical installation industry? How does the analyzed entity implement these processes and how does it control them? Is it possible to improve these processes?

1. Warehouse process description

The warehouse process comprises all activities consisting in picking and packing of products for each order. Alternative solutions related to the delivery may be reflected in the course of specific activities and in the costs. As far as standard orders are concerned the time to fill an order in the analyzed company is from

several up to 36 hours. The sales department issues an invoice and a goods issue document (a goods issue note) using a computer. Goods issue notes are grouped on the basis of transport routes and directions to reach recipients. The information is forwarded to the sales unit in the shipping department. Having received a goods issue note, the warehouse worker analyzes it in terms of the volume of ordered goods and whether pallets should be used or not. Not every shipment needs pallets. If batches are small, or when a customer handles the transport on his own and specifies in the order that pallets should not be used, the warehouse worker assembles goods on a warehouse trolley. However, in most cases orders are on pallets. The order picking activities include:
– picking up goods from the storage area and transporting to the loading area;
– depalletizing;
– palletizing shipping pallets and protection of pallets, i.e. wrapping in foil to prevent movement of goods.

Then, the complete order in the form of shipment is delivered to the loading ramp. When the goods are issued and loaded onto the means of transport it is checked if the actual quantity of goods is the same as the quantity stated in the goods issue documents. The carrier confirms receipt of the goods on the goods issue note. This document with a copy of the invoice are archived in a unit of the Finished Goods Warehouse. From the moment of loading to the moment goods are delivered to a customer the responsibility for the order fulfilment lies with the carrier.

1.1. Warehouse infrastructure

Operations related to the picking and issue of goods require that various technical measures are used to ensure that these operations are carried out effectively. These measures make up the infrastructure of warehouse processes. In the analyzed company which has high production volumes, this infrastructure is very complex and includes many components. These are in particular:
– the warehouse building;
– technical manipulation equipment;
– warehouse equipment.

The finished products warehouse

The enterprise has a finished products warehouse which is a steel building with the usable height h = 700 cm. The building comprises a one-storey warehouse section and a two-storey back section. The overall dimensions are the following:
– development area – 709.20 m^2;
– usable area – 619.42 m^2;
– cubic space – 5607.00 m^3.

Technical manipulation equipment

The firm uses technical and transport equipment in the warehouse processes related to order picking. These include:
– a high lift truck – designed for storing and transporting (at short distances) all kinds of goods on pallets, in boxes, etc.;

– pallet trucks – suitable for horizontal transport, at low heights, of cargoes placed on euro pallets, non-standard pallets, stands and in containers;
– hand pallet trucks with hydraulic lifting – necessary for loading and unloading operations;
– hand trolleys – where the trolley handrail can be folded which makes it easier to transport loads;
– a travelling ladder with extension of up to 4 m.

Warehouse equipment

The main warehouse of the enterprise is equipped with APR 12 high storage racks which are used for storing inventory in the form of pallet unit loads. The maximum shelf capacity is 885 pallet spaces. Owing to the high storage racks it is possible to use the storage space in a highly effective way and store inventory at five storage levels:
– level one is used for storing products in smaller unit loads – unit or bulk packaging;
– levels: two, three, four and five are used for storing palletized products.

1.2. Warehouse process analysis

The warehouse process analysis was conducted on the basis of: the process mapping method and the indicator analysis.

The activities comprising the storage process are presented in the process map (Figure 1).

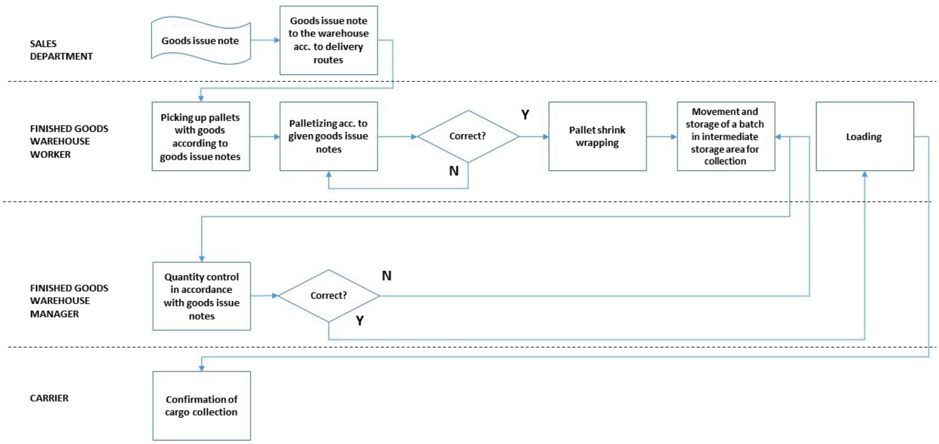

Figure 1. Warehousing process – process map
Source: (own elaboration based on information provided by the enterprise)

The warehouse process analysis shows a very significant problem related to determining the size of inventory. The software used by the company does not have the function of inventory and procurement management. Workers do not make any calculations concerning the optimal stock levels, nor do they set the safety stock or the optimum delivery batch. As the entire warehousing process is overseen by the marketing department staff, it is necessary to add additional modules to the software.

The indicator analysis of the warehousing process uses variables which are measured in the analyzed enterprise throughout the accounting period, as well as at certain selected points of time. The variables are used to construct indicators to evaluate the warehouse process. These figures are presented in Table 1.

Table 1. Warehouse process measures

Warehouse process variables	Measurement in time (year)
Value of inventory	PLN 9150156.12
Orders processed immediately	15650
Orders processed within 48 hours	13870
Warehouse area	619.42 m^2
Cubic space	5607.00 m^3
Storage capacity in unit loads	885 pallet spaces

Source: (own elaboration based on information provided by the enterprise)

The following indicators were used to analyze the warehouse process (Twaróg, 2003): warehouse management indicators, warehouse indicators, technical performance indicators.

Warehouse management indicators

Meeting the demand projection:

$$\frac{\text{actual demand}}{\text{projected demand}} \times 100\% = \frac{3\,807\,666}{3\,400\,000} \times 100\% = 111.99\%$$

Indicator of orders accepted for processing to all orders incoming in the analyzed period:

$$\frac{\text{accepted orders}}{\text{total orders}} \times 100 = \frac{15\,630}{15\,650} \times 100\% = 99.87\%$$

Indicator of fulfilled orders to all accepted orders:

$$\frac{\text{fulfilled orders}}{\text{accepted orders}} \times 100\% = \frac{15\,630}{15\,630} \times 100\% = 100\%$$

Warehouse indicators

Warehouse use rate:

$$\frac{\text{occupied pallet spaces}}{\text{total spaces}} \times 100\% = \frac{880}{885} \times 100\% = 99.44\%$$

Usable area effectiveness:

$$\frac{\text{usable area}}{\text{storage capacity in inventory units}} \times 100 = \frac{619.42}{885} \times 100 = 0.72\ \text{m}^2/\text{pallet}$$

Warehouse usable cubic space effectiveness:

$$\frac{\text{cubic space used}}{\text{storage capacity in inventory units}} \times 100 = \frac{5607{,}00}{885} \times 100 = 6.33\ \text{m}^3/\text{pallet}$$

Technical performance indicators

Indicator of storage space technical equipment:

$$\frac{\text{value of warehouse technical equipment}}{\text{usable storage capacity}} \times 100 = \frac{150\,000}{5607} \times 100 = \text{PLN } 26.75/\text{m}^3$$

Indicator of means of transport for storage space:

$$\frac{\text{value of warehouse means of transport}}{\text{warehouse usable cubic space effectiveness}} \times 100 = \frac{120\,000}{5607} \times 100 = \text{PLN } 21.40/\text{m}^3$$

The results in the category evaluating the warehouse management seem to be of particular importance in this case. Attention should be paid most of all to the high values of the following indicators:

– fulfilled orders – at the level of 100%. This indicator shows that the operations related to the order picking are correct and with no errors. It is due to the checking system in place in the warehouse and the competence of employees;
– warehouse use rate – 99.44%. This indicator shows to what extent the warehouse space is used for finished products.

On such basis the following conclusions can be drawn:

– the quantity of finished products in the warehouse is large. The enterprise intending to increase the capacity in the future, or to increase the inventory, will have to invest to enlarge the existing storage space or build a new warehouse;
– cash blocked in the inventory of finished products is of high value.

Table 2. Warehouse process measures – summary table

Indicator	Indicator value	Standards
Warehouse management indicators		
Meeting the demand forecast	111.99%	90%
Orders accepted to fill to total orders	99.87%	90%
Orders filled to orders accepted	100%	95%
Warehouse indicators		
Warehouse use rate	99.44%	80%
Usable area effectiveness	0.70 m^2 / pallet	–
Warehouse usable cubic space effectiveness	6.33 m^2 / pallet	–
Technical performance indicators		
Storage space technical equipment	PLN 26.75/m^3	–
Means of transport for storage space	PLN 21.40/m^3	–

Source: (own elaboration based on information provided by the enterprise)

2. Transport process description

The analyzed enterprise delivers its products by using:

- its own vehicle fleet which includes vehicles of the following types:
  - Volkswagen Transporter – 2 vehicles;
  - Lublin – 2 vehicles;
- regular carriers with which the enterprise enters into contracts for transport services;
- customer transport.

A transport service to deliver a product to the customer is initiated by the Shipping Unit dispatcher on the basis of a "delivery order" received from the marketing department. The order having been received, the dispatcher records it in a special register. The register includes – similarly as in the case of registration of inquiries or orders – such basic information as:

- date on which a request for quotation is received;
- name of the customer;
- date and place of delivery.

Then, the dispatcher analyzes the order in terms of how it can be executed. This activity includes:

- checking the delivery date set by the customer – usually orders are carried out in two ways:
  - immediately – if received by 12.00;
  - on the next day after receipt of the order – if received after 12.00;
- checking how large the order is in terms of quantity.

2.1. Shipping

Having analyzed the document, the dispatcher decides what means of transport to select. It should be noted at this point that the shipping department worker can only choose between the enterprise's own transport and transport companies. In situations where the customer decides to pick up the purchased products himself, the marketing department worker bypasses the shipping department and transfers the order directly to the sales department.

Transport companies

At the present time, the enterprise uses the services of DHL Express under a commercial contract. The procedure to select the appropriate carrier that could take over some of the enterprise's transport services was very careful. When making decisions to select the transport operator, the enterprise is guided by the following criteria:

- required knowledge and technical experience;
- ensured continuity of deliveries;
- financial problems;
- liability for losses;
- reputation of the supplier;
- price;

– quality and method of quality control;
– time of performance;
– storage problems;
– legal issues.

The management expected that the logistics operator would most of all help achieve such goals as reduction of logistics costs and improving the enterprise's competitive position. In the course of negotiations, a commercial contract was executed between the enterprise and the logistics operator, DHL Express.

The carrier's tasks stipulated in the contract include:
– carriage of goods;
– protection of cargo against damage in transit;
– loading and unloading of goods;
– the carrier's liability for the consigned cargo.

Own transport

As the number of delivery vans is small the share of the enterprise's own transport is at the level of 35% and 65% is outsourced using specialized transport companies. The dispatcher decides to use the enterprise's own transport when:
– the processed order will ensure a full load of the vehicle in terms of quantity and volume;
– the place of delivery is within a distance of approx. 100 km from the enterprise's site;
– several smaller orders are addressed to the same destination or a close place at the same time.

The dispatcher's work affects the efficiency of the whole physical distribution process. The accurate organization of vehicle routes guarantees that:
– the distribution costs are minimized;
– orders are executed on a 48-hour basis;
– less equipment and fewer people are needed to execute all orders;
– the customer satisfaction level is higher owing to the rapid processing of an order.

2.2. Delivery

Where the enterprise's own transport is chosen, the dispatcher requests the appropriate vehicle and issues a transport order document. Such order is confirmed by the driver's signature. However, if the dispatcher decides to commission a carrier to perform the service, he/she confirms the order himself/herself, at the same time requiring a warehouse worker should confirm a waybill which is the basis for settlement of the work of DHL Express drivers. Based on the documents received from the dispatcher, the driver collects the products and executes the transport order. When the order is carried out by the logistics operator, the responsibility for the quality of the product in transit rests with the carrier.

Transport process analysis

Similarly to the storage process, the transport process analysis was conducted on the basis of the process mapping method and the indicator analysis. The activities comprising the transport process are presented in the process map (Figure 2).

The transport process analysis using the mapping method showed issues related to providing the dispatcher with information about the actual delivery volume. This issue had already been outlined earlier with the analysis of the customer service process. The dispatcher's task could be facilitated, if a tool that is used by logistics operators, the so-called price calculator were developed. While making a decision to use the services of a private carrier, the dispatcher could calculate the cost of the service offered by the operator in a short time.

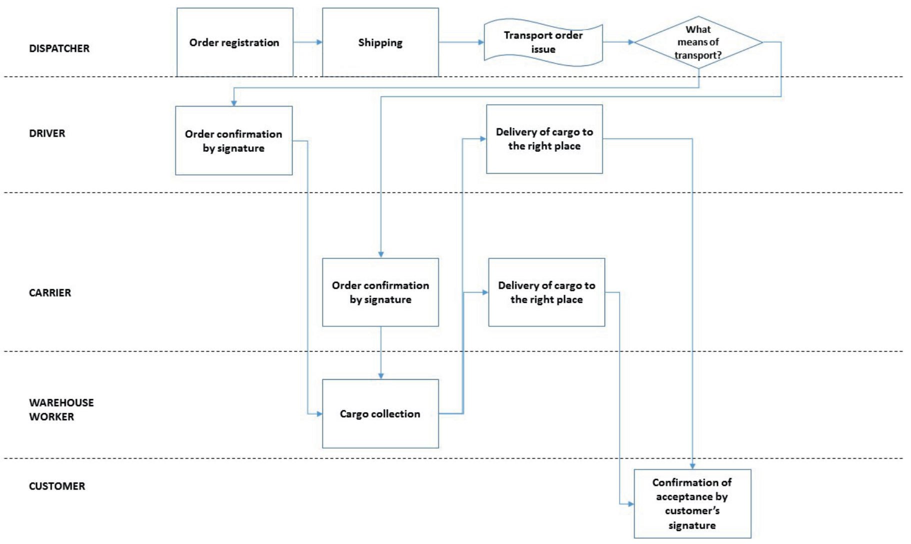

Figure 2. Transport process map
Source: (own elaboration based on information provided by the enterprise)

Transport process indicator analysis

The indicator analysis of the transport process uses variables shown in Table 3. The variables include figures that are measured throughout the accounting period as well as at selected points of time. Most variables are recorded and settled in the enterprise's Controlling Department.

Table 3. Transport process measures

Transport process variables	Measurement in time (year)
The number of kilometres travelled	35053.0 km
Number of transport workers, including: – day pay workers – drivers – white-collar workers	7 6 1
Nominal working time	11520 h
Used working time	5007.63 h
Transport costs	PLN 266405.80
Number of shipments	15630

Source: (own elaboration based on information provided by the enterprise)

The following indicators are used in the transport process analysis (Twaróg, 2003): quantitative indicators, qualitative indicators.
Quantitative indicators – transport cost per kilometre:

$$\frac{\text{cost of transport}}{\text{kilometres}} \times 100 = \frac{266\,405.80}{350\,534.00} \times 100 = 0.76 \text{ zł/km}$$

Quantitative indicators – transport cost per shipment:

$$\frac{\text{cost of transport}}{\text{cost of shipments}} \times 100 = \frac{266\,405.80}{15\,630} \times 100 = \text{PLN } 17.05\text{/pcs}$$

Quantitative indicators – use of working time:

$$\frac{\text{use of working time}}{\text{nominal working time}} \times 100 = \frac{5007.63}{11\,520} \times 100 = 43.47\%$$

Qualitative indicators – transport reliability:

$$\frac{\text{transport tasks completed on time}}{\text{total transport tasks}} \times 100 = \frac{15\,310}{15\,630} \times 100 = 97.95\%$$

Qualitative indicators – transport flexibility:

$$\frac{\text{transport requirements fulfilled}}{\text{total requirements}} \times 100 = \frac{1680}{1720} \times 100 = 97.67\%$$

Table 4. Transport process measures – summary table

Indicator	Indicator value	Standards
Quantitative indicators		
Transport cost per kilometre	PLN 0.76 zł/km	0.71
Transport cost per shipment	PLN 17.05/shipment	–
Use of working time	43.47%	100%
Qualitative indicators		
Transport reliability	99.44%	99%
Transport flexibility	0.70 m^2/pallet	–

Source: (own elaboration based on information provided by the enterprise)

The results obtained when performing the indicator analysis reflect a good appraisal of the company in terms of accomplishing transport tasks related to the transport of finished products to the customer. Most of the orders are processed on the same day and the remaining ones within the contractual 48 hours. The indicator concerning the information on the use of working time may become a starting point for analysis of a possible reduction of the number of employees in the transport department. However, the low value of this indicator results from the nature of the work of drivers who are instructed to take on other tasks when there are no transport orders. The indicators concerning reliability and flexibility, which are at the level of 98%, demonstrate the high quality of the transport processes conducted by the analyzed company.

The use of the process mapping method and indicators made it possible to draw conclusions as to the effectiveness of logistics activities carried out in the company. By answering the questions asked, it can be stated that these processes are implemented smoothly in the company. It could be done for the analyzed processes, e.g. value stream maps, in order to find possible sources of waste in these processes. Separate processes responsible for the physical distribution of finished products and their assessment in terms of the criteria: time, quality and cost can become an area of further research. Namely, it can be examined how distribution logistics processes (transport and storage) affect the profitability of an enterprise. Distribution processes include at least several types of activities (order processing, storage, handling and transport). Each of these activities is very important for the company's financial standing. Often, the quality of logistics processes determines which market segment manages to master a given company, effectively displacing competitors. Similarly, the efficiency of logistics processes, especially in the sphere of distribution, can be a direct factor in increasing revenues from the sale of products, goods and services. Logistics processes are therefore closely related to the volume of revenues obtained from the company's activities, as well as the costs that are incurred in this respect.

Conclusions

Distribution processes consist in at least several types of activities, including processing of orders, storage, handling, manipulation and transport. Each of these activities is very important for the financial situation of an enterprise. The quality of logistics processes often determines which market segment can be won by a given company effectively driving competitors out. Similarly, the efficiency of logistics processes, particularly in the area of distribution, may be a direct factor in increasing revenues from sale of products, goods and services. Generating revenues and costs of the enterprise logistics processes directly affect profitability of the business. All the advantages of the organization can be efficiently and effectively used when logistics processes are realistically embedded in the operations of the enterprise. Hence, if the process is to be formed correctly, it would require first of all to take into account the opportunities arising from the organization of work, the knowledge and skills of contractors, as well as proper selection of contractors for the anticipated tasks and the careful observation of the environment in which the process is to be implemented.

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THE ROLE OF RAILWAY INFRASTRUCTURE IN SERVICING FREIGHT AND PASSENGER TRANSPORT IN AGGLOMERATION – ON THE EXAMPLE OF POZNAŃ

Abstract

An appropriate infrastructure is required to efficiently meet the mobility needs of citizens and the needs of business in the implementation of transport processes. This infrastructure must be taken care of by local authorities and other entities. Hence, the role of local government cannot be overestimated in this respect. The development of the rail transport infrastructure should not lag behind the development and changing needs of the city. Adequate development of the railway infrastructure makes it possible to increase the competitiveness of rail transport in cities and agglomerations, both in respect of passenger and freight transport.

The article examines the current state of the railway transport infrastructure in the city of Poznań and in the Poznań agglomeration, paying attention to the potential of its use in the above mentioned transport groups. The aim of the author is to indicate the problems faced by the city today and the directions of railway infrastructure development in the city.

Keywords: city logistics, rail transport, rail infrastructure

JEL: R41

Introduction

Problems of modern cities are inseparably connected with the challenges of proper organization of transport. Progressive urbanization makes it possible both in the area of passenger and freight transport in cities. This makes this issue extremely topical and, as cities and agglomerations develop, the search for new solutions and the promotion of good practices plays an increasingly important role. "The population living in cities is growing day by day and consequently, urban areas are expanding. On the one hand, technology development such as e-commerce offers new services which increase end-customer expectations, for instance, same-day delivery. On the other hand, satisfying all citizens' needs requires enormous resources and infrastructure deployment as well as efficient planning and managerial efforts which are extremely costly" (Neghabadi et al., 2018, p. 866).

1. Freight transport infrastructure and vision of urban development

The issue of cargo and passenger transport remains one of the important challenges of city management. Nowadays, efficient transport is not the basis of a high quality of life, being just one of the key elements in assessing how urban centres function. "The selected problems of efficient and effective movement of people and cargo have long been present in the theory of strategic management of local development and in real urban development strategies" (Kiba-Janiak, Witkowski, 2014, p. 164). "Increasing traffic within limited city space leads to negative effects in terms of emissions and congestion. Here, city logistics service providers compete against other road users for the scarce traffic space, which cannot be extended unlimitedly" (Ehmke, 2012, p. 12).

Decisions on the choice of the city logistics model are more and more often the effect of the influence of private entities, including "The overview of the stakeholders represented in the city logistics models suggests that representation of various stakeholders in modelling has increased over the period with more models considering decisions by the private stakeholders such shippers, carriers and receivers" (Anand et al., 2015, p. 711).

Over the years, cities have undergone obvious transformations. Occupying about 1% of the planet's surface area, cities are responsible for the consumption of about 75% of energy and the emission of about 80% of greenhouse gases. Half of the world's population lives in cities today, which raises the question of how to organise procurement and logistics processes in cities. The fastest growing cities double their population in a decade, which means additional challenges. The demographic change, but also transport problems are the reasons why the city is becoming an area where many problems meet at the same time (Bretzke, Barkawi, 2013).

One of the key elements determining the efficiency of both passenger and freight transport remains an adequate infrastructure base. "Efficient movement within the city area is impossible without an appropriate transport infrastructure, both linear and point-based. This infrastructure is organically linked to the urban tissue. Its shape and parameters have a decisive influence on how movements within the city are carried out and is an element limiting the range of possible logistics solutions" (Szołtysek, 2016, p. 78).

The transport infrastructure, combined with the organization of transport at an appropriate organizational level, allows skilful development of the city, and the effect is a constant increase in the quality of life of its inhabitants. "Intelligent, sustainable development of the city takes place with respect to the existing resources or through their modification, as a result of which the living conditions of the inhabitants and the functioning of other stakeholder groups in the city in its urbanised space are improved" (Nowicka, 2014, p. 3).

It should be taken into consideration that the city is a system, a system of connected points and parts. The individual subsystems of this system cannot be considered independently of each other. When analysing the problems of transport in a city, all its subsystems should be taken into account, in particular with regard to different groups of users or types of transport. It should also be remembered that cooperation between urban and regional self-government is necessary in many aspects because, although it is a city, it is the voivodeship government that may have the right to decide on the railway transport issues.

Efficient transport drives the economic development of the city, agglomeration, region. "The economic dimension of urban development has a general reference. It transports itself to other urban realities. The condition of companies located in the city and its prospects are among the most important factors of development. Current barriers to the development of Polish cities seem to confirm this. (…). The emphasis on the development of social infrastructure without constant attention to the economic dimension of the city's existence seems to be a mistake on the part of authorities of many cities. In this context, investment in the technical infrastructure is particularly justified when it contributes to the activation of the urban economic activity and, above all, that which creates the economic base of the city" (Czornik, 2008, p. 115). The arguments about the "economic dimension" of the transport policy seem to be valid especially for freight transport. It is here, apart from the urban function, that a clear function related to the management of resources by private entities using these services appears.

Rail transport does not have to compete with the urban transport system. "The world practice shows that the development of transport links in the agglomeration should be taken by transforming "commuter train" into "Stadtbahn" – "city train", as a full part of the intercity transportation system. Railway lines should be the "overground metro" by which passengers must be evenly distributed on the territory of the city" (Morozova et al., 2016, p. 116).

2. Rail transport in strategic documents of the Poznań City Hall

Transport issues have been present in the strategic documents of the Poznań City Hall for many years. "In order for a transport system to work efficiently, it must be coherent and structured. Therefore, on 18 November 1999 the Poznań City Council signed the Transport Policy of the City of Poznań" (UMP, 2018). Already in the first paragraph of the Vote on Transport Policy (UMP, 1999), attention was drawn to the "fundamental role of transport for the proper development and efficient functioning of the City" (UMP, 1999, p. 1) and its metropolitan functions.

The specific policy objectives include "maintenance and reconstruction of the transport infrastructure", "stimulating the economic and spatial development of the city"; or "reduction of noise, exhaust emissions, congestion inconveniences (…)". Obviously, in principle, the list of objectives consists of a large number of items, but those listed are the closest to the challenge of organizing the transport of goods within the city. While passenger transport by rail in the city and agglomeration is an increasingly important topic, freight transport is much less researched.

The Transport Policy of the City of Poznań (UMP, 1999) outlined, *inter alia*, the development objectives in the area of freight transport in a multi-branch system indicating:

- "creation of a logistics system offering comprehensive services, including not only basic transport, but also: loading and unloading, delivery and transport operations, storage and warehousing, as well as accompanying services such as sorting and processing of goods, distribution, control, sanitary and documentary services;
- organising combined transport, which in the agglomeration of Poznań should include rail/road and possible river shipping;
- offering door-to-door express services within a guaranteed period of time with specialised rolling stock adapted to the nature of the load;
- improving the quality of freight transport, also with a view to reducing the traffic on roads, especially in inner-city areas" (UMP, 1999, p. 4).

Subsequent stages of the transport policy included legal regulations dedicated to particular transport subsystems of the city. Thus, dedicated documents devoted to the issues of public transport, bicycle, parking or road policy were adopted. Importantly, there are no documents directly related to the issue discussed in this publication. Neither freight transport within a city or agglomeration nor rail transport have been the subject of a dedicated "policy" document. Therefore, the only guidelines for both rail transport and the organisation of freight transport at the city or agglomeration level, are the general documents relating to the areas in question. Table 1 provides an overview of the previously mentioned transport policy supporting documents.

Table 1. Supporting documents for the UMP Transport Policy

Document	Signature date
Sustainable Public Transport Development Plan for 2007–2015 (Poznań Metropolitan Area)	24 October 2006
Cycling Programme of the City of Poznań	15 January 2008
Parking Policy of the City of Poznań	10 June 2008
Road Programme of the City of Poznań for the years 2008–2015	16 September 2008

Source: (UMP, 2018)

The transport policy is not the only document defining the directions of transport development. Attention should also be paid to the regulation of the document called "Study on the Conditions and Directions of Spatial Development of the City of Poznań" from 2008. In this documents it is written that: "The need to upgrade the existing rail network, consisting of main, primary and secondary lines, including stations and stops, is recognized". In addition, "it is considered advisable to use railway space for the operation of other means of rail transport, including the possibility of introducing a dual system vehicle (rail-tram), taking into account the link between suburban areas and the city centre" (MPU, 2008, pp. 59–60).

Sections of this Study indicate the directions which the development of the infrastructure dedicated to freight transport should take. "It is assumed that railway sidings are integrally connected with the serviced industrial and service areas, and the justification for their construction, maintenance or possible liquidation should result from the railway priorities related to the necessity of their use, as well as from the possibility of fulfilling all the principles set out in the Acts, this "Study…" and government guidelines. Under these conditions, it is possible to locate new railway sidings. The sidings that need to be liquidated because of the development of the street and rail network are listed in the table" (MPU, 2008, p. 60).

These records come from the 2008 Study. Six years later, by the decision of the City Council of Poznań, on 23 September 2014 Resolution No. LXXII/1137/VI/2014 was signed, with an updated, new version of the Study. Both the 2008 Study and the 2014 Study identified specific areas in the city that should take part in the development of freight services. "The basic terminal Poznań-Franowo, potential satellite terminals: Poznań Wola, Poznań Golęcin, Poznań Antoninek and other terminals: Poznań Wschód, Poznań Starołęka, Poznań Krzesiny, Poznań Górczyn, Poznań Strzeszyn are envisaged for cargo transport" write the authors of the earlier Study (MPU, 2008, p. 60).

"The basic terminal Poznań-Franowo is planned for cargo transport, potential satellite terminals may be: Poznań Wschód, Poznań Górczyn, Poznań Piątkowo, Poznań Koziegłowy, and other terminals: Poznań Krzesiny, Poznań Starołęka, Poznań Antoninek, Poznań Wola, Kiekrz" (MPU, 2014, p. 89) – such locations were indicated in the current Study (2014). In principle, the indicated locations are similar, which shows that these areas have been selected consciously and have the potential to be used for the purposes indicated.

3. Use of rail for urban transport – challenges and examples

In the literature on this topic, the concepts of the use of freight transport include, but are not limited to, possibilities of adaptation of the railway transport infrastructure to passenger transport, development of solutions such as urban railway (like the German S-Bahn railway system) or dual-system tram networks. The number of publications devoted to freight transport is much lower.

Obviously this does not mean that freight transport within the city and agglomeration does not have much potential. There are many opportunities here, both with the use of the rail transport infrastructure and, for example, the tram infrastructure. This is a multithreaded issue and there are many challenges here. "Rail freight transport in the city area faces a number of problems due to technical, legal and organisational reasons. This transport can be based on the use of classic railway wagons, logistics platforms and freight trams. Linking all technical means of transport requires a solution to the issues of organisational compatibility and cargo standardization" (Lewandowski, 2004, p. 51).

In the 1980s, the railway transport infrastructure in the City of Poznań comprised several dozen facilities in total. The number of these is gradually decreasing. At present, regular liquidation of railway transport infrastructure elements used for cargo handling, in particular railway sidings, can be observed in the city area. In the last twenty years, railway sidings for industrial plants in the Podolany area (including the former Officer School, later the Land Forces Training Centre, numerous industrial plants in the vicinity of Jasielska Street or the siding along Podolańska Street, which was in operation several years ago) have been dismantled. The siding at the Poznań Strzeszyn railway station was liquidated along with the current upgrading of Railway Line No. 354.

The noteworthy examples of sidings liquidated in recent years include not only sidings in the north-western part of the city, in the area of Podolany and Strzeszyn, but also, for example, the siding of the Poznań International Fair (Międzynarodowe Targi Poznańskie – MTP). It was disconnected from the railway network (and then liquidated) around 2012, along with the construction of a tram route, the so-called Poznań Fast Tram (Poznański Szybki Tramwaj – PST). The PST new tram section has been included in the city network in the place where the tramway route crossed the rail track leading to MTP.

4. Railway infrastructure in the city and agglomeration

Currently, the infrastructure of sidings in the City and Agglomeration counts, according to the data of the Railway Transport Authority, 30 sidings (UTK, 2019b). There is a clear correlation between the location and the main railway routes passing through the City. Many facilities are located along Railway Line No. 3 (Warszawa Zachodnia – Kunowice) and Railway Line No. 352 (Poznań Starołęka – Swarzędz), i.e. routes constituting: an axis on the east-west line and a link allowing freight trains to bypass the city centre, respectively. On Line 352 there are also railway facilities of the city's hinterland, located in Franowo (the Franowo station is the largest freight station in the region, equipped, *inter alia*, with a shunting hill, where a container terminal operated by PKP Cargo is also located). The detailed location of the sidings is presented in Figure 1. Table 2 presents the list of sidings, together with their users and detailed location. In Table 3 these sidings are divided according to the railway line number in the vicinity of which they are located.

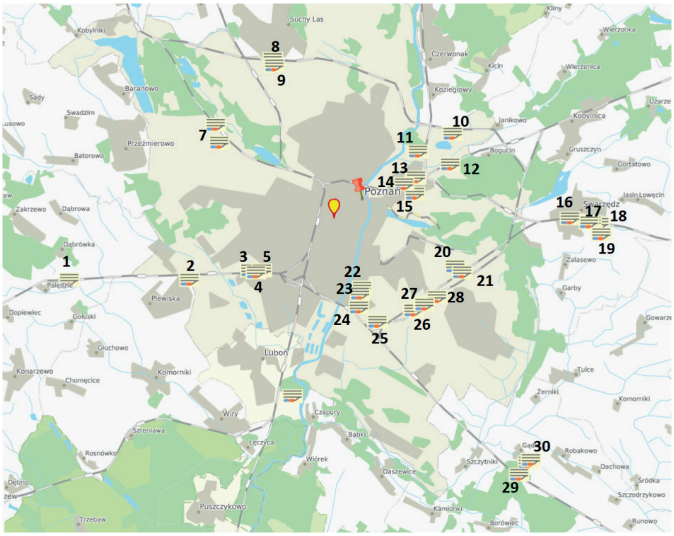

Figure 1. Freight sidings in the city of Poznań and the Poznań agglomeration – location
Source: (own elaboration based on: UTK, 2019b)

Table 2. Freight sidings in the city of Poznań and the Poznań agglomeration – users

No.	User	Location	Railway line no.
1	COLAS KRUSZYWA SP. Z O.O.	Palędzie	Palędzie Station, from Track No. 12, Switch No. 22, Railway Line No. 3, at km 318,419
2	Syndyk Masy Upadłości FEROCO S.A. w upadłości likwidacyjnej	Poznań Górczyn	Poznań Górczyn Station, from Track No. 2, Switch No. 45, Railway Line No. 3, at km 312,232
3	Grupa LOTOS S.A. Zakład w Poznaniu	Poznań Górczyn	Poznań Górczyn Station, from Track No. 4b, Switch No. 200, Railway Line No. 3, at km 309,853
4	LOTOS KOLEJ SP. Z O.O.	Poznań Górczyn	Poznań Górczyn Station, from Track No. 4b, Switch No. 17, Railway Line No. 3, at km 309,692
5	LOTOS TERMINALE S.A.	Poznań Górczyn	Poznań Górczyn Station, from Track No. 4b, Switch No. 200, Railway Line No. 3, at km 309,853
6	LUVENA S.A.	Luboń k. Poznania	Luboń Station, from Track No. 3, Switch No. 2, Railway Line No. 357, at km 110,998
7*	THYSSENKRUPP ENERGOSTAL S.A.	Poznań Wola	Poznań Wola Station, from Track No. 10, Switch No. 10, Railway Line No. 351, at km 6,994
8	GÓRAŻDŻE CEMENT S.A.	Poznań Piątkowo	Track Group No. 1 – Delivery G: Poznań Piątkowo Station, from Track No. 4, Switch No. 6, Railway Line No. 395, at km 13,577 and Switch No. 23, at km 14,357
9	GÓRAŻDŻE CEMENT S.A.	Poznań Piątkowo	Track Group No. 2 – internal company siding, from Track No. 16, Switch No. 101, Railway Line No. 395, at km 14,629

No.	User	Location	Railway line no.
10	Dalkia Poznań Zespół Elektrociepłowni S.A. / EC II Karolin Dalkia Poznań ZEC S.A.	Koziegłowy	Koziegłowy Station, from Track No. 12, Switch No. 26, at km 4,252 and Track No. 20, Switch No. 21, at km 4,117, Railway Line No. 395
11	Centrozłom Wrocław S.A. Oddział Poznań	Poznań Wschód	Poznań Wschód Station, from Track No. 107, Switch No. 801, Railway Line No. 356, at km 1,054
12	CEMBRIT S.A.	Poznań Wschód – Skandawa	From Station Track No. 7, Switch No. 13, Railway Line No. 353, at km 9,650
13	VOLKSWAGEN GROUP POLSKA SP. Z O.O.	Poznań Wschód	Poznań Wschód Station, from Track No. 22, Switch No. 122, Railway Line No. 3, at km 299,157
14	MARIUSZ GRYGIER M.M.-TRANS / MARCIN GRYGIER „M.M.-TRANS"v	Poznań Wschód	Poznań Wschód Station, from Track No. 20, Switch No. 131, Railway Line No. 3, at km 299,593
15	Kulczyk Tradex Sp. z o.o.	Poznań Wschód	From the access Track No. 301 of Poznań Wschód Station, Switch No. 401
16	Centrum Logistyczno Inwestycyjne Poznań II Sp. z o.o.	Swarzędz	Swarzędz Station, from station Track No. 6b, Switch No. 6, Railway Line No. 3, at km 291,017
17	STENA RECYCLING Sp. z o.o.	Swarzędz	Swarzędz Station, from Track No. 6a, Switch No. 7, Railway Line No. 3, at km 290,997
18	Terminal LPG w Swarzędzu	Swarzędz	From Track No. 251, Switch No. 301, at km 0,107 of PKP CARGOTOR Sp. z o.o. siding (which starts from Swarzędz Station: Track No. 6, Switch No. 6, Railway Line No. 3, at km 291,618)
19	STS Centrum Dystrybucji Samochodów Sp. z o.o.	Swarzędz	From CLIP II siding, Switch No. 301 from Track No. 251, at km 281,755, Switch No. 300 from Track No. 206, at km 289,721 and Derail No. 401 from Track No. 400, at km 289,643, Railway Line No. 3
20	KOMPANIA PIWOWARSKA S.A.	Poznań Franowo	From Track No. 1, Switch No. 951, Railway Line No. 352, at km 0,627
21	PKP CARGO S.A.	Poznań Franowo	From Track No. 403, Switch No. 775 and from Track No. 402, Switch No. 774, Railway Line No. 822, at km 1,783
22	LUVENA S.A.	Luboń k. Poznania	From Track No. 3, Switch No. 2, Railway Line No. 357, at km 110,998
23	„Al Pari" – Piotr Ostrowski, Elżbieta Pieprzycka Sp. j.	Poznań Starołęka	From Track No. 17a, Switch No. 851, Railway Line No. 272, at km 195,304
24	„DRAPOL" Sp. z o.o.	Poznań Starołęka	From Track No. 17, Switch No. 30, Railway Line No. 272, at km 0,634
25	LAFARGE Kruszywa i Beton Sp. z o.o	Poznań Franowo	From Track No. 321, Switch No. 444, Railway Line No. 352, at km 8,371
26	PKP CARGO S.A.	Poznań Franowo	From Track No. 521, Switch No. 524, Railway Line No. 352, at km 7,080

No.	User	Location	Railway line no.
27	MARIUSZ GRYGIER M.M.-TRANS / MARCIN GRYGIER „M.M.-TRANS"	Poznań Franowo	From Track No. 1, Switch No. 512, Railway Line No. 806, at km 0,150
28	PKP Cargo Connect Sp. z o.o.	Poznań Franowo	From Track No. 521, Switch No. 524, Railway Line No. 352, at km 7,080
29	HHLA Intermodal Polska Sp. z o.o.	Gądki	From Track No. 5, Switch No. 22 ab/cd, Railway Line No. 272, at km 185,529
30*	Elewarr Sp. z o.o. Oddział Regionalny w Gądkach	Gądki	From Track No. 5, Switch No. 12, Railway Line No. 272, at km 184,637

* on the map provided by UTK, the siding is marked with a pictogram twice, in the list it is placed once.
Source: (own elaboration based on: UTK, 2019b)

Table 3. Freight sidings in the city of Poznań and the Poznań agglomeration – by line

Railway line	Route	Number of sidings	Siding numbers (as listed above)
3	Warszawa Zachodnia – Kunowice	12	1–5, 13–19
272	Kluczbork – Poznań	4	23–24, 29–30
351	Poznań Główny – Szczecin Główny	1	7
352	Swarzędz – Poznań Starołęka	4	20, 25–26, 28
353	Poznań Wschód – Skandawa	1	12
356	Poznań Wschód – Bydgoszcz Główna	4	11
357	Sulechów – Luboń	2	6, 22
395	Zieliniec – Kiekrz	3	8–10
806	Poznań Franowo PFD – Nowa Wieś Poznańska	1	27
823	Poznań Franowo PFD – Stary Młyn	1	21

Source: (own elaboration based on: UTK, 2019b)

The sidings are not the only infrastructure components used for handling loads in the agglomeration. In Poznań, there is also potential for the implementation of the so-called "dry port", the concept of an intermodal logistics hub, as an intermediate link between the seaport and the target customers. This concept is particularly interesting today, when the intermodal transport market is constantly evolving. "The Poznań agglomeration has great potential for the implementation of the dry port concept, as it has the economic and logistics potential to become one of the main nodes of the national intermodal logistics network" (Andrzejewski, Fechner, 2014, p. 11). Andrzejewski and Fechner draw attention to the characteristics of the Poznań agglomeration, which create the potential for the construction of the "dry port", such as its attractive geographical location, its location in terms of logistics in the transport corridor of the TEN-T network, the variety of a logistics infrastructure (line infrastructure, including rail infrastructure saturation, as well as roads of different categories), the potential for intermodal transport services, the supply of warehouse space or cargo transport services provided by the Poznań airport (2014).

The development of intermodal transport is one of the interesting directions for the development of rail freight transport, not only in terms of transit, but also in relation to the needs of the city and agglomeration.

The Railway Transport Authority in its lists currently indicates four main intermodal terminals located in the agglomeration, owned (operated by) CLIP Logistics Sp. z o.o., Loconi Intermodal S.A., PKP CARGO CONNECT Sp. z o.o. and Polzug Intermodal Polska Sp. z o.o. The Ostsped Intermodal terminal, located in Szamotuły, next to Railway Line 351 (UTK, 2019b) should also be mentioned among the facilities of this type. Detailed parameters of these terminals are presented in Table 4.

Table 4. Intermodal terminals in the city of Poznań and the Poznań agglomeration

Name	Centrum Logistyczno-Inwestycyjne Poznań II (1)	Loconi Intermodal Terminal Poznań (2)	Terminal Kontenerowy Poznań Franowo (3)	Polzug HUB Terminal Poznań (4)
Location	ul. Rabowicka 51b, 62-020 Swarzędz – Jasin	ul. Nowosolska 40, 60-171 Poznań	ul. Ostrowska 300, 61-312 Poznań	ul. Magazynowa 8, 62-023 Gądki
Owner/operator	Clip Logistics Sp. z o.o.	Loconi Intermodal S.A.	PKP CARGO CONNECT Sp. z o.o.	HHLA / Polzug Intermodal Polska Sp. z o.o.
Mode of transport to be handled	Rail, road	Rail, road	Rail, road	Rail, road
Supported logistics units	Containers, swap bodies, intermodal semi-trailers	Containers 20′, 30′, 40′, 45′, HC	Large containers 20′, 30′, 40′, 45′, HC, swap bodies, semi-trailers, tank containers, isothermal units	Containers (20′–40′ / 40′ HC / 45′ / TC), swap bodies, semi-trailers
Railway line: Railway Line No.	E-20	Poznań – Rudnicze	Poznań Franowo Station, from Railway Line No. 521	Gądki Station, from Railway Line No. 272
Total area (ha)	10 ha	1.6 ha	2.8 ha	16 ha
Maximum transhipment capacity (TEU)	135 000 TEU	40 000 TEU	117 000 TEU	385 400 TEU
Storage area (TEU)	4 500 TEU	1 000 TEU	1 800 TEU	1 500 TEU
Number of railway sidings	1	2	1	1
Number and length of railway tracks for loading and unloading	1 527 m	1 x 350 m	2 x 610 m	4 x 610 m
Total length of railway tracks 1435 mm (m)	4 067 m	600 m	1 419 m	3 050 m
Number of railway cranes	0	0	0	0

Name	Centrum Logistyczno-Inwestycyjne Poznań II (1)	Loconi Intermodal Terminal Poznań (2)	Terminal Kontenerowy Poznań Franowo (3)	Polzug HUB Terminal Poznań (4)
Lifting and handling vehicles	5	4	3	6
Parking spaces for trucks	600	0	5	16

Source: (UTK, 2019a)

The location of the four terminals described above is shown in Figure 2. Intermodal terminals are located under numbers 1–4 and the location of the transshipment station (terminal, shunting hill) Poznań Franowo under number 5.

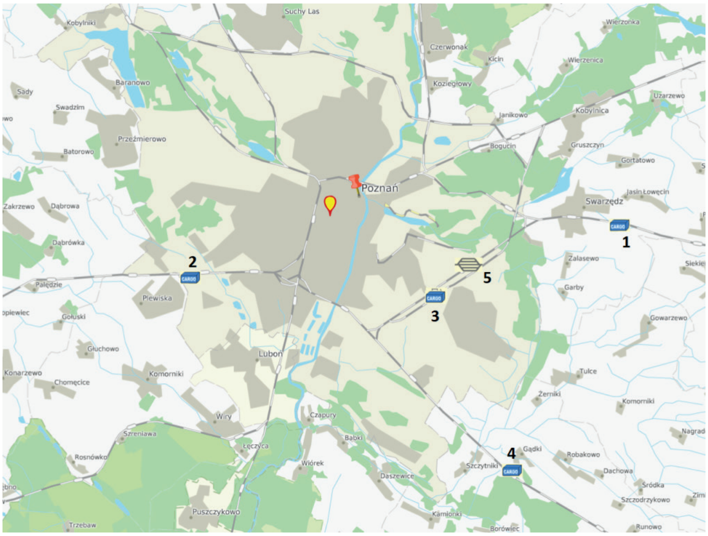

Figure 2. Intermodal terminals in the city of Poznań and the Poznań agglomeration – location
Source: (own elaboration based on: UTK, 2019b)

5. Potential for the use of infrastructure in passenger transport

Although the creation of the agglomeration railway (called the Poznań Metropolitan Railway, [Poznańska Kolej Metropolitalna – PKM]) has been discussed in Poznań for a long time, it is only in recent years that activities in this area have been intensified. "Despite the favourable layout of the network, good technical performance of the routes and high capacity, rail is still underutilised, especially in the city area and its immediate hinterland" (Bul, 2016a, p. 13).

Over the years, the idea has remained in the concept phase, and it is slowly becoming a reality. "The determination of all levels of territorial self-government units to establish the PKM system should be stressed. Activities carried out by the Poznań Metropolis Association are of key importance in this respect. Thanks to the implementation of the "Masterplan for the Poznań Metropolitan Railway" project, it has already been possible to determine the basic parameters of the system and prepare concepts for its operation" (Bul, 2016b, p. 29). The first trains with the PKM logo have already appeared on the routes, although at present we can rather speak of rebranding the already serviced regional routes, and a fully-fledged urban railway system is still in under construction.

The railway infrastructure in the city of Poznań and the Poznań agglomeration offers great potential for use in passenger transport, which is one of the elements of the origin of the PKM project. The following figure (Figure 3) shows a current map of stations and passenger stops used in regular passenger traffic. This figure contains stations in the city of Poznań.

Figure 3. Stations and passenger stops in Poznań – passenger traffic
Source: (ZTM, 2019)

Figure 4. Passenger stations and stops in the agglomeration – passenger traffic
Source: (ZTM, 2019)

The above Figure 4 shows a schematic view of stations and stops operated within the framework of a common railway, tram and bus ticket, within the ZTM Poznań (public transport network operator). In practice, this area is wider than the area commonly considered as an agglomeration, but it may be a valuable comparative material, as it indicates the actual extent of the transport impact within the transport system of the Poznań agglomeration.

It is worth noting the potential for the development of passenger networks, both with the use of the existing infrastructure and new facilities. Two examples are given here.

The Poznań Podolany passenger stop was opened for passenger traffic in 1932. The design of the stop included two platforms, a waiting room building with a ticket office, an inn on the side of the Podolany estate and descent from the platforms on the escarpment. Currently, there is no trace left of the former station, originally named Poznań-Golęcin, and later Poznań-Podolany (Zubielik, 2013). Together with the decision to upgrade Railway Line No. 354, it was also decided to rebuild this stop. The construction of this stop has been in progress since 2017, first of all the platform edge was built on the track in the direction of Piła. In the spring of 2019 the construction of the platform in the direction of Poznań Główny station started. The implementation of the railway upgrading project is also one of the elements of the infrastructure development for the future agglomeration railway. As part of the project, four new stops are built: Poznań Podolany, Poznań / Suchy Las / Os. Grzybowe, Złotkowo and Bogdanowo / Gołaszyn. The first three are located in the area of Poznań, therefore, they will constitute valuable infrastructural support for the Poznań Metropolitan Railway.

This is an example of infrastructure reconstruction (Poznań Podolany) and construction of a new one (Os. Grzybowe and Złotkowo) for the agglomeration railway. "The upgrading of the line between Poznań and Piła is financed under the Regional Operational Programme of the Wielkopolska Region. The net value of the project is about PLN 500 million. The amount of co-financing from the European Union is about PLN 425 million net, i.e. 85% of the task value" (Railway Market, 2017). The current state of progress of works on the construction of the Poznań Podolany passenger stop is presented in Figures 5 and 6.

Another interesting example is the siding of Wojskowe Zakłady Motornizacyjne – WZM (Military Motor Works). "Wojskowe Zakłady Motoryzacyjne S.A. is an enterprise which has been present on the Polish armaments market since 1945. (…) The plant is located on the international A-2 Warsaw – Berlin route, has its own railway siding and is adjacent to the international airport. (…) The basic activity of (…) the plant is the repair and modernization of armoured, tracked and wheeled equipment as well as passenger cars, off-road vehicles, trucks and buses" (WZM, 2019).

Figure 5, 6. Construction of the Poznań Podolany passenger stop, as at 19th October 2017 and 31st March 2019
Source: (own archive)

In 2007, on behalf of the voivodeship (Marshal Office of the Wielkopolska Region in Poznań), the concept of using this siding to service passenger traffic at the Ławica Airport was developed. The route is planned based on the use of the existing Poznań – Szczecin railway line (4.6 km section), the newly designed branch track (1.0 km), the existing railway WZM siding track (0.6 km) and the extension of this siding – the newly designed section of the track towards the airport (3.0 km). A line with a total length of 9.29 km would have four stops in total – two for local traffic and two directly at the airport (UMWW, 2007). Analyses conducted by the local government started a long discussion on the optimal way of organizing the public transport for the Poznań airport. The analysis was based on three basic concepts: access with the use of a railway siding, construction of a tram line or change in the traffic organization on roads and separation of bus lanes (Bojarski, 2007). In the following years bus lanes were separated in selected sections of Bukowska Street (which is an access road to the airport), to this day other concepts (tram, extension of the siding) have remained only in the planning phase.

Conclusions

No railway freight transport management strategy is defined at the level of the city and the agglomeration. The Poznań Metropolitan Railway project is in progress, but there are no system solutions for freight transport. The development of the railway transport infrastructure lags behind changes in the functions of individual areas of the city. At the same time, the needs of the city (conditioned by economic development and increased mobility of residents) require development in this area.

It should be noted that the closure of freight sidings is a natural consequence of the closure of industrial plants. New production, commercial and service facilities (including logistics real estate) are often built at a considerable distance from the rail transport infrastructure and use it to a very limited extent. This worrying phenomenon, together with the reduction in the transport of goods within an agglomeration by rail are the reasons why there is a risk of an increase in congestion and road transport overburdening.

While a regression can rather be observed in the case of freight transport, there is an increase in the importance of railways on the agglomeration map as far as passenger transport is considered. The implemented Poznań Agglomeration Railway project, combined with the purchase of rolling stock and the construction of new stops give hope that the role of the rail transport in providing transport services to the city and the agglomeration will increase in the forthcoming years.

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DEMATEL METHOD IN SUPPLIER EVALUATION AND SELECTION

Abstract

The increasing complexity of supply chains creates a number of areas that need to be optimized. Complicated relations between different actors on various markets indicate the need for simplification of the decision-making process and, at the same time, being focused on the organization's goals and needs. The development of multi-criteria methods of supporting decision making applies in particular to the area of logistics support, including supply management. One of the methods widely used in this field is the DEMATEL method, which is a classical approach to evaluate suppliers according to survey or interview results. The article aims to present the application of the supplier evaluation procedure according to the criteria indicated by the decision-makers as significant. The literature review was used for specifying the variables. Then, the evaluation procedure was presented, followed by an empirical example. The paper can be useful for decision-makers both in single organizations and supply chains to improve their evaluation procedures to meet the requirements about which they care the most.

Keywords: supplier selection, logistics, procurement, supply management

JEL: C61, D22, L14

Introduction

Supply chains evolve all the time, trying to respond to dynamic and hard-to-predict changes on the global market. The growing complexity of the types of their elements and the number and types of relations between them cause emerging new problems in supply chain management, including the supply area (Nazma Sultana et al., 2016). New logistics strategies should be the answer for new obstacles within the material and non-material flows, with special regard to the growing role of information logistics (Weiland, 2018; Wierzbowski, 2018), including the cooperation within information sharing and the Internet of Things (Hsu, Yeh, 2017).

The evolution of those supply chains is the reason why all the functional areas of logistics management need to be continuously improved. One of them is supply management, the procure-to-pay process, as one of the basic logistics processes. A part of the process is supplier selection and evaluation, very much related to the supply strategy. This area will be the main focus of this study.

The aim of the paper is to present the usefulness of the DEMATEL method in supplier selection and evaluation. The study is organized as follows. Firstly, a brief description of the literature review is presented to highlight the main areas of the supplier selection and evaluation process. Additionally, the methods used for calculating the results within those areas are mentioned in this section. The next part presents the variables collected in the review as important for the calculation of the final results, the research procedure and the DEMATEL method itself. In the results section, the implementation of the method is described and the final scores are interpreted. In the last section the paper is concluded, its limitations are indicated, and some possible future research directions are drawn.

1. Supplier selection and evaluation

Supply management is one of the main parts of supply chain management. Suppliers are selected according to previously identified and confirmed criteria, important for decision-makers. For many years this problem has been addressed by a huge amount of academic papers, trying to adjust the statistical and mathematical methods to real decision-making problems (Hald, Ellegaard, 2011). Logistics strategies in this area have been also developed. Within this group, the following should be mentioned: built-to-order, build-to-stock, lean management, agile management, vendor managed inventory, single sourcing, double sourcing, multi-sourcing, just-in-time, just-in-sequence and mixed approaches.

Suppliers play a crucial role in shaping the logistics strategies of single companies and whole supply chains (Shaik, Abdul-Kader, 2018). The postponement strategies and implementation of different types of supplier parks have changed the balance of power in supply chains. Mega-suppliers are often treated as integrators of 1st and 2nd tier suppliers (Szmelter-Jarosz, 2018). Supply selection highly impacts the supply chain relationships, and the score of the supply chain itself (in different fields: effectiveness, efficiency, lead-time, etc.) (Chang et al., 2011).

A basic element of the supplier evaluation is the identification of important variables. They are different in the case of small and medium enterprises (Madoranova, Horvath, 2013; Politis et al., 2010), and big corporations, usually using a wide range of criteria and subcriteria. They are different when creating a new product, developing and improving existing products, and in standard procurement procedures within long-term supplier-customer cooperation (Madoranova, Horvath, 2013). A prevalent approach is to define key performance indicators as goals to be achieved by suppliers (Imeri et al., 2014). A popular approach is multi-attribute decision making (especially in the area of supplier selection) and using multi-criteria methods (Zhan, 2019).

The set of methods used for measuring industrial performance is very wide and includes both qualitative and quantitative ones (Nazma Sultana et al., 2016). The methods most often used in this group for supplier evaluation are the weighted average method, QFD (Quality Function Deployment), regression analysis (Chang et al., 2011), DEMATEL-ANP-VIKOR (Lee et al., 2013; Nazma Sultana et al., 2016; Shaik, Abdul-Kader, 2018), AHP (Politis et al., 2010), ANOVA, the multi-attribute granulation approach (Zhan, 2019), supported by surveys and interviews.

2. Methodology

2.1. Research procedures and variables

The first step to achieve the stated goal of the study was to create a research framework and procedure to clarify the process of obtaining final results (see Figure 1). Firstly, the literature study was conducted to identify the variables which should be analyzed in the further collecting of primary data. This set of criteria was presented to three different teams of people working within the supply area of one company to make the assessment process less biased. This feedback from decision-makers, responsible for contacts with suppliers in their everyday work, was supposed to present only initial use of the selected method and will be developed in future research. The mentioned teams had to assess the relations between variables important for supplier selection and evaluation. Then, according to the method, calculations were carried out to evaluate the results and refine the list of the most important variables (criteria) within the mentioned process.

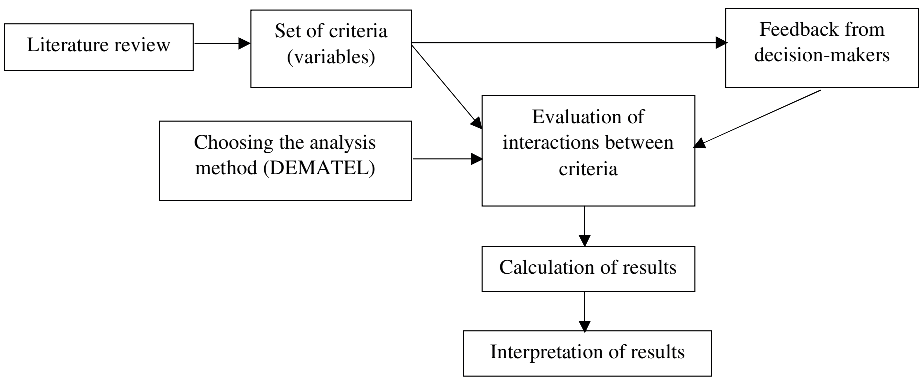

Figure 1. Research framework
Source: (own elaboration)

As mentioned before, the literature review allowed defining a list of important variables which may have an impact on a real assessment of suppliers within supply chain management. Those criteria were described in different literature items, although some appeared in every study, like price conditions, on-time delivery and quality of products (see Table 1).

2.2. DEMATEL method

Multi-criteria decision-making methods help to manage different types of data (qualitative and quantitative) with a large number of criteria and their possible values, high flexibility to take into consideration the preferences of decision-makers. They have value for decision-makers when they are easy to use and understand (Politis et al., 2010). The classical methods for such analyses are AHP, ANP and DEMATEL (Shaik, Abdul-Kader, 2018). Nowadays, those methods in the modified form (fuzzy DEMATEL, hybrid DEMATEL and AHP) are often used to solve decision-making problems, including but not limited to such as TOPSIS MDCM, PROMETHEE, grey DEMATEL (Chang et al., 2011; Govindan, Chaudhuri, 2016; Nazma Sultana et al., 2016; Shaik, Abdul-Kader, 2018). Both method groups enable including many needs of different stakeholders or decision-makers into the analysis.

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) is a method best suited for analyzing the interrelationship and interdependencies by neglecting the sample size limitation (Govindan, Chaudhuri, 2016). Therefore, it is good for a small number of respondents or, sometimes, groups of respondents (for example project teams). First used for social problems research in 1973 (Gabus, Fontela, 1973), with time, it has become a classical method for multi-criteria analysis in economic science. Its main benefit is the possibility to identify the core driving factors of a specific problem based on interactions and relationships between the criteria specified for the specific problem (Morauszki, Attila, 2015; Torbacki, 2017).

Table 1. List of variables

No.	Criteria	Description	Source
1	Quality	Measuring the quality, assessing quality, implementation of quality standards, continuous improvement, customer service	(Chang et al., 2011; Govindan et al., 2016; Govindan, Chaudhuri, 2016; Kawa, Koczkodaj, 2015; Mirmousa, Dehnavi, 2016)
2	Services and products	Portfolio of services and products	(Chang et al., 2011; Govindan et al., 2016; Mirmousa, Dehnavi, 2016)
3	Flexibility	Ability to accommodate a special or non-routine request, reaction to demand change	(Chang et al., 2011; Govindan et al., 2016; Govindan, Chaudhuri, 2016; Kawa, Koczkodaj, 2015; Mirmousa, Dehnavi, 2016)
4	Price	Attractiveness of price lists, cost reduction programs, programs for big and loyal customers	(Chang et al., 2011; Govindan et al., 2016; Govindan, Chaudhuri, 2016; Kawa, Koczkodaj, 2015; Mirmousa, Dehnavi, 2016)
5	Production capability	Production capacity, production planning process and scheme, lead-time	(Chang et al., 2011; Falatoonitoosi et al., 2014; Govindan et al., 2016; Kawa, Koczkodaj, 2015)

No.	Criteria	Description	Source
6	Technical capability	Modern technology, research and development programs, modern equipment, traceability, tracking, level of innovations, research and development	(Chang et al., 2011; Govindan et al., 2016; Kawa, Koczkodaj, 2015; Mirmousa, Dehnavi, 2016)
7	Reliability of delivery, security	Timely delivery, safety of transactions, including transport	(Chang et al., 2011; Kawa, Koczkodaj, 2015; Mirmousa, Dehnavi, 2016)
8	Communication	Information sharing scheme, openness for cooperation, IT solutions	(Govindan et al., 2016; Govindan, Chaudhuri, 2016; Mirmousa, Dehnavi, 2016)
9	Financial stability	Financial performance confirming continuity of providing products and services, fixed assets management	(Govindan et al., 2016; Kawa, Koczkodaj, 2015; Mirmousa, Dehnavi, 2016)
10	Trust and reputation	Brand awareness, trust to the brand, opinions of business partners	(Govindan et al., 2016; Mirmousa, Dehnavi, 2016)
11	Environmental management	Green design, ISO 14000, pollution control, eco-labelling, life cycle management, greenness	(Falatoonitoosi et al., 2014; Mirmousa, Dehnavi, 2016)
12	Experience	History of operating on the market, history of company development	(Govindan et al., 2016; Kawa, Koczkodaj, 2015; Mirmousa, Dehnavi, 2016)
13	Location	Location and geographical scope of deliveries	(Govindan et al., 2016)
14	Human resources management	Talent management, employee skills improvement programs	(Govindan et al., 2016)

Source: (own elaboration)

The DEMATEL method allows separating a factor into cause and effect groups (Chang et al., 2011) and identifying the most important criteria from the group of all criteria indicated as crucial in the decision-making process according to stakeholder needs. The main result of the analysis is an impact digraph map. The key factor criteria in the field of supplier evaluation show supplier performance and provide valuable data on supplier selection in the case of pre-purchase activities.

DEMATEL was used to solve multiple logistics problems, like the performance of reverse logistics enterprises (Shaik, Abdul-Kader, 2018), risk management of third party logistics service providers (Govindan et al., 2016; Govindan, Chaudhuri, 2016), supply chain risk management (Govindan, Chaudhuri, 2016), remanufacturing barriers, supply chain performance, city logistics, green supply chains (Govindan, Chaudhuri, 2016), the Internet of Things (Hsu, Yeh, 2017), 3PL selection (Govindan et al., 2016), using ERP systems (Torbacki, 2017). It was used for transport and logistics (Duchaczek, 2015; Torbacki, 2017), also the problem of supplier selection (Chang et al., 2011; Falatoonitoosi et al., 2014; Govindan, Chaudhuri, 2016; Lee et al., 2013; Mirmousa, Dehnavi, 2016; Shaik, Abdul-Kader, 2018).

The DEMATEL method contains several steps to reach the final value. Those are described below.

Step 1. Calculating direct relation matrix A

After collecting assessments from decision-makers concerning their opinion about relations between variables (see Table 2), the direct relation matrix should be calculated (see Equation 1). Usually, the results in the matrix are average values from all the results obtained from the surveyed persons or groups.

Table 2. DEMATEL scale

Type of relations between variables	Influence score
No influence	0
Very low influence	1
Low influence	2
High influence	3
Very high influence	4

Source: (own elaboration based on: Chang et al., 2011)

Equation 1. Matrix A

$$A\square = \begin{bmatrix} 0 & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & 0 & \mathrm{a}_{23} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & a_{n3} & \dots & 0 \end{bmatrix}$$

Step 2. Normalization of matrix A to matrix S

Normalization of the primary matrix is made with the use of equations allowing placing all the elements between 0 and 1 (see Equation 2 and Equation 3).

Equation 2. Matrix S

$$S = s \times A$$

Equation 3. Indicator s

$$s = \min\left[\frac{1}{\max\limits_i \sum_{j=1}^{n} |a_{ij}|}, \frac{1}{\max\limits_j \sum_{i=1}^{n} |a_{ij}|}\right]$$

Step 3. Calculation of total relation matrix M

Matrix S is used to calculate the total relation matrix (see Equation 4).

Equation 4. Matrix M

$$M = S(I - S)^{-1}$$

Step 4. Summing up the rows and columns

In this step, the equation for the sum of rows and columns is solved (see Equation 5 and Equation 6).

Equation 5. Result r_i

$$r_i = \left[\sum_{j=1}^{n} m_{ij}\right]_{n\times 1}$$

Equation 6. Result s_i

$$s_i = \left[\sum_{i=1}^{n} m_{ij}\right]_{1\times n}$$

Step 5. Presenting $r_i - s_i$ and $r_i + s_i$ values and causal-effect graph

In the final step, the graph is constructed using $(r_i + s_i)$ as the horizontal axis and $(r_i - s_i)$ as the vertical axis. The graph allows defining the relationships between the factors and identification of those most important and influential (see Figure 2).

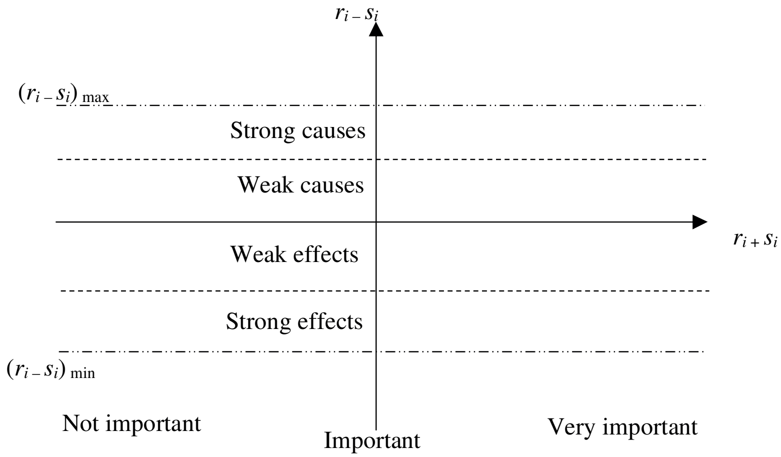

Figure 2. Cause-effect diagram in DEMATEL method
Source: (own elaboration based on: Dytczak et al., 2014)

The higher the value of $r_i + s_i$, the higher the degree of importance of a given factor in the decision-making process. On the other hand, the $r_i - s_i$ value defines the general nature of the variable (Dytczak et al., 2014). If this value is greater than 0, it dominates over other values, if it is negative, it is dominated by other variables. In addition, the location of the result on the scatterplot in the causal-effect plot can be used to determine whether a given variable is a cause or an effect (Sohrabinejad, Rahimi, 2015).

3. Results and discussion

According to the previously described research procedure (see Figure 1), the determined variables were presented to three teams of people associated with the procurement process, more precisely – relations with suppliers. The purpose of their evaluation was to describe, using the influence table (Table 1), how strong the relationships between the variables were. The results of this assessment are presented in Table 3. The values in the table are the arithmetic means of valuations made by the three groups. It was assumed that the decision on the allocation of influence belonged to the assessment teams, so there were no restrictions on the impact of individual variables on each other. In some cases, such a restriction is applied, but in this study it has not been implemented, leaving the choice to individual working teams to assign the existence of a relationship between variables or the lack of such.

Table 3. Matrix A – relations between variables (mean values)

Criterion	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Sum
1	0.00	3.67	2.67	3.67	2.00	2.33	3.67	1.33	0.67	1.67	2.33	2.67	0.67	1.67	29.02
2	2.33	0.00	3.33	3.67	4.00	3.33	1.67	1.33	2.33	2.67	1.00	1.67	2.67	1.67	31.67
3	2.00	3.33	0.00	3.67	4.00	3.33	1.67	2.33	1.00	2.67	0.67	1.00	2.67	1.33	29.67
4	4.00	3.33	3.67	0.00	3.67	2.67	3.67	2.33	3.33	2.33	1.67	2.33	2.67	0.67	36.34
5	1.33	3.67	4.00	3.33	0.00	4.00	3.00	0.67	1.67	2.33	1.33	0.67	1.33	0.33	27.66
6	2.67	3.00	3.00	3.67	4.00	0.00	3.33	3.33	1.00	2.33	3.00	1.67	1.33	0.67	33.00
7	1.33	1.00	3.00	1.33	2.33	2.67	0.00	1.67	3.33	4.00	0.33	0.67	1.67	1.67	25.00
8	0.67	0.33	3.33	1.67	1.00	1.67	2.67	0.00	1.67	3.67	0.67	1.33	2.33	2.33	23.34
9	2.33	2.00	1.67	2.00	3.33	3.00	3.33	2.33	0.00	3.33	3.67	2.00	3.00	3.33	35.32
10	3.33	0.67	1.00	3.33	0.67	1.33	1.00	1.33	3.33	0.00	1.67	0.67	1.00	1.67	21.00
11	2.67	3.33	2.33	3.33	2.00	3.67	1.33	2.00	1.33	3.67	0.00	1.67	1.00	1.00	29.33
12	3.33	3.67	2.67	3.33	1.67	3.33	2.67	3.67	2.33	4.00	2.00	0.00	1.67	2.00	36.34
13	2.67	3.33	2.00	4.00	3.67	4.00	2.33	2.67	2.00	3.00	3.67	1.33	0.00	3.33	38.00
14	3.67	1.67	1.33	1.67	3.33	4.00	2.33	4.00	2.33	3.67	1.67	1.33	2.33	0.00	33.33
Sum	32.33	33.00	34.00	38.67	35.67	39.33	32.67	28.99	26.32	**39.34**	23.68	19.01	24.34	21.67	–

Source: (own elaboration)

Then, according to the established *s* (see Equation 7), a normalized matrix S was calculated (see Table 4), which was converted according to Equation 4 into matrix M (see Table 5). Using Equation 5 and Equation 6, a final matrix was calculated with the data necessary to evaluate the effect of each variable on the supplier's score (see Table 6). The next step was to present the final results using the cause-effect diagram (see Figure 3) and, based on it, prepare an interpretation of the results of the study according to the previously mentioned pattern (see Figure 2).

Equation 7. Empirical s

$$s = \min\left(\frac{1}{39.34}; \frac{1}{38}\right) = 0.02542$$

According to the final matrix and cause-effect diagram, the results are related to assigning the variables to the group of causes and effects. In this step, also the strength of being the cause or the effect can be implied. Another dimension is to assess the level of influence on the final grade as weak or strong (important or unimportant variable).

Table 4. Matrix S

S	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.00	0.09	0.07	0.09	0.05	0.06	0.09	0.03	0.02	0.04	0.06	0.07	0.02	0.04
2	0.06	0.00	0.08	0.09	0.10	0.08	0.04	0.03	0.06	0.07	0.03	0.04	0.07	0.04
3	0.05	0.08	0.00	0.09	0.10	0.08	0.04	0.06	0.03	0.07	0.02	0.03	0.07	0.03
4	0.10	0.08	0.09	0.00	0.09	0.07	0.09	0.06	0.08	0.06	0.04	0.06	0.07	0.02
5	0.03	0.09	0.10	0.08	0.00	0.10	0.08	0.02	0.04	0.06	0.03	0.02	0.03	0.01
6	0.07	0.08	0.08	0.09	0.10	0.00	0.08	0.08	0.03	0.06	0.08	0.04	0.03	0.02
7	0.03	0.03	0.08	0.03	0.06	0.07	0.00	0.04	0.08	0.10	0.01	0.02	0.04	0.04
8	0.02	0.01	0.08	0.04	0.03	0.04	0.07	0.00	0.04	0.09	0.02	0.03	0.06	0.06
9	0.06	0.05	0.04	0.05	0.08	0.08	0.08	0.06	0.00	0.08	0.09	0.05	0.08	0.08
10	0.08	0.02	0.03	0.08	0.02	0.03	0.03	0.03	0.08	0.00	0.04	0.02	0.03	0.04
11	0.07	0.08	0.06	0.08	0.05	0.09	0.03	0.05	0.03	0.09	0.00	0.04	0.03	0.03
12	0.08	0.09	0.07	0.08	0.04	0.08	0.07	0.09	0.06	0.10	0.05	0.00	0.04	0.05
13	0.07	0.08	0.05	0.10	0.09	0.10	0.06	0.07	0.05	0.08	0.09	0.03	0.00	0.08
14	0.09	0.04	0.03	0.04	0.08	0.10	0.06	0.10	0.06	0.09	0.04	0.03	0.06	0.00

Source: (own elaboration)

Table 5. Matrix M

M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Sum
1	0.191	0.283	0.272	0.316	0.263	0.282	0.281	0.199	0.179	0.265	0.191	0.179	0.164	0.162	3.227
2	0.266	0.218	0.306	0.341	0.331	0.328	0.257	0.215	0.230	0.307	0.180	0.167	0.224	0.176	3.545
3	0.242	0.280	0.214	0.323	0.314	0.309	0.242	0.223	0.188	0.289	0.160	0.142	0.213	0.158	3.297
4	0.326	0.321	0.342	0.285	0.350	0.342	0.328	0.258	0.274	0.331	0.213	0.198	0.244	0.172	3.984
5	0.215	0.275	0.293	0.301	0.209	0.309	0.258	0.175	0.193	0.268	0.164	0.127	0.174	0.126	3.087
6	0.271	0.288	0.303	0.341	0.328	0.249	0.295	0.259	0.202	0.303	0.221	0.167	0.194	0.152	3.573
7	0.195	0.188	0.243	0.228	0.237	0.254	0.166	0.182	0.215	0.284	0.130	0.114	0.166	0.148	2.751
8	0.171	0.162	0.239	0.223	0.195	0.220	0.218	0.135	0.170	0.267	0.129	0.122	0.173	0.158	2.580
9	0.284	0.280	0.285	0.322	0.331	0.342	0.311	0.255	0.191	0.348	0.254	0.185	0.244	0.228	3.860
10	0.223	0.164	0.177	0.249	0.177	0.200	0.174	0.157	0.198	0.166	0.148	0.106	0.134	0.135	2.409
11	0.256	0.275	0.263	0.311	0.262	0.310	0.228	0.213	0.192	0.308	0.139	0.157	0.170	0.147	3.232
12	0.312	0.322	0.315	0.359	0.300	0.351	0.302	0.289	0.251	0.367	0.218	0.141	0.219	0.201	3.947
13	0.311	0.331	0.315	0.390	0.362	0.386	0.308	0.278	0.254	0.359	0.267	0.182	0.187	0.237	4.167
14	0.297	0.255	0.262	0.296	0.312	0.343	0.275	0.278	0.232	0.335	0.197	0.161	0.216	0.139	3.600
Sum	3.558	3.643	3.832	4.283	3.971	4.226	3.643	3.115	2.970	4.198	2.610	2.149	2.723	2.339	47.259

Source: (own elaboration)

The higher the value of $r_i + s_i$, the higher the degree of importance of a given variable in the decision-making process, which is the supplier selection or evaluation process. Therefore, looking at the results of calculations, the five most important ones are services and products (portfolio), flexibility, price (the highest score in the results), production and technical capability. What is surprising, the quality, described always as a very important variable, had a lower score than expected.

Table 6. Final matrix

Criterion	r_i	s_i	$r_i + s_i$	$r_i - s_i$
1	3.227	3.558	6.786	–0.331
2	3.545	3.643	7.188	–0.098
3	3.297	3.832	7.129	–0.534
4	3.984	4.283	8.267	–0.299
5	3.087	3.971	7.057	–0.884
6	3.573	4.226	7.799	–0.652
7	2.751	3.643	6.395	–0.892
8	2.580	3.115	5.695	–0.534
9	3.860	2.970	6.829	0.890
10	2.409	4.198	6.607	–1.789
11	3.232	2.610	5.842	0.622
12	3.947	2.149	6.097	1.798
13	4.167	2.723	6.890	1.444
14	3.600	2.339	5.939	1.261

Source: (own elaboration)

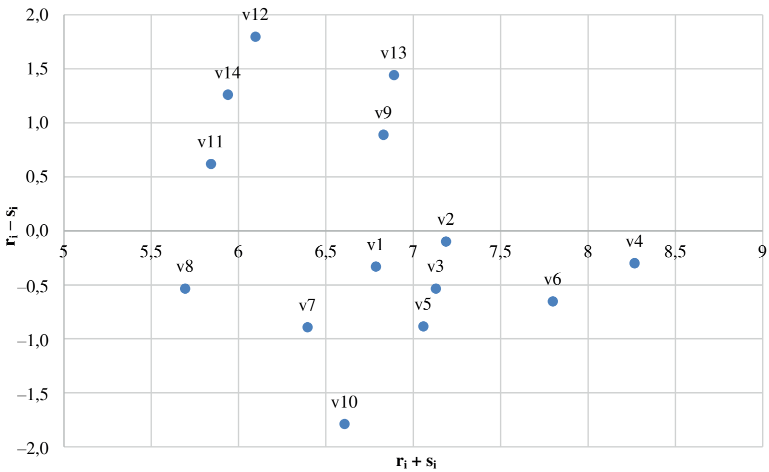

Figure 3. Cause-effect graph
Source: (own elaboration)

The decision-makers were focused mostly on prices, including special offers for loyal and biggest customers. This is an obvious result. The second score belongs to the technical capability, assumed with many types of innovations, determining also – to some extent – production capability. Research and development may have an impact on the communication, quality, the portfolio of products and services, including tracking of goods and traceability as a whole set of tools aimed at identifying goods within the supply chains. The production capability itself is an important variable. Especially pre-production activities, like production planning and scheduling, are very much correlated with the supplier's flexibility. Also, the comprehensive offer is an attractor, which is highly recommended by assessment teams. If the supplier is reliable, decision-makers may be more willing to order more goods or services from him rather than seeking for another supplier. This confirms the trend in supply chains to closer cooperation with suppliers, the emergence of mega-suppliers or suppliers integrators and shifting from multi-sourcing into single-sourcing, resulting in a long-term cooperation. Taking into account today's complexity of supply chains, rapid changes on the global market and fluctuations of demand, flexibility can be the response to the uncertainty. This variable was also highly rated. Supplier reaction for non-routine requests can be a valuable attitude toward spreading cooperation with subsequent customers.

Looking at the $r_i - s_i$ values, the general nature of the variable can be determined. The dominating variables in the analysis are financial stability, environmental management, experience, location and human resources management. They influence other factors, thus being the determinants of creating the other variables. The strongest cause in this group is experience, therefore, it has the strongest impact on the other variables. The second score is calculated for location, and the third – for human resources management. They also affect the shaping of variables defined as dependent.

The variables dominated by others are quality, services and products, flexibility, price, production and technical capability, delivery reliability, communication and trust. It is worth noting that trust is the most dependent variable, so its value depends on many other variables.

Those results are similar to those presented in the literature (Chang et al., 2011; Govindan et al., 2016; Mirmousa, Dehnavi, 2016). Although, Morauszki and Attila (2015) reported changes in the importance of criteria over time. Those results of the literature study are totally opposite, with some exceptions, to those presented in this study. In the mentioned literature source, in the 1960s the most important criteria were quality, delivery reliability, performance and warranties. Then, it changed, and 30 years later, the highest ranks were assigned to prices, supplier profitability and financial disclosure records. In 2003, the most important variables in the supplier selection and evaluation were the ability to meet the deadline, quality, technical capability and prices. Those last mentioned are quite compatible with the results presented here. It can be assumed that this set of variables will change over time as it has happened before.

Conclusions

The results of this study can hopefully help organizations, especially companies, assess suppliers by focusing on the most crucial factors. The results are ready-to-use for the SCM decision-making process, hence, the practical implications can be described as important. The set of variables included in the analysis is based on different results, from literature review studies, thus, they can be described as objective and well-thought-out, and build a full set of criteria important for decision-makers.

The study finds that the most important criterion is the price, the supplier's experience is a dominating issue, and the most relative criterion is trust, being the result of many variables. Usually, in their assessments companies focus on the price, quality and delivery performance only (Chang et al., 2011). However, as this study shows, other factors are also important and should be taken into consideration. The knowledge about the interdependencies between variables and their importance for the final score can serve as a basis for defining the set of criteria for supplier selection and evaluation. In fact, the analysis presented in this study could objectify the process of defining such criteria, often created, as a whole assessment procedure, according to the subjective opinions of one decision-maker.

However, this study has several limitations. Undoubtedly, the literature review is not full and probably, a systematic review could provide additional variables or a possibility of breaking down cumulative variables into detailed ones. Secondly, this study was only an example of using the DEMATEL method on a small group of observations. Presumably, a larger number of assessments would allow objectifying the results to a greater extent. Thirdly, the DEMATEL method is now often modified by researchers to find new ways of calculating the results for complex decision-making processes in the field of logistics, which undoubtedly is the supplier selection and evaluation process. In addressing future work, the framework presented here should be expanded to include more sophisticated mathematical methods, as has been done in many research papers. Exploratory studies will be developed in future research, maybe some more variables will be found as important for the discussed process in terms of logistics management and supply chain management.

Future studies should be focused on customizing the classical multi-criteria decision-making methods to adjust them to the real needs of decision-makers in companies and the goals of organizations and supply chains (Adamus, Gręda, 2005; Lin et al., 2009; Seker, Zavadskas, 2017; Sohrabinejad, Rahimi, 2015). What is worth noting, the direction of SCM towards sustainable green supply chains will affect the future set of important variables, and thus, the calculation of their relations (Falatoonitoosi et al., 2014; Kara, Firat, 2016). If the current trends are still developed at the current pace, also the role of suppliers will change in the forthcoming years. Therefore, supplier evaluation studies will evolve and continue to be one of the most important research areas within the field of logistics.

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LOGISTICS IN RACING SPORTS ON THE EXAMPLE OF F1

Abstract

Logistics operations are an inseparable part of every process that humans can conduct. No major process could proceed in a right way without logistics. In the case of every sport, and in the case of racing sports in particular, providing the right resources not only enables the race to take place but may be decisive about the potential results of each team as well. F1, which is called the "Queen" of motor sports, a main process in this case, has an essential need for logistics services. Considering this case, the purpose of this paper was to present the extent of logistics services within F1 as a good example of operation of logistics processes. The work is a review, basing mainly on various examples and practices from the 2018 season. The writing of this article was supported mainly by foreign internet sources, along with domestic literature and the author's own observations on the functionality of F1 races and the tasks of logistics processes.

Keywords: logistics, racing, F1, transport

JEL: R490

Introduction

The F1 races are recognized as the highest level of car racing. Year to year there are more and more people which are interested in this form of sport. In addition, this racing sport type is constantly developed and upgraded, and many changes have been introduced thereto over the years since the first Grand Prix (GP). The races take place in various countries and on various continents. In addition to the racing drivers, every weekend each racing event is served by professional mechanics and many other people taking care that the races should run smoothly, safely and properly. Moreover, this great interest is the reason why fans and reporters more and more often visit racing venues for a ″live″ experience. The entire F1 functionality involves much service which has to be provided by logistics. Providing all the necessary resources in accordance with the 5R rule is quite a big challenge for people who are planning all the operations but also for those who are personally responsible for their performance. In this respect, the aim of this paper is to show, on examples, how logistics services are provided according to the 5R rule. Formula 1 is a significant example of how important serving the main process is and the fact that such process would not be possible without logistics. The article has the nature of a review based mainly on foreign sources of information, along with the domestic literature and the author′s own observations.

1. Logistics service

Every action connected with conducting various processes requires appropriate resources. The same situation arises when it comes to racing, as it would not be possible without the proper factors. To put in the simplest way, it is possible to indicate that logistics services, in accordance with the 5R rule, are a necessary component of every action with various types of sports which can be presented as the main process (Chaberek, Mańkowski, 2017). Referring to these requirements for the purpose of this article, providing adequate resources according to the 5R rule will enable the proper way of dealing with the F1 Grand Prix during one weekend. Logistics operations must be performed at the highest level due to the requirements of the main process constituted by the GP every weekend. Determining the appropriate resources in the appropriate quantity, delivering them at the correct time to the right place at the right cost, conditions the success or lack thereof during a main process which is F1 GP (Chaberek, 2014). On the basis of such statements it is possible to define how big a challenge the logistics service of F1 racing is. In addition, it is worth mentioning that the requirements for the needed resources have been increasing for almost over 70 years now (the first F1 race was staged in 1950). F1 is an interesting example of how proper logistics services should look like. Such an example is good because of the various requirements and the short periods of time for making the necessary decisions. Both processes: the main process and logistics are connected with each other and cannot proceed separately. The main process determines all the requirements which must be met by logistics processes. Due to this fact the F1 races are an important source of a "job well done". The 2018 season races were organized in 21 countries on 5 continents, and there was no situation when one of the 5Rs was not fulfilled, as such situation would have caused serious losses, both for the teams but also for sponsors and fans, and it is therefore that logistics operations within F1 are of such importance.

2. F1 logistics in practice

Access to this specific sport is highly limited and only the best drivers around the world may participate in races. Since 1950 races have been staged around the whole world attracting crowds of tourists. However, for this to be possible, thousands of people must do their jobs properly to enable the functioning of the weekend's Grand Prix. The GP is organized every year, starting from February, ending in December. The tour is staged in 21 countries on the 5 continents, which in itself is a logistics challenge (*Formula 1®. The Race Behind the Race…*, 2018). While drivers and teams are competing between themselves, the main part of the logistics service rests with the official operators such as, for example, DHL, that needs to deliver the required "equipment" and supervise all the necessary components for the race preparations and progress, so that they should be at the right place at the right time. Their operations are the essence of the 5R rule of logistics.

2018 F1 championship was staged in 21 various countries, and it was really a special year for Formula 1, as it was for the first time in history that the GP was held three weekends in a row, what was an enormous challenge for the logistics operators. Each racing weekend consisted of three days of competition (Friday, Saturday, Sunday), but the special "racing town", garages and service had to be ready and operational no later than on Thursday before the race. In 2018 there were ten teams represented by two drivers each (*F1 Racing Teams 2020…*, 2018). The statistics for the 2018 year are highly impressive, as far as the required resources (goods) needed for transport in a nine-month period only are considered. The average weight of cargo necessary to be transported between every race is about 2000 tonnes of which 600 tonnes was transported via air transport and 1000 tonnes via maritime transport (the remaining cargo was transported by trucks). Boeing 747 planes flew around 132 000 kilometres during one racing season. It has been measured that there are about 40–50 tonnes of cargo on average for one team. And these are the resources for the racing only. DHL which is a long-time partner delivers also other resources for broadcasting and hotel services. It has been also measured that over 150 000 of additional broadcasting equipment, 30 hotel service containers and about 10000 kg of electronic devices for every team were transported in 2018 (*Formula 1®. The Race Behind the Race…*, 2018). Numerical statistics show how much effort must be put into logistics services to deliver the right resources for Formula 1. The presented statistics are limited only to the "technical" requirements of teams. In addition, it is necessary to "deliver" people, arrange booking the accommodation, where one team may need more than 100 hotel beds. Furthermore, special vehicles and machines which will be used in team villages and in the paddock area need to be provided. The technological development has also affected the main process which is the race itself. In such case there is also the requirement for special IT services whereby the right resources are also demanded (*Formula 1®. The Race Behind the Race…*, 2018). It is a crucial point, as appropriate telemetric data allows making strategic decisions which may determine the victory or loss, however, in such situation, logistics is also responsible for the appropriate resources such as telemetric data which may contribute to the winning of the driver or the team. Other limitations and challenges concerning the logistics service may result from political issues and country-specific requirements. The first race during the 2018 season which was held in Australia can be used as an example here. The motorhome and the racing circuit are located in a park, which imposes additional needs on teams concerning potential pollution or damage to green areas. On the other hand, in China there are very stringent rules concerning hazardous goods and lithium batteries, which must be planned and accepted by the country long before the teams arrive (PCM_ADMIN, 2018).

The adequate resources for every team are transported using three modes of transport: road, air and sea. As long as weekend's races are staged in Europe, most of the equipment is transported by trucks on road. The situation is slightly more complicated when transport between continents is needed. Appropriate equipment, tools and devices (resources) are divided into two types – necessary and standard parts. The necessary parts have priority when it comes to air transport, while standard parts are divided into five sets which will be transported between two race locations. One set is sent to the first of four "away" races and the other three sets will be sent back to the headquarters of a team. As an example, it is shown that the set from Malaysia is sent directly to Canada, the set from Singapore is shipped to Brazil, and the set from Japan is sent to Abu Dhabi. The required sets for Russia or Austria are sent directly from the headquarters. These sets are usually transported by sea, what of course needs suitable planning and prior arrangement and division in what directions the resources will be sent to be delivered to the right place at the right time (Iyengar, 2017) (Table 1).

Table 1. Differences between using air and sea transport in the logistics of the Red Bull Racing F1 team

Air transport	Maritime transport
Sent 7–9 days before the race	Sent 4–6 weeks before race
Renault sends engines, Pirelli sends tyres	Usage of car transport to deliver the cargo to the harbour and pit lanes
Plane charter by Formula One Management	Significant savings compared to air transport
–	Used for transport of heavy items and items with the shelf life of about 4–5 years
Statistics	
13 specially designed containers with: Electronics and IT systems 2 race cars Spare chassis Bodyworks 40 sets of wheels (without tyres)	5 containers with: All garage equipment No sensitive parts No car parts

Source: (own elaboration based on: Iyengar, 2017)

Each team "packs" its cars in specially designed containers in such a way as to maximize the usage of cargo space. As statistical data shows, it is possible to say that every team transports spare parts to be ready to prepare their vehicles, about 40 sets of tyres and wheels, 2500 litres of fuel, 200 litres of engine oil and about 90 litres of a cooling factor are shipped. These things need tools, computer hardware, IT and appropriate amounts of food for the whole team, which should be enough for preparation of 200 meals (including the tableware and cookware) (Davies, 2014). According to such statistics the biggest teams have about 50 tonnes of needed resources. In addition, the rising popularity of this sport is the reason why the needs for logistics services are rising proportionally to the needs for the right resources. Thus, we can say that teams which are responsible for logistics services of various teams, are also potentially responsible for the performance of drivers and the rest of the team on the track, and all of this owing to successful fulfilment of the 5R rule of logistics.

Another example of the actions carried out by logistics services on a racing weekend (main process) needs to be presented to get a fuller meaning of logistics and its responsibilities. The example will be a description of the logistics services provided by a logistics operator, Mercedes-AMG Petronas, after a race finished at the SPA circuit in Belgium in 2017. The official logistics partner of the Mercedes team is DB Schenker. The situation after the race was rather tense as the next race was just within a week and it was supposed to take place on the Monza circuit in Italy. When the press conferences were coming to an end, the first actions to disassembly the motorhome were taken. The crew started to pack the first items. The team consisted of 63 members and they had 18 heavy goods vehicles. Simultaneously to these activities, extra crews along with race engineers were disassembling carefully the cars. The prepared vehicles started their journey first thing in the morning on the next day (Monday) to another race track located about 1100 km away. The trucks which were carrying the parts of the motorhome and race cars are always of the latest type to ensure fluent and safe transport at the right time. The reliability of transport in this case is fully connected with the accomplishment of two aims, namely, the right place and the right time. During the night the whole motorhome was disassembled and loaded onto trucks which needed to arrive at the next track as first (*Formuła 1: początek…*, n.d.). The vehicles with the necessary equipment had to get to the next track not later than on Thursday (before the racing on Friday), so that the crews could prepare the motorhome, equip the garages and assemble the race cars before Friday morning. Tasks in this field require a high level of planning and commitment of the whole crew. It is one of the key factors determining the success of teams and drivers. The Mercedes-AMG Petronas team won the best constructor title and their driver won the 5th world F1 championship (in the 2018 season), and such achievements would not have been possible without the right resources provided with the 5Rs.

Another example of the relevance of actions in the field of logistics worth mentioning is the situation from 2018 when for the first time in the F1 history, races were staged during three straight weekends on various tracks in Europe, France, Austria and England (Young, 2018). It was an enormous challenge for every logistics operator, with the main focus on enterprises such as DB Schenker and DHL. They needed to cover over 4000 km with the equipment weighting about 20 tonnes per team. The works including the planning and setting of routes were commenced five days before the first race, which was to take place in France with the arrival of the first vehicles on the 19th of June. On the next day the work of assembling garages for the teams was completed. Obviously the rest of the equipment would be gathered until Saturday night, so that, right before the race the team should have access to fresh parts and needed components. During the performance of last tasks in France, the first vehicles would start the route to the subsequent stages. Due to the short periods of time between the races, the teams were also using the air transport and some vehicles started the route directly to the venue of the third race which was to be held in England. On Saturday, the 23^{rd} of July the first vehicles which had set out from the DHL base started arriving at the Red Bull track in Austria after travelling for almost 1480 km (despite the fact that the race in France had not started yet). Due to the previously mentioned tense plan each of the teams was using two various race sets. The sets which were transported by air would be used in Austria, and those from France would be moved to England next Tuesday (the 26^{th} of July). On Monday (the 25^{th} of July) the trucks would start to transport the motorhomes with the plan to unload them on the next day – with a distance of 1118 km to cover. Also on this day, the trucks with fuel would start their journey from the appropriate supply depots planning to arrive on Tuesday, the 26^{th} of July, as well. In addition, as of the 25^{th} of July the first works on the preparation of the pit lane and the paddock were gaining momentum. Tuesday, the 26^{th} of June brought new progress in the process of building the paddock in Austria, along with the arrival of the first trucks from France and supply bases in Europe. The remaining transport trucks from France were carrying garage equipment and supplies needed for the Pit Lane in England – the distance covered was about 1445 km. The planned arrival date was Saturday (the 30^{th} of June). On Wednesday the paddock works were finished and the first drivers started to arrive. Saturday, the 30^{th} of June was the day on which the first works on the Silverstone (England) track started. On the 1^{st} of July (Sunday), immediately after the awards ceremony, the first vehicles with packed race cars and parts of the motorhome began their journey to England. During this journey the fuel trucks would join for the next race which was to be staged Great Britain. The distance between those two venues was 1587 km. Additional challenges for the teams would be connected with various race car upgrades. This would result in a requisition for additional transport from factories based in England, Italy and Switzerland. On Tuesday (the 3^{rd} of July) the first vehicles from Austria arrived, and the work to build the motorhome and the paddock started and had to be completed by Thursday. On the 5^{th} July (Thursday) the racing village in Silverstone was open, and the last works before the practice session were coming to the end. The interesting fact here is that the teams and their resources were one thing, but parallel to this, a large number of reporters were also travelling the same way from France to England via Austria, which obviously required a proper approach to for planning and organization of logistics processes (*Formula 1®. DHL Ensures Smooth Logistics…*, 2018). In this way, the first day of the last race of an unusual triple-header started. The operation which was carried out over a period of these three weeks proved once again the importance of logistics in the proper functioning of a main process which are the various Grand Prix weekend's races. Not even one of the described races would have taken place without the right resources. It shows once again the side of logistics which can be labelled as "good work" which also confirms the fact that no action is possible without logistics.

Conclusions

Every activity, sport, process requires the right resources. The 5R rule has its "reflection" in our every activity every day. The five factors which are the source of the 5R rule may be subjectively considered as a simple thing. In such a case it is important to show an example, such as the functioning of the Formula 1 event. The first Grand Prix ever took place in 1950, and since that time, F1 has been the subject of numerous changes, each of which generating needs for new resources. Not a single race could be held without sufficient logistics facilities and planning. The logistics services are responsible for: building the motorhomes on time, having the right equipment for mechanics, and ensuring that drivers have the right racing cars. The outcome of various races depends mostly on the driver's skills, the efficiency of his mechanics, the whole team, and of course, the car itself. At the same time, the extremely important logistics operations should not be forgotten, or what would be even worse, skipped. The fact that some of these operations are invisible to spectators does not mean that they do not exist. One can say that without proper logistics the Mercedes team and their drivers would not have won the constructor championships five times, and their driver would not have won the fifth world champion title, if it had not been for the logistics operations carried out in a proper way according to the 5R rule.

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A MODEL OF AN ECONOMIC EFFICIENCY EVALUATION SYSTEM OF A MARITIME CONTAINER SUPPLY CHAIN

Abstract

Containerization was one of the catalysts of the globalization processes that took place in the 20th century. Nowadays container shipping is one of the main transport modes in the global economy. The ability to connect distant production centres with consumption centres largely influenced the acceleration of the global trade. Due to the globalization and characteristics of the global trade it is almost impossible to perceive global supply chains without maritime transport. Although the efficiency of the supply chain is a crucial factor of the economic perspective of supply chain management, not much space is devoted to that issue in the literature. The main purpose of this paper is to design and develop a model of an economic efficiency evaluation system of maritime container supply chains. Some general research methods, such as a critical literature review and methods of logical reasoning were used to achieve this goal. Additionally some economic modelling methods were adapted. The presented model is developing the current state-of-the-art knowledge in the field of economic efficiency evaluation of supply chains. Unfortunately this model could not be confronted with real business data due to research limitations.

Keywords: economic efficiency evaluation system, supply chain efficiency, reference model, supply chain management

JEL: B27, R40

Introduction

One of the features of the modern trade is globalization which is expressed in the possibility to connect distant production centres with consumption places through a set of complex processes and operations. Such operations are performed within supply chains, which are complex structures in respect of which, due to many links on various levels, a more applicable term would be a supply network (Pryke, 2009). Within these networks the maritime transport plays an important role, as an integrator of different transport nodes. The average increase in sea freight during the period 2005–2016, in million loaded tones, was 5.2%. In 2016 the global containerized trade expanded by 3.2% year-to-year, with volumes attaining an estimated 140 million TEUs per annum (Hoffmann et al., 2017). General cargo accounts for around 60% of the global shipped goods by value, most of which is transported by containerized liner services (Stopford, 2009).

Although much space in the literature has been devoted to efficiency and performance issues (e.g., Gunasekaran et al., 2004; Banaszewska et al., 2012; Brandenburg, 2016; Charłampowicz, 2017, 2018; Mathivathanan et al., 2017) there has been no focus on issues of the economic efficiency of maritime container supply chains (Charłampowicz, 2017, 2018). The current state-of-the-art knowledge in the field of maritime container supply chains does not propose any proper model of economic efficiency evaluation of maritime container supply chains. The purpose of this paper is to develop and design a model of an economic efficiency evaluation system for maritime container supply chains. The above stated purpose is carried out through a research process which covers general research methods, such as: a critical literature review and methods of logical reasoning as well as methods oriented on modelling and simulation of economic systems, including a reference model of the system proposed in this article.

Some research limitations were encountered when conducting the research. A main research limitation was the lack of a possibility to confront the proposed model with real business data expressed in global supply chains.

The paper is divided as follows: section 1 provides a literature review concerning the supply chain efficiency, section 2 presents a model of economic efficiency evaluation of a maritime container supply chain, section 3 provides discussion and finally section 4 includes final conclusions.

1. Literature review concerning supply chain efficiency

Supply chain management is a set of processes and actions the main target of which is to coordinate processes and relationships occurring inside and outside a supply chain with the aim of maximizing the surplus for the final customer. These actions are carried out through the implementation of a proper supply chain management strategy. The main strategies of supply chain management are: lean, agile, leagile, resilient, green and sustainable (Stratton, Warburton, 2003; Kisperska-Moron, de Haan, 2011; Carvalho et al., 2012; Nieuwenhuis, Katsifou, 2015; Kamalahmadi, Parast, 2016; Tseng et al., 2019). Those strategies have different targets, hence, the implementation of a strategy to a supply chain depends on the market environment and the supply chain characteristics. Based on the implemented strategy the output of the system will be different. It can be said that the main target of every strategy is to maximize the final efficiency of the supply chain in different contexts. It can be said that, e.g., the main target of a lean supply chain would be maximizing the cost efficiency.

The literature of the subject fails to distinguish between the concept and indicators of efficiency and performance which are understood in the same way (Ganga, Carpinetti, 2011; Estampe et al., 2013; Shafiee et al., 2014). On the other hand, there are researchers, who conceptualize efficiency as one of the factors influencing the overall performance and perceive efficiency from the economic point of view, which is connected with the cost of manufacturing and delivering goods to the final customer (Chopra, Meindl, 2003; Roh et al., 2014). Azfar et al. (2014) proposed a conceptual framework for measuring the performance of a supply chain managed with regard to the LARG practices which are a combination of lean, agile, resilient and green methods. This framework was divided into operational performance, economic performance and environmental performance. The factors included in the category of the economic performance are in fact connected with the economic efficiency of a supply chain.

In the literature there is a gap in the knowledge concerning the efficiency of supply chains in the context of designing and developing a proper model of efficiency evaluation. However, the literature connected with a model of performance measurement of a supply chain is extensive. The most frequently examined and implemented model is the one developed by the Supply Chain Council, which is the Supply Chain Operations Reference (SCOR). This model is generally used in identification, measurement, reorganization and improvement of overall supply chain processes (Delipinar, Kocaoglu, 2016; Dissanayake, Cross, 2018). These processes, namely plan, source, make, deliver and return, are presented in Figure 1.

Figure 1. SCOR model
Source: (own elaboration based on: Delipinar, Kocaoglu, 2016)

The SCOR model provides a methodology for managing SC activities and processes. "Plan" refers to analyzing information and forecasting market trends, "Source" is connected with the procurement system, "Make" refers to the manufacturing of goods, "Deliver" involves activities of provision of goods or services and "Return" refers to returning goods or receiving a product (Trkman et al., 2010). This model has 4 SC management levels. Level 1 provides an extensive definition of basic processes and helps entities form the supply chain management objectives.

Level 2 defines the core processes that are possible components in the supply chain. Level 3 provides the company with information needed to set goals successfully for SC improvements. Level 4 is connected with implementation. Since supply chains operate in different market environments and supply chain management improvements are unique for each company the SCOR model does not provide any specific parts of this level (Stewart, 1997; Delipinar, Kocaoglu, 2016; Dissanayake, Cross, 2018).

The SCOR model has been widely and successfully implemented in the manufacturing business. Lee et al. (2012) examined the effects of the SCOR model implementation in a Taiwanese manufacture industry. The results indicate that the SCOR model can be widely and successfully used in other companies. Based on an extensive literature review concerning the SCOR model (Delipinar, Kocaoglu, 2016), in the context of gaining a competitive advantage, it can be said that the SCOR model is not applicable in every industry. As shown in the research, the SCOR model is suitable for the manufacturing industry, however, it is not easy to apply in the construction industry (Delipinar, Kocaoglu, 2016). A similar situation can exist in other industries, where the SCOR model possibly does not fit. It is crucial to remember that the SCOR model provides a measurement system for the overall performance of a supply chain, and in the literature there is no space devoted to the measurement system for the efficiency of maritime container supply chains.

The maritime container supply chains which are a part of the maritime container shipping markets have volatile characteristics and must have abilities to rapidly react in a changing market environment. Those features are present due to the high market concentration on the maritime container shipping market (Hirata, 2017).

The main purpose of this paper is to make an attempt to design and develop a suitable economic efficiency evaluation system for maritime container supply chains. When conducting the research on the economic efficiency evaluation of maritime container supply chains it is crucial to remember that economic efficiency is a derivative of other types of efficiency, such as technical, managerial and technological, and this overall efficiency is one of the components of the supply chain performance. The literature in the field of supply chain efficiency does not provide a suitable solution for the evaluation of maritime container supply chains efficiency with reference to the above mentioned types of efficiency. Some general research methods were applied to conduct this study properly. First, a literature review concerning the supply chain efficiency was conducted and a model of supply chain performance measurement was performed. Based on this review the gaps in the knowledge were identified. Secondly, the research was conducted based on economic modelling and simulation methods including a reference model of the proposed system.

2. Reference model of economic efficiency evaluation of maritime container supply chains

The literature study performed earlier in the article proves that there is a gap of knowledge concerning the economic efficiency evaluation of maritime container supply chains. Therefore, the reference model of a system of economic efficiency evaluation of the maritime container shipping market is proposed in Figure 2.

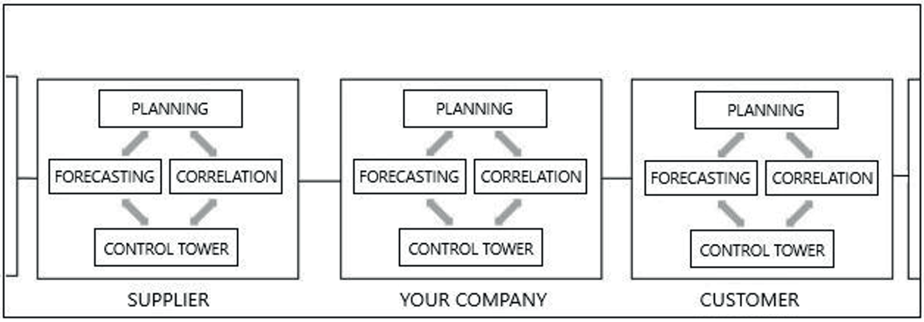

Figure 2. Model of the structure of a system of economic efficiency evaluation of a maritime container supply chain
Source: (own elaboration)

The model of the structure of a system of economic efficiency evaluation of a maritime container supply chain consists of four interrelated modules:
– planning module;
– control module;
– correlation module;
– forecasting module.

Each of the modules has several sub-modules which are presented in Figure 3.

The planning module should integrate various information on strategic, tactical and operational levels. The information and data regarding numerous subjects are crucial for managerial and operational activities. The first sub-module is connected with economic issues which can be distinguished as demand, customer needs, competitiveness and human resources management. The above mentioned information can be used in developing a plan concerning economical and financial data. The sub-module on technical and technological issues should contain such information as: the cost of repairs and maintenances, the degree of equipment utilization, prices of new and used equipment, the cost of ICT systems and the cost of integration within the chain. The last identified sub-module is the operational level which can be divided into two categories: work organization of physical employees and work organization of administrative and managerial staff. The work organization should contain information regarding specific tasks and division of labour.

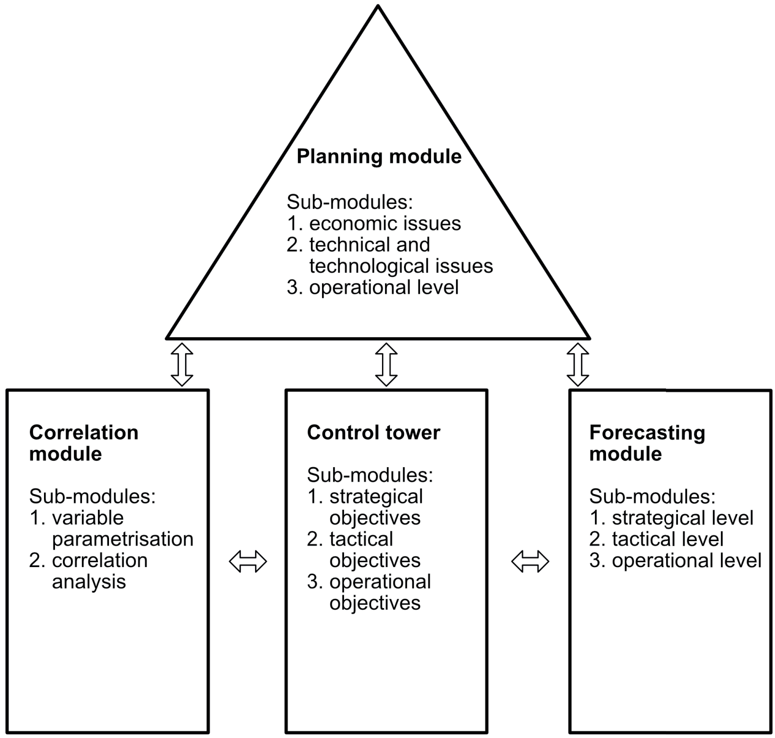

Figure 3. Sub-modules of the system of economic efficiency evaluation of a maritime container supply chain
Source: (own elaboration)

Another identified module in the economic efficiency evaluation system of maritime container supply chains is the correlation module. This component includes two sub-modules: variable parameterization and correlation analysis. In each sub-module it is possible to create and develop suitable indicators of economic efficiency, e.g. the condition and availability of a superstructure. It is crucial to remember that some of those indicators are strongly correlated with each other, and it is important to examine the impact of the change of one indicator on another (e.g. high prices of a new ICT system, which increase the integration within the supply chain can have influence on a lower ability to invest in this asset which can have influence on a decrease in the ability to acquire information, which can have influence on a lower ability to be resilient, weaker competitive power and lower income). The relation between specific indicators should be found with regard to strategic and tactical plans.

The third module is a control tower which is also divided into three categories, which are responsible for the correctness and control over the implementations of plans at the strategic, tactical and operational levels. The sub-module of the strategic objectives should provide constant supervision over the company's actions with reference to the set strategic targets. This verification should be made based on the key performance indicators and their relations to the planning module. Every major change and difference between the plan and reality should be examined for its source and correctness with the plan. The second sub-module of the control tower is connected with control over achieving the tactical objectives. This component is connected with the verification of achieving, and the ability to achieve the targets at the tactical as well as strategic levels. To accomplish this goal it is crucial to develop and examine the correlation between indicators at strategic and tactical levels with reference to the plan. Every major change and difference between the plan and reality should be reported and revised. The last sub-module in the control tower is dedicated to the control over achievement of operational objectives. Even though it is important to set operational objectives with reference to the tactical and strategic goals and plans, this sub-module is the only one which can be adjusted almost every day. Major changes at the operational level can influence the ability, or lack of the ability, to achieve targets at the tactical and strategic levels. Reports and related actions should be taken immediately after modifications of operational objectives and as fast as the variation between plans and results occurs.

The last identified module is a forecasting module which is also divided into three categories connected with the range of the forecast. These categories are: strategic, tactical and operational level forecasts. It is important to remember that the forecast at every level should consist of three sections: economic issues, technical and technological issues and operational issues. This systematization gives a clear view that the forecasting should be made based on the sub-modules of the planning module. Although during the forecast it is crucial to take into account the control tower module which verifies the fulfilment of the earlier plan and correctness of the forecasts that have been made.

As it is shown in Figure 2, the above presented model of economic efficiency evaluation for maritime container supply chains should be implemented at every stage of the supply chain. The information flow concerning specific data from every module, with a high level of the supply chain integration, gives an opportunity to correlate forecasts and plans to create a higher value for the final customer.

3. Discussion

The above presented model is a reference model, what gives the advantage of generalization. Although this model has been designed and developed specifically for maritime container supply chains, however, due to its general nature, it can be implemented to any supply chain. On the other hand, the main disadvantage of this model can be perceived as the requirements for developing suitable indicators and metrics in every process, which can be challenging from application point of view. Therefore, the development of indicators should be made with reference to the specific maritime container supply chain characteristics, which can also differ from each other, although it should be applicable at the global level, as well. Another important issue is connected with the specific number and exact indicators in every sub-module. The proposed set of measures can differ in relation to the characteristics of specific links in the supply chain, and the supply chain as a whole. An additional problem is dedicated to the weight of particular sub-modules and the weight of the indicators of the sub-modules. This weight can differ in relation to the characteristics of the partner in the supply chain, e.g. special attention should be paid to the economic issues, and to the technical and technological issues.

Conclusions

A gap in the knowledge concerning economic efficiency evaluation for maritime container supply chains was identified based on the literature review. Most papers focused on the performance issues using the SCOR model (Lepori et al., 2013; Dissanayake, Cross, 2018), which is not always applicable for all industries (Dissanayake, Cross, 2018). During the literature research, it was noticed that the SCOR model had not been implemented in the maritime container supply chain and there was no space devoted to the economic efficiency evaluation of the maritime container supply chain. This paper made an attempt to fill this gap by developing an original method of economic efficiency evaluation of the maritime container supply chain.

The above presented model should be confronted with the economic reality expressed in the form of implementation of this model to the maritime container supply chain. The results of this action would be very interesting from the managerial as well as scientific points of view. Another research direction of great importance is the further development of this model in the three categories:

– development of specific indicators for every sub-module;
– verification of indicators with the real business data;
– setting weights to specific sub-modules.

The lack of a possibility of acquiring empirical data concerning the maritime container supply chain strategy and plan achievement at the strategic, tactical and operational levels at every stage of the supply chain, greatly limited the ability of the conducted research. Therefore, based on the research findings, the main conclusions can be stated as follows:

1. The proposed model gives an opportunity to assess the economic efficiency of maritime container supply chains in a more reliable and accurate way than another solution.
2. Empirical verification of the proposed model is needed with respect to the business environment, and specific indicators and metrics should be developed for every sub-module based on its design.

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LOGISTICS OF INTANGIBLE RESOURCES IN BUILDING A COMPETITIVE ADVANTAGE IN THEORETICAL TERMS

Abstract

The purpose of the article is to systematize the concepts related to the logistics of intangible resources. To accomplish this objective, the author has employed chiefly the methodology of a systematic review of literature. In the work, the author has raised issues concerning the theory of resources in building a competitive advantage also indicating how important it is to compile appropriate resources (tangible and intangible) to build such an advantage. Furthermore, taking into consideration the theory of a process approach to logistics, the author pinpoints the importance of intangible resources in logistics processes occurring in the course of building a competitive advantage.

Keywords: logistics of intangible assets, competitive advantage, information logistics, resources in logistics

JEL: L10, O10

Introduction

The current business environment is characterized by high volatility in terms of both business and technology. New ways of conducting business activities combining both the traditional theory of economy and IT industry solutions are becoming increasingly popular. Such an alliance results in the growing importance of e-business, and in taking up other activities aimed at reaching greater numbers of customers and having an effect on building a competitive advantage. Modern organizations rely not only on the flow of tangible resources, but it is the processing of intangible resources with special consideration given to the resource of information that are increasingly gaining in importance. Enterprises have started to see the potential in the access to information, its quality, acquisition and processing, and how important it is to absorb state-of-the-art IT solutions. IT solutions are increasingly important not only in organizations, the possibilities of adapting them in many areas of human life have defined a new stage in the development of humanity and the whole civilization. The fruit of such changes is the emergence of an information society, i.e. a relatively new form of society wherein the decisive role is played by the productive use of information and knowledge-oriented intensive production (Papińska-Kacperek, 2008). The dynamic development of information systems which are part of the information system combined with education and development of the information society has contributed to the development of economic systems and the growing complexity of relations between market players (Szmelter, 2013). Changes in organizations are driven by all these links enclosed within a loop, transferring the business to be conducted in an entirely different dimension which is most often virtual (Kalisz, Szyran-Resiak, 2018). The development of organizations of such type and the transfer of business into a virtual sphere result in an even greater change in the relation between intangible and tangible resources. Thus, a basic question is raised whether logistics-related theories require to be formulated or restructured anew due to the changing type of resources and the channel in which they flow. The change of both the resources and the channels in which they flow can be seen primarily in the implementation of digitization on a large scale, the automation of processes, the development of the Internet of Everything, the use of more and more advanced analyses of Big Data, while using cloud computing on a mass scale at the same time.

The purpose of the article is to systematize the theory related to the logistics of intangible resources and present the logistics role of intangible resources in building a competitive advantage, and proving that the essence of logistics is to control the processes of the flow of any resources (tangible and intangible) in any channels and between them, functioning between any users (physical and non-physical).

1. Methodology and theory

The main research problem of this study is the fact that there are no publications on the subject in the literature that would refer the theory of logistics to intangible resources which are gaining increasing importance in today's economy. The narrative (classic) literature review (bibliometric analysis, content analysis, narrative and descriptive review) was used to accomplish the assumed objective and ensure greater certainty in the process of verification of the formulated hypothesis. The system analysis method was employed to identify the resources which influence the building of a competitive advantage.

In many, even contemporary publications related to the theory of logistics, logistics is defined only and solely with reference to tangible resources (Qin, 2009; Abt, Woźniak, 1993; Gołembska, 1994) or to the flow of tangible resources and related information streams, with the understanding at the same time that information not related to physical movement is not subject to logistics operations (Christopher, 2011; Beier, Rutkowski, 1995; Skowronek, Sarjusz-Wolski, 1995; Garbarski et al., 1998; Fijałkowski, 2000). Some of the definitions of logistics found in the literature refer directly to tangible resources, information and other defined resources (Sudalaimuthu, Raj, 2009; Chaberek, 1999). However, few of such definitions refer to the enterprise's resources in the general meaning of the word (Krawczyk, 1998; Niziński, 1998; Chaberek, 2011, 2014). It is only the last group of authors that treat the approach to logistics in the terms of resources, without clearly defining the type of resources.

2. Economic resources as a basis for competitiveness of economic activities

Economic management, but also management in the broader sense, is human activity aimed at satisfying the arising human needs but also the needs expressed by other business entities. Cygan (1999) defines the essence of management as "allocation of disposable resources between various uses", which is the "human activity resulting from the pursuit of the fullest possible satisfaction of unlimited needs in the conditions of a limited nature of such resources". To complete the notion of the essence of management, it is worth noting that by reason of the continuous renewal and practically unlimited development of needs expressed by man, or more broadly, by the society, economic activity is continuous and uninterrupted in many areas, including, but not limited to production, distribution, exchange and consumption of goods (Milewski, Kwiatkowski, 2008).

In the traditional approach to economics, economic resources fall into the three main factors of production, namely, land capital and labour. Nonetheless, bearing in mind the development of management sciences and the popularization of the resource approach, it is necessary to extend these three factors by adding non-material factors in the form of the most important resource for decision-making processes, i.e. information (Weiland, 2017). Analyzing these factors, it should be assumed that labour is related to the use of human resources, financial resources and tangible resources are within the notion of capital, while land is related to the use of various natural resources. And information becomes an inseparable resource of every enterprise, although the above mentioned resources do not have to appear in the group of factors and resources of modern enterprises, every enterprise uses information resources. In the event of virtual enterprises and when running e-business in the broad sense of the word, information resources outweigh the tangible resources in terms of the quantity of flows. As a result of the growing importance of intangible assets in building a competitive advantage and the development of competences in management sciences, the classification of resources has been expanded to include an increasingly large collection of intangible resources. The importance of intangible resources grows proportionally to the process of transformation into a knowledge-based economy (Mikuła, 2018).

One of the major variants of classification of economic resources is their division into tangible and intangible assets (Bednarz, 2013). The category of tangible resources comprises: tangible fixed assets, plant and equipment, tangible current assets and financial assets. The group of intangible assets comprises human, market and organizational resources. Another example of classification has been proposed by Griffin (2010) who classifies resources of enterprises into four basic groups: human resources, financial resources, tangible resources and information resources. The fact that information resources have been included emphasizes their key importance for enterprises and for building a competitive advantage. It is the resources and skills and the way in which they are used by the organization that are strategic for its functioning as their weight translates into building a competitive and market advantage, as well as the ability to compete (Godziszewski, 2001). Nevertheless, it should be remembered that each resource has a different strategic value in building a competitive advantage, wherefore it is necessary to properly identify and evaluate them. A significant contribution to the development of the resource approach in organizations was made by Barney (1991) who defined the features of resources influencing the building of a competitive advantage. The "VRIN" approach proposed by him assumes that the useful resources in building the advantage should be:

– valuable;
– rare;
– inimitable;
– non-substitutable.

Summing up, the primary and original source of the competitive advantage are the enterprise's adequate tangible and intangible resources, but also the effective and efficient use of such resources. If resources should contribute to building a competitive advantage, their configuration has to be unique (Czerniachowicz, 2016), and they should fulfill the following goals: the adequate resource should be in the right place, at the right time and in the right amount, and its cost should be acceptable.

3. Logistics of intangible resources in the process of creating value and building a competitive advantage

As has been previously noted in the literature, it is possible to distinguish many different definitions of logistics. The difficulty to define logistics clearly results mostly from its nature and the source of origin, i.e. socio-economic sciences. Nevertheless, following a detailed analysis of the definitions in terms of the subject matter of this work, it is possible to distinguish many common features among them, whereby they can be grouped by the object of logistics activities. A categorization of the definitions by the object of logistics is presented in Table 1.

Table 1. Definitions of logistics categorized by subject

Object of logistics	Tangible resources, including those defined as products	Tangible resources and related information flows	Tangible, information and other defined resources	Generally presented resources without clear definition
Author, publication date	American Marketing Association, 1935, 1948 (Qin, 2009) National Council of Physical Distribution Management, 1960 (Qin, 2009) (Lalonde et al., 1970) Japanese Comprehensive Research Institute 1981 (Qin, 2009) (Abt, Woźniak, 1993) European Logistics Association, 1994 (Qin, 2009) (Gołembska, 1994) (Skowronek, Sarjusz-Wolski, 1995) Cox M.D., LogLink / Logistics World, 1997 (Sudalaimuthu, Raj, 2009)	Council of Logistics Management, 1985 (Qin, 2009) (Christopher, 1992) (Beier, Rutkowski, 1993) (Blaik, 1997) Canadian Association of Logistics Management, 1998 (Sudalaimuthu, Raj, 2009) Council of Logistics Management, 1998 (Sudalaimuthu, Raj, 2009) (Garbarski et al., 1998) (Fijałkowski, 2000)	(Sudalaimuthu, Raj, 2009) (Chaberek, 1999)	(Krawczyk, 1998) (Niziński, 1998) (Chaberek, 2011, 2014)

Source: (own elaboration based on: Qin, 2009; Lalonde et al., 1970; Christopher, 2011; Abt, Woźniak, 1993; Beier, Rutkowski, 1995; Gołembska, 1994; Skowronek, Sarjusz-Wolski, 1995; Blaik, 1997; Grabarski et al., 1998; Krawczyk, 1998; Niziński, 1998; Fijałkowski, 2000; Chaberek, 1999, 2011, 2014)

From the perspective of the subject matter of this article, the author draws attention to definitions which do not clearly indicate the resources being the object of logistics. Krawczyk (1998) indicates that logistics comprises planning, coordination and control of the progress of processes carried out to achieve the assumed goals both in time and space. Hence, the definition does not clearly give any indication as to what processes are covered by logistics and what resources should be provided to implement these processes. At the same time Niziński (1998) defines logistics as a field of knowledge about rational, comprehensive and economical mass-energy and information security for the functioning of operating systems using the existing resources, limitations and disruptions in the set conditions and time. This definition also shows the freedom of use in terms of resources, limitations and disruptions at the specific time and under the specific conditions of the operation of an enterprise. From the author's perspective it is the definitions proposed by Chaberek (1999, 2011, 2014) that are of key importance. The first of these (1999) defines logistics as the control of the flow of all resources within businesses and non-commercial organizations and between these organizations in logistics channels and chains. This definition emphasises the role of all resources required from the point of view of a given process. The second definition of logistics proposed in 2011 (Chaberek, 2011) describes it as a process aiming to support any rational human activity focused on realizing any objective to provide adequate resources at the right place and time, in an adequate quantity and at a reasonable cost (price) in such a way that all the activities to realize the main objective are carried out in an efficient, effective and beneficial manner. In 2014, this definition was slightly modified in terms of logistics goals (Chaberek, 2014) compared to the previously mentioned definition of six logistics goals (6R), it was replaced with five goals (5R). In the author's opinion, from the perspective of the subject matter of this work, this is the best definition of logistics by reason of its universal nature. This definition indicates directly that the subject matter of logistics are all the resources required to carry out any process that plays the role of the main process. Logistics plays a support function with respect to the main process, providing all the required resources in accordance with the logistics goals (5R), so that the whole process of realizing the main objective (main process) should be implemented in an efficient, effective and beneficial way. Hence, it should be assumed that any process defined by the enterprise as main that is aiming to accomplish the pursued goal requires implementing supporting processes which are logistics processes. Therefore, the role of logistics processes is optimal (in line with the five goals of logistics) management of the available resources. From the perspective of the author of the publication and its subject matter, it should be assumed that the major process is the process of building a competitive advantage with the aim to develop this advantage in a specific time and under specific conditions. The supporting logistics processes have to provide adequate resources from the perspective of the main process implementation, these being both tangible and intangible resources, since, as indicated in a previous section of this article, the adequate compilation of these two types of resources has an effect on building a competitive advantage. The relationship between the process of building a competitive advantage and the logistics process is presented in Figure 1.

While the logistics of tangible resources is widely accepted by many in the world of both science and practice, the logistics of intangible resources arouses many emotions and controversies. Nevertheless, irrespective of whether science will argue about the existence of information logistics or, reaching farther, the logistics of intangible resources, the economic practice shows that the operation of intangible resources allows building a competitive advantage and it is extremely important from the point of view of the organization. The controversies are caused chiefly due to the lack of a clear definition of intangible resources and no clear indication which resources are intangible. The simplest way would be to assume that intangible resources are everything that does not have a material form but has nonetheless impact on building the enterprise's value and is necessary for accomplishing the pursued goal. Nevertheless, it should be noted that each and every intangible resource is linked to the corresponding carrier of this asset. With this approach to intangible resources, it should be assumed that an intangible resource creates some kind of added value to a tangible resource, which means that we can talk about the existence of carriers of intangible resources, where an example can be information and its carrier, i.e. data stored on hard disks, portable memory servers, in the case of knowledge the carriers are people with adequate knowledge and skills, in the case of software and other forms of IT tools, the carriers are similar as in the case of information. However, as far as organizational intangible assets are concerned, their carriers may be a combination of many tangible resources, which, by achieving a synergistic effect, create an added value that is intangible.

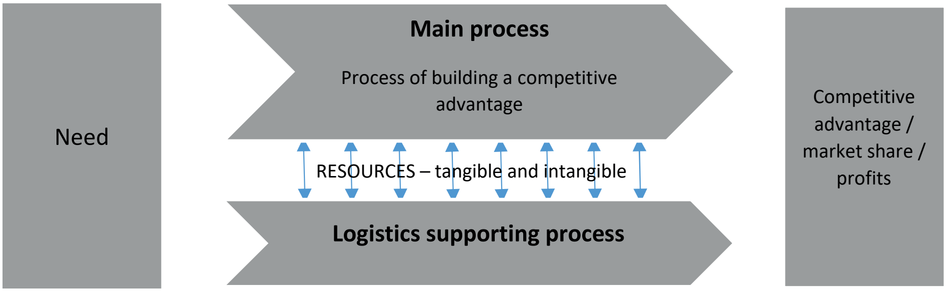

Figure 1. The process of building a competitive advantage and the supporting logistics process
Source: (own elaboration based on: Chaberek, 2002)

The importance of intangible resources in logistics processes, as well as their role as the subject of these processes, will be continuously increasing as a result of technical development. A few years ago only, any reference to teleportation of anything would appear solely in sci-fi movies and related literature. However, the development of technology has contributed to the fact that this concept, fantastic until recently, has become a fact. It is possible already today to teleport the quantum state (Sobota, 2014), which may contribute to the teleportation of information and data. Therefore, it becomes very likely that tangible (material) resources will have a part of their flow in an immaterial form in the future. Obviously, talking about teleportation requires a two-dimensional logistics approach – due to the virtual resource and due to the development of new virtual logistics channels.

Summing up, the building of a competitive advantage and the process of creating the value of enterprises is influenced by both tangible and intangible resources. Hence, assuming that the process of building a competitive advantage is the main process, the essence of logistics (reflected in logistics supporting processes) is to control the supporting processes in such a way that they should ensure resources, whether tangible or intangible, in any logistics channels (virtual, traditional) and between these channels which function between any users, both physical (people) and organizations or non-physical resources (machines, software, virtual units). The importance of intangible resources seems to be growing year by year. While tangible resources such as natural resources, as well as the products manufactured from them will probably be irreplaceable in the long term continuing to be very important in the process of economic development (Krawiec, 2009), the technological progress as well as digitization and virtualization understood in the broad sense will become the driving force for earning high profits and increasing the efficiency and effectiveness of activities in the intangible sphere. This state of affairs finds confirmation in the market value, amounting to billions of dollars, of entities focusing their activities exclusively on the virtual sphere, e.g. Google, Facebook, Microsoft and many others (Mazurek, 2012).

Conclusions

Tangible and intangible resources, and in fact, their compilation and fulfilment of logistics goals in this respect, namely, ensuring the appropriate resources, in the right place, at the right time and in the right quantity and at an acceptable cost are the basis for building a competitive advantage. Taking this approach, it should be assumed that the object of logistics are both tangible and intangible resources. Hence, we can talk about logistics of intangible resources by reason of the object of logistics. The scientific development combined with the simultaneous development of the IT sector gives unimaginable possibilities for creating new intangible resources, but also creates new channels for the their movement. Owing to the virtualization of enterprises creating completely new forms and ways of conducting business it can be said that the users of resources in these channels are both physical and virtual users. Taking into account the growing importance of intangible resources in the contemporary economy as well as the development of new channels of movement of these resources, subsequent research of logistics of intangible resources is needed.

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COBOTIZATION AS A KEY ELEMENT IN THE FUNCTIONING OF SMART FACTORIES AND A NEXT STEP IN THE AUTOMATION OF LOGISTIC PROCESSES

Abstract

This paper aims at presenting the innovative methods of automation of manufacturing processes and their accompanying supporting processes. The author has reviewed scientific articles whose focus of study are modern technologies developed in line with the idea of Industry 4.0. The paper also includes a brief description and an analysis of the course of technological progress which has eventually led to the next industrial revolution. It also identifies the basic pillars of the functioning of the fourth industrial revolution, such as the Internet of Things, Computing Cloud and Cyber-Physical Systems, all of which simultaneously constitute the foundation of existence of Smart Factories – which should become crucial to contemporary economy. The automation of technological lines and transport systems and their robotization and cobotization have been described as phenomena leading to advanced automation of logistics processes. Smart Factories have been presented as entities that will, through the application of the aforementioned systems and technologies, lead to the achievement of optimum management and maximum place and time utility of tangible and intangible resources at their disposal. Last but not least, the paper discusses the forms of human-machine cooperation, distinguishing three basic types.

Keywords: logistics process, automation of manufacturing, robotization, cobotization, Smart Factories, Industry 4.0, Internet of Things, Cloud Computing

JEL: M11, M21, O31, O33

Introduction

Increased demand for logistics services resulting from increased global demand for goods and services, in particular goods purchased via the internet, combined with a decrease in easily accessible workforce are among the main reasons for the necessity of improving the efficiency and quality of logistics services. Owing to the advancement of modern technologies, the world is developing at a considerably faster pace. Economic entities, faced with the contemporary realities, are forced to search for more efficient, effective and profitable methods of resources management.

As the trade volume grew, and hence manufacturing, so did demand for logistics services in the field of manufacturing and those related to the management of the warehouse, internal and external transport, as well as those aimed at streamlining the management of IT resources. The ongoing fourth technological revolution is one of the phenomena that appeared in response to the conditions of operation of enterprises providing logistics services. This revolution consists in universal digitisation, which is to lead to the subsequent automation of business processes, and thus logistics processes. Digitisation and process automation are carried out through the implementation of advanced IT systems, the use of the Internet of Things, Big Data analysis, i.e. Cloud Computing, and robotization of manufacturing, up to the use of early forms of artificial intelligence.

Going along with the current of the next industrial revolution, enterprises are modernising the existing manufacturing centres or building new automated centres called Smart Factories, where production is optimized through the Internet of Things, Cloud Computing, automation, robotization and cobotization. Thus individual components of manufacturing processes are combined into bigger processing units. The manufacturing space is utilised as a system of reactive modules, where all processes are supported by IT systems which plan, execute and control the ongoing manufacturing processes and the accompanying supporting processes. Speaking of the automation of logistics processes, it is necessary to stress the significant role of robotization of certain tasks fulfilled in these processes, where cobots – robots cooperating with humans – provide significant support for the manufacturing, warehouse and transport staff.

The objective of the paper is to identify the key phenomena and technological solutions affecting the automation processes of logistics processes. The author has identified the technologies that can support human work or completely replace human participation in production processes. Automation processes have been defined as consistent with the assumptions and direction of development of the fourth industrial revolution. The author has pointed to the Intelligent Factory as one of the basic pillars of the fourth industrial revolution. The Intelligent Factory is also the place of implementation and application of technologies previously identified by the author.

1. Method and theory

One of the principal research questions of the paper is to determine how the advancement of the fourth industrial revolution may affect the formation of the system of logistics services to manufacturing enterprises. A major part of the paper is devoted to an analysis and synthesis of phenomena and solutions identified in the contemporary manufacturing industry. Hence the main research method used is an analysis and synthesis of content found in secondary sources, such as books, scientific articles, trade journals and documentation.

Behind each purposeful human activity there is a desire to satisfy a specific need. Needs are commonly satisfied by purchasing adequate products or services. A transaction of purchase by a consumer must be preceded by a properly structured manufacturing process. The manufacturing process is thus identified as an element essential to the satisfaction of needs. Being essential, it must be given the status of a core process. A core process, like the consumer's need from which it originates, needs to be appropriately handled. The handling is carried out through supporting processes, which take the form of logistics processes. The main task of logistics processes is optimum management of the available resources. Supporting processes are therefore intended to give the resources an adequate level of place and time utility. In summary, it is possible to put forward a thesis that every activity leading to the achievement of a goal is accompanied by integrated core processes and supporting logistics processes (Chaberek, 2002). The relationships between the core process and the logistics process are shown in Figure 1.

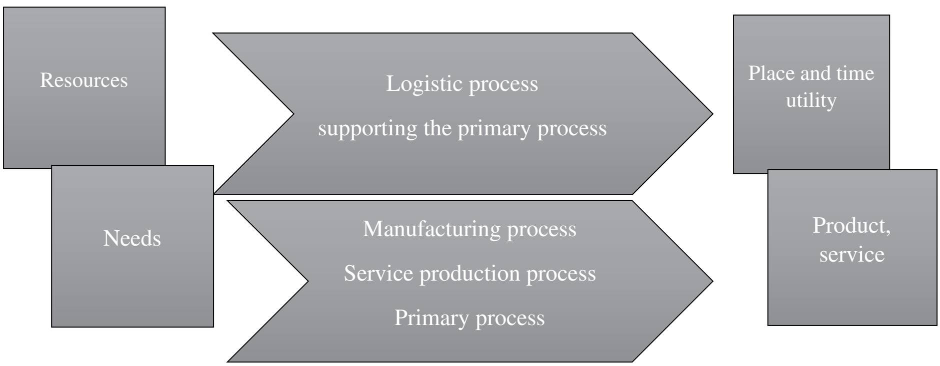

Figure 1. Coexistence of core processes and logistics processes supporting them
Source: (own elaboration based on: Chaberek, 2002)

When identifying the objectives of logistics processes, one cannot concentrate solely on the type of resource which is being moved. The point of logistics activities is largely controlling the processes of flows of resources: raw materials, half-finished products, materials, spares, employees and the accompanying information, in such a way as to offer the customer the highest possible level of service at the specific, lowest possible, cost (Chaberek, 2002).

2. Origin of process automation

The advent of the 20th century marked the decline of the "steam" industrial revolution 1.0, which had continued since the late 1700s (Chojnacki, 2018). Revolution 2.0 meant the invention and popularisation of electricity and the appearance of the combustion engine (Michalski, 2017), which offered possibilities of improving logistics owing to the construction and application of devices already operating in the logistics reality. One of the most noteworthy inventions was the electrical forklift truck, which can be regarded as a milestone in the development of an efficient internal transport system. The first half of the 20th century was a time of building vast industrial plants and regions. One of the basic pillars of industrial revolution 3.0 was the pursuit of optimization by minimising the use of resources while maintaining or even improving the quality of products (Chojnacki, 2018). The third industrial revolution is also a period when enterprises began the computerisation of their activities. The increase in efficiency and the simultaneously falling prices of computer equipment stimulated the implementation of the systems of production control and planning and warehouse management. Thanks to greater precision in the planning and monitoring of manufacturing processes, manufacturing became more flexible and more precise (Płoszyński, 2018). Industrial revolution 3.0 also brought the first attempts at reducing the area of the emerging technopoles. There were attempts at using smaller spaces to obtain the results obtained from bigger areas. This period was also characterised by the first steps at using technology to replace human work with the work of machines or computer systems. In summary, the two principal achievements of industrial revolution 3.0 were the optimisation of the use of resources and the optimisation of manufacturing space management (Chojnacki, 2018). Additionally, it should be noted that it was during the third industrial revolution that intense development was observed in the area of design, implementation and application of software for controlling the flow of goods, materials and information. Since the 1950s, tools assisting in the management of warehouse inventory started to be developed, both in the material and non-material (informational) aspect. The following years brought further development of these tools and the extension of their functionality onto the domain of material requirements planning (MRP), where the first MRP systems were applied. The end of the millennium was a time marked by even more dynamic development of applications supporting manufacturing processes by scheduling production and sales, and finance management in Manufacturing Resource Planning II (MRP) systems up to advanced management systems of material, financial and information resources flow – MRP III / ERP (Enterprise Resource Planning). These evolved into the most advanced form: ERP II (Extended ERP), which offers the possibility of coordination and cooperation of suppliers and customers throughout the value chain of product or service creation (Wesołowska, 2013). Figure 2 illustrates the successive industrial revolutions, identifying the most characteristic discoveries and advances for each period.

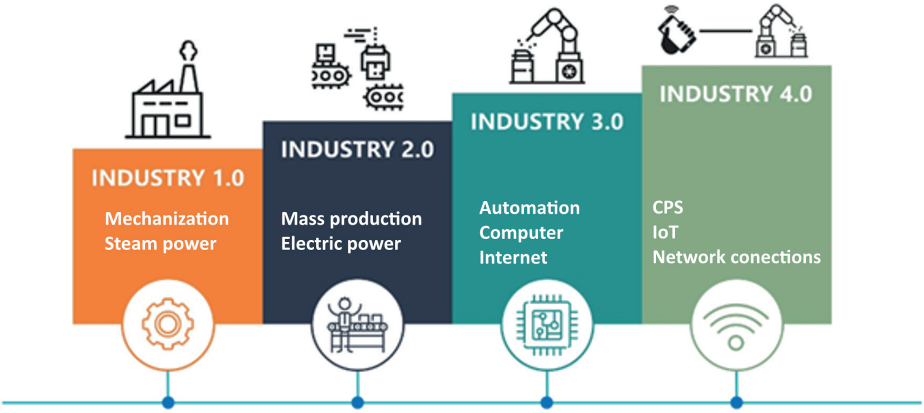

Figure 2. Technological revolutions in industry
Source: (own elaboration based on: Trillium Network, 2019)

3. Industry 4.0 and its foundations

The ongoing fourth industrial revolution is technologically the most complex one. Dynamic market changes, broad and universal access to modern technologies and innovative scientific research have given new possibilities to the creators of logistics services (Goncerz, 2018a). The high level of education in society, changing lifestyle, migration to cities, strong interest in social media and widespread access to the internet are among the drivers of technological progress. The progress can be defined as a three-dimensional space comprising the following three dimensions:

– smart factories;
– universal digitisation;
– value chain management.

It is therefore obvious that modern enterprises aspiring to market competitiveness should find themselves on all the three planes listed (Goncerz, 2018b). Figure 3 illustrates the components affecting the potential development of enterprises under the concept of Industry 4.0.

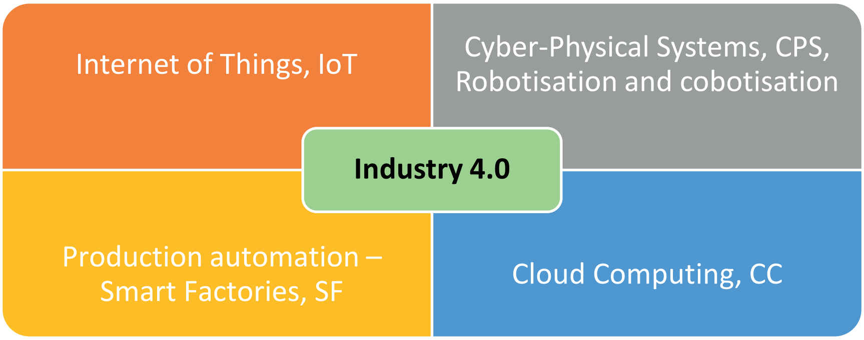

Figure 3. Main components determining the development of the idea of Industry 4.0 as the fourth industrial revolution
Source: (own elaboration)

To face the contemporary market challenges, enterprises need modernisation measures aimed at applying modern technologies, which should lead to partial or even total automation and robotization of manufacturing.

3.1. Internet of Things (IoT)

When writing about Industry 4.0 as a technological trend conducive to the development of automation of logistics processes, it is necessary to recall the pillars supporting the revolution. The first one is the Internet of Things. One of the key elements necessary for continuous development is the appropriate level of data availability (Goncerz, 2018a). The Internet of Things is based on the assumption that all sorts of devices will be connected in a network. This idea somewhat suggests a vision of the future world, where physical and digital devices are connected to an infrastructure that enables the sending, sharing, collecting and processing of information. The concept of the Internet of Things, like any concept, has its main demands: always, everywhere and with everything, which indirectly relate to the time and place utility of transferred and processed data. In order to meet these demands and adopt the concepts of IoT, manufacturing firms have to reach out for a technology that will initially allow them to fully digitalise the processes implemented so that the machinery park and its constituent devices are capable of accurately and efficiently identifying events, communicating and cooperating. IoT is currently considered to be one of the key components of the already omnipresent internet, simultaneously constituting a clear direction of its development and a huge socio-technological leap transforming the perceptions of the methods of resource exploitation (Brachman, 2013).

3.2. Cloud Computing (CC)

Analyses of how many variables and factors, including unpredictable ones, such as climate conditions or disasters, affect production nowadays lead to the conclusion that it is information, its amount and quality that is of a very high value. At the same time, it needs to be stressed that with the growth rate of the order of magnitude of data growing exponentially, it is not only information itself but the methods of recording, gathering, storing and processing it that prove to be crucial. The next foundation of the fourth industrial revolution is Cloud Computing. The most accurate description of what Cloud Computing is by enumerating the major tasks performed by this tool: performing mass, complex calculations and analyses based on data from numerous feeding channels. Figure 4 presents potential sources of data feeding Cloud Computing. They include, above all, analogue recorders, sensors, transaction records and information "downloaded" from the internet, fora, online shop websites and social media.

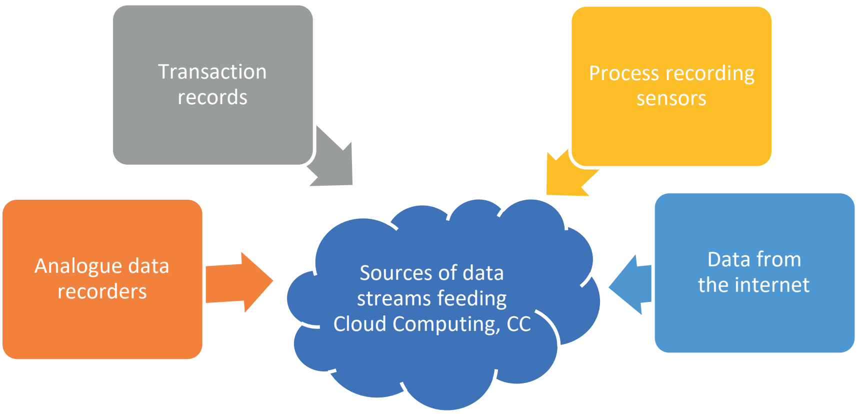

Figure 4. Sources of data streams feeding Cloud Computing
Source: (own elaboration)

Cloud Computing itself is a new kind of service where computing power is a product made available for a payment in the capacity and at the time adjusted to the customer's needs (Goncerz, 2018a).

3.3. Cyber-Physical Systems (CPS)

Cyber-Physical Systems are an essential element of the fourth industrial revolution. These systems make it possible to build smart networks of communication between people, devices or even products and resources. Growing demand for a highly individualised product requires a lot of flexibility from production lines and systems managing them. As a consequence, the time of potential reaction to external stimuli or those coming from within the enterprise must be as short as possible. The application of an appropriate technology permits efficient and successful human-machine communication. The most commonly used technologies that can facilitate manufacturing processes and communication-related processes in Cyber-Physical Systems are Radio Frequency Identification (RFID), Near Field Communication (NFC), mobile robots and Augmented Reality (AR). RFID is a technology used to streamline the reading of data included in labels or microprocessors by means of radio waves. NFC is a technology enabling proximity communication between two participants of the process implemented, also based on radio waves. Mobile robots are usually autonomous devices used to transfer resources or goods. Augmented reality is a technology with the strongest impact on human work – through the digital visualisation of elements non-existent in reality, new information or objects are plotted on an element of machinery park, production line or a specific product or resource, existing in reality (Kiraga, 2016).

The current industrial revolution can thus be divided into three clusters: technological, digital and biological. The subject of activity within the physical cluster are all modern materials and technologies. Autonomous devices such as drones, self-driving systems and robots cooperating with people during production-related activities – the so-called cobots – are good examples of such technologies used in logistics processes. The digital cluster is the most essential area serving as the driving force of the fourth industrial revolution. This cluster includes all the devices and solutions enabling access to the internet and the efficient exchange, storage and processing of unlimited amounts of data through it. Hence the universality of digitisation and the great significance of the physical cluster give rise to the refinement of human-machine integration and cooperation. The biological cluster has the least to do with the subject matter of the paper as it involves specialist studies on human DNA codes (Goncerz, 2018c).

4. Robotization in logistics

A high quality of products, one of the key factors of the consumer's decision in today's market, depends very strongly on the quality control system of the manufacturing enterprise. In a modern model factory, the collection of samples, to be later used to evaluate the quality of products, will be performed by autonomous robots. They will be called to the production line by a specialised CPS, which will launch the sample-collecting process on the basis of data transmitted from the production line, sensors built in the production line and a special algorithm (Goncerz, 2018a).

4.1. Automation of logistics processes

Automated production lines, autonomous machines, equipment facilitating warehouse processes and industrial robots, designed in such a way as to minimise the necessity of human work and physical effort, are among the basic elements of the logistics support system. Owing to such systems, less physical power is needed during the picking of products, boxes and containers onto pallets. The concepts of automated warehouse, automatic data management system and automatic distribution of goods in a warehouse are aimed at eliminating human errors in processes associated with the storage of raw materials and goods. The targets of significant automation of manufacturing and warehousing processes also imply a reduction of the physical presence of staff. The reduction of physical participation of people is just one of the elements of savings through automation. No need of physical human intervention in manufacturing or warehousing processes could also lead to cost reductions in the domain of energy consumption for lighting and heating of the facilities. The implementation of robotization and automation of logistics processes requires all the conducted tasks and activities to be subordinated to a specific management system, usually based on information from CC (Čujan, Marasová, 2018).

4.2. Cobotization in logistics

However, the phenomena of automation and robotization of logistics processes do not lead to absolute elimination of human participation in the process of manufacturing goods or services. Under the concept of Industry 4.0, certain human-machine relations come into being and become consolidated. Technology used in the process of production automation, predominantly in areas related to physical flows and their robotization, can affect employees to a lesser or greater extent. This involves an array of new possibilities, but also numerous challenges. Hence, one of the first steps taken during the automation/robotization of production should be to define the type of interaction between humans, machines and IT systems, coexisting in the production system. Four types of such interaction are generally distinguished: coexistence, cooperation, collaboration and substitution (for human work by machines) (Bauer et al., 2018). Figure 5 illustrates three types of human-machine physical interaction during the performance of manufacturing activities.

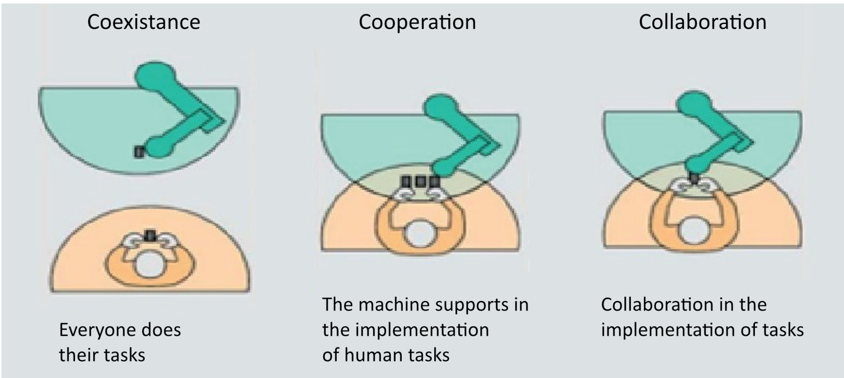

Figure 5. Types of human-machine cooperation
Source: (own elaboration based on: Bauer et al., 2018)

In the case of coexistence, the work areas of the human and the machine are completely separated. Moreover, the machine carries out a completely different phase of the production process, so the goals of the human's and machine's activities are also different. Cooperation shown in the middle image is a situation where the work areas of the machine and the human overlap. Thus, each of them performs certain activities the combination of which is supposed to achieve a common goal. The most integrated form of cooperation is the situation shown on the right of the picture.

Total integration of activity stands not only for a common goal or area of activity, but also jointly performed activities which are complementary. Complementary activities are being adjusted to the current situation, leading to the achievement of maximum productivity of the process implemented (Onnasch et al., 2016).

5.1. Smart Factory (SF)

Technological innovations and their application in production justify a thesis about the next industrial revolution. Intelligent production taking place in factories complying with the generally accepted model of Smart Factory is not only a current trend, but also a response to the demand side of the market and the effect of adjustment to the increasingly common implementation of sustained development policy. However, despite the increasing prevalence of applications of automation and robotization in manufacturing, there is no consistent definition of Smart Factory. A model Smart Factory is presented in Figure 6.

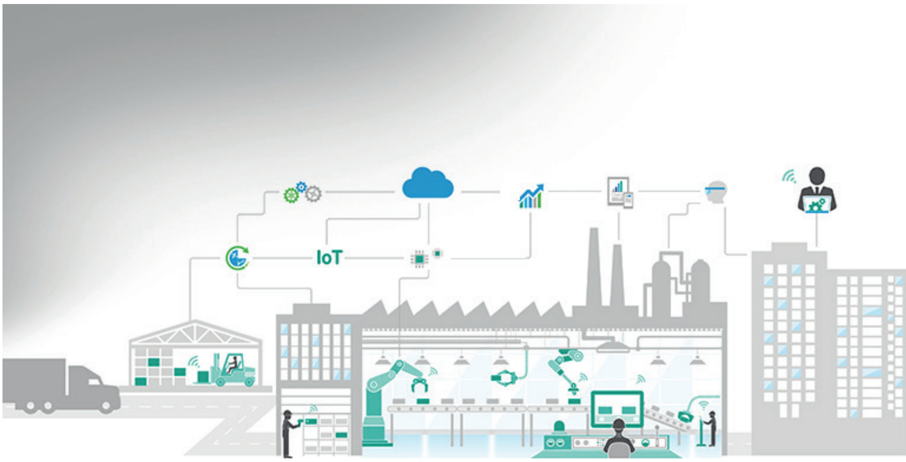

Figure 6. Smart Factory model
Source: (own elaboration based on: Orbis Company, 2019)

A tentative definition of SF should include several characteristics of Smart Factory. Firstly, it is the autonomous and systemic identification of phenomena taking place in manufacturing processes, combined with the ability to record, gather and process data. Secondly, SF uses technologically advanced sensors in the processes of data acquisition and management. Thanks to the sensors, data are processed in real time and oftentimes Cloud Computing is used simultaneously. Also, it is noteworthy that one of the fundamental conditions of the establishment of Smart Factory and its subsequent effective functioning is the use of the Internet of Things. Owing to the previously discussed networking of machines and devices operating in an enterprise, production will involve the cooperation of all the entities participating in the manufacturing process and supporting processes. Such a solution also means that decisions will made autonomously by using and exchanging information collected at the appropriate place and time (Cheng et al., 2018). What is important, the functioning of a Smart Factory is not possible without the application of automated production lines, fully or partly autonomous devices and cobots supporting humans at work. Figure 7 presents another major characteristic of SF, i.e. having a constantly updated virtual equivalent of a physical factory whose cyber model is based on digital models.

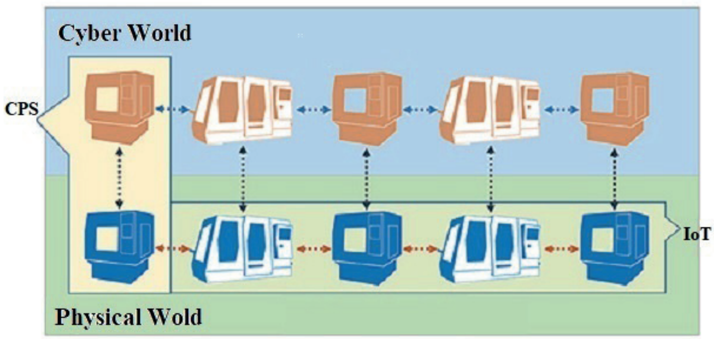

Figure 7. Coexistence of the physical and cyber world in Cyber-Physical Systems
Source: (own elaboration based on: Behrad Bagheri, 2015)

Thanks to this solution, it is possible, on the basis of a virtual factory model, to efficiently and reliably make a synchronous simulation and correction of plans while controlling current production. Giving data an appropriate value and effective utilisation of data offers a lot of potential in terms of reliable decision-making. Through proper integration of the entire production system by means of effective data exchange, a factory can not only improve its flexibility in manufacturing capacity, but also acquire the ability to smoothly adapt to uncertain requirements and conditions imposed by customers or to possible disruptions and failures (Cheng et al., 2018).

6. Discussion

The approach to the automation of logistics processes presented in the paper is different from the way the phenomenon was perceived a few years ago. As the previous third industrial revolution was developing, the idea of process automation was systematised through the use of systems supplied with historical data. Production planning, forecasting and scheduling on the basis of historical data is no longer flexible enough, while the sequence of actions taken during the execution of these functions is too complex. Systems supporting production processes based on the Internet of Things and Cloud Computing, supported by autonomous sensors, have become one of the key methods of adding flexibility to the logistics processes supporting production, warehousing and transport. The study area offers multiple possibilities of a yet deeper analysis of the presented issues and phenomena. Along with the emergence of innovative technologies, enterprises tend to rush to adjust their machinery park, without adequate planning, implementation, monitoring and subsequent control of the project undertaken. This phenomenon may lead to overcapitalisation or venturing into a modernisation project that the enterprise is unable to finalise or fully benefit from. The source literature is full of overoptimistic descriptions of the automation of logistics processes. In the author′s view, however, before undertaking an activity aimed at achieving the expected goal, it is necessary to thoroughly analyse whether a solution leading to full automation always is the optimum solution. A vision of fully autonomous production lines or Smart Factories which are totally independent of employees is real. However, in the author′s opinion, the pursuit of this goal should gradual. Thus a perfect interim phase could be the introduction of partial automation of processes through the implementation of technologies based on human-machine cooperation.

Conclusions

Automation through robotization and cobotization is one of the key methods of streamlining production processes and the supporting logistics processes. The essence of the fourth industrial revolution is best reflected by Smart Factories. Their construction should be composed of elements identical with the identified pillars of Industry 4.0, and so in fulfilling specific goals in production and logistics processes they should be based on the Internet of Things, Cloud Computing and Cyber-Physical Systems. A technology management system thus organised will permit an efficient, effective and beneficial utilisation of the resources at the enterprise's disposal, while complying with the goals of logistics processes, namely giving the tangible and intangible resources adequate time and place utility. Automation does not necessarily mean total exclusion of manufacturing, warehouse or transport employees. Initially, robotization can be introduced by employing cobots to support people at work. Indeed, integral human-machine cooperation can significantly streamline logistics processes while lowering their costs. Robots are able to fulfil certain tasks more efficiently and faultlessly, but very often they are not able to autonomously carry out all the tasks in the entire value chain of a product. Through integral cooperation within Cyber-Physical Systems of humans and machines, enterprises could implement the initial stages of automation of their production processes and build an efficient internal transporting and warehousing system. At the same time, the existence of an information management system, often in the form of Cloud Computing, and the ability of machines to communicate (the Internet of Things) create solid foundations for new Smart Factories or the modernisation of existing facilities, which can become the response to the needs of both the demand and supply side of the market and the solution to the problems tackled by manufacturers and logistics services providers.

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