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MOTIVES FOR PARTICIPATION IN THE SHARING ECONOMY – EVIDENCE FROM LITHUANIA

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ABSTRACT

Information and communication technologies enable the emergence of a new phenomenon called the “sharing economy”. An increasing number of articles in the media as well as debates about the positive and negative aspects of the sharing economy show a growing interest in the subject. The paper aims to review the different approaches to the definition of the sharing economy and to present the authors’ views on the concept. The reviewed literature reveals the main drivers for participating in the sharing economy. A survey was conducted to learn more about the motives of Lithuanian people participating in this concept. The survey reveals the following leading factors of using the sharing economy platforms: an easy way to make extra money; supporting individuals and/or small/independent companies; meeting new people and having an interesting experience/doing something most people haven’t tried yet. The survey also reveals that most of the respondents prefer to own things rather than share them. Despite the widespread popularity of the sharing economy platforms in the world, this phenomenon is in its infancy in Lithuania.

KEY WORDS

sharing economy, collaborative economy, collaborative consumption, peer-to-peer

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INTRODUCTION

The last few years have seen a keen interest in a new phenomenon – the sharing economy. A new paradigm of consumption and shared use instead of ownership of resources is emerging. As Leadbeater (2009) wrote: “in the economy of things, you are identified by what you own – your land, house, car. In the economy of ideas that the web is creating, you

are what you share... The biggest change the web will bring is in allowing us to share with one another in new ways”. Leadbeater (2007) states “if the 20th century was the age of industrial work, mass production for mass consumption, then mass participation will be one of the defining features of the century to come”. An increasing number of articles in the press and on the Internet as well as discussions in social networks

show a growing interest in the sharing economy. Questions have been raised about the overall importance of the sharing economy and future directions. There are also discussions about the main factors determining the rise of the sharing economy, its impact on economic growth and the ways, in which it affects the labour market. However, it can be observed that there are different approaches to the sharing economy. Proponents and opponents have investigated positive and negative aspects (Schor, 2010, 2014; Childs, 2013; Sundararajan, 2014; Zervas et al., 2016; Gaskins, 2010; Yglesias, 2013). Supporters of the sharing economy highlight the benefits that it provides: the possibility to earn extra money, meet people, find new friends, and save costs. Proponents of the sharing economy assert that it provides new opportunities for individuals by putting their inactive assets to work, thus earning additional income. For example, an empty room, a car or some tools they do not need to use every day can be shared as underutilized assets and earn money. This allows people to use the assets only when needed and pay for their temporary use rather than ownership. This changes consumer behaviour. It can, therefore, be said that a new approach to the ownership of things is emerging. Sharing can be described as an alternative to private ownership. Items can be used when they are needed, not requiring their ownership. Sceptics, on the other hand, emphasize potentially negative aspects of the sharing economy and the new challenges it brings, e.g. De Grave (2014) states that “people in the sharing economy are nothing but an extreme precariat”. Orsi (2013) refers to the legal problems of the sharing economy. Malhotra & Van Alstyne (2014), Koopman et al. (2015), Katz (2015) examine the impact of the sharing economy on traditional businesses and regulation issues. The traditional service providers, e.g. hotels, taxi companies and banks complain that the rules of the game are unfair. It is argued that while normal services are regulated (e.g. licenses, employment regulations, hygiene, security, etc.), the sharing economy platform companies are not. It should be noted, that the largest sectors of the sharing economy are accommodation, transport, household, professional, technical, and financial services.

Despite numerous discussions about positive or negative aspects of this new phenomenon, there is no commonly accepted definition of the sharing economy. New terms such as the collaborative consumption, the collaborative economy, the sharing economy, the peer economy, and the gig economy are emerging in the literature, and in many cases, these new terms

describe the same phenomenon. However, it should be emphasized that some authors use these terms interchangeably, while others differentiate between them by offering separate definitions for each. Regardless of the fact, there is no consensus on the definition of the sharing economy. Differences in the understanding of this rapidly growing phenomenon are also observed. Moreover, there have also been discussions whether the meaning of sharing has been consistent with the phenomenon that we refer to as the “sharing economy”. In general, the literature of the sharing economy could be divided into two main groups: one concerning legal aspects of the sharing economy, and the other studying its impact on traditional businesses. It should also be noted that some authors examine whether the meaning of the word “sharing” is the same in the business model described as the sharing economy.

The main purpose of this article is to learn how the sharing economy is characterized by different authors. Therefore, the main literature on the sharing economy will be reviewed. Moreover, the paper seeks to investigate the motives for and arguments against the participation in the sharing economy. If people are willing to participate in the sharing economy, what assets are they willing to share? Furthermore, the authors have raised the question whether the motives to participate in the sharing economy differ among countries. Surveys have been conducted in various countries, but not in Lithuania. The authors raise the question whether people in Lithuania are aware of the sharing economy and what motives they have to participate in it.

1. DEFINITION ISSUES OF THE SHARING ECONOMY

The Oxford English Dictionary (OED) provides the following definition of the sharing economy: “an economic system in which assets or services are shared between private individuals, either for free or for a fee, typically by means of the Internet”. Zervas et al. (2016) define the sharing economy just as “multi-sided technology platforms” (Table 1). In many cases, the terms sharing economy, collaborative consumption, and connected consumption are used interchangeably. Besides, we can discover that the concept of the sharing and collaborative economy has been used synonymously (e.g. it illustrates the event, which

Tab. 1. Definition of the sharing economy

AUTHOR (SOURCE)	DEFINITION
Belk, R. (2007)	Sharing is an alternative to the private ownership that is emphasized in both marketplace exchange and gift giving
Botsman, R. (2015)	An economic system based on sharing underused assets or services, for free or for a fee, directly from individuals
De Grave, A. (2014)	The sharing economy is just one part of the collaborative economy, as is distributed production, P2P (peer-to-peer) finance and the open source and knowledge movements
Dervojeda, K. et al. (2013)	Accessibility-based business models for peer-to-peer markets
Hamari, J. et al. (2015)	An umbrella concept that encompasses several ICT developments and technologies, among others CC, which endorses sharing the consumption of goods and services through online platforms
Matofska, B. (2016)	A socio-economic ecosystem built around the sharing of human, physical and intellectual resources
Olson, M. J. & Kemp, S. J. (2015)	A sharing economy is a market whereby: 1) Users are individuals, businesses, or machines; 2) There is excess supply of an asset or skillset and sharing creates economic benefit for both the sharer and the user; 3) The Internet provides means for communication and coordination of the sharing
Parsons, A. (2014)	The sharing economy leverages information technology to empower individuals or organisations to distribute, share and re-use excess capacity in goods and services
PricewaterhouseCoopers (2015)	Sharing economies allow individuals and groups to make money from underused assets
Schor, J. B., & Fitzmaurice, C. J. (2015)	The wide and varied range of old, revamped and new practices whose central characteristics are the ability to save or make money, provide a novel consumer experience, reduce ecological and carbon footprints, and strengthen social ties
Stephany, A. (2015)	The sharing economy is the value in taking underutilized assets and making them accessible online to a community, leading to a reduced need for ownership of those assets
Woskow, D. (2014)	Online platforms that help people share access to assets, resources, time and skills
Zervas, G. et al. 2016	Multi-sided technology platforms
www.investopedia.com	A sharing economy is an economic model in which individuals are able to borrow or rent assets owned by someone else
www.oxforddictionaries.com/words/about	An economic system in which assets or services are shared between private individuals, either for free or for a fee, typically by means of the Internet

has been held in Brussels on February 2016. The event's title "The sharing/collaborative economy" (<http://bruegel.org/events/the-sharingcollaborative-economy/>). However, De Grave (2014) states that the concepts of the collaborative economy and the sharing economy are different. De Grave (2014) emphasizes that the sharing economy is part of the collaborative economy, it "is distributed production, peer-to-peer finance and the open source and knowledge movements". Still, the terms sharing economy and collaborative consumption are used interchangeably by De Grave as well (2014). Table 1 shows the definition of the sharing economy suggested by various authors.

Erving (2014) has raised the question of how profit-making companies and individuals who share their assets for free, could fit into the category of the sharing economy. Furthermore, in Matthew Yglesias' (2013) view, the sharing economy is an inappropriate term to describe business models, such as short-term car or bike rentals. According to the author, when a firm owns a number of cars and offers them to its customers as short-term rentals, this kind of activity cannot be attributed to the sharing economy. That is not car sharing but business. Transactions in the sharing economy do not encompass sharing in the traditional understanding of the word "sharing". Belk (2014) sustains that approach and argues that some new activities, using such new terms as the sharing

economy, in essence, are not sharing at all and are better characterized as “pseudo-sharing – commodity exchanges wrapped in a vocabulary of sharing”. According to Belk (2007) “sharing is an alternative to private ownership that is emphasized in both marketplace exchange and gift giving. In sharing, two or more people may enjoy the benefits (or costs) that flow from possessing a thing. Rather than distinguishing what is mine and yours, sharing defines something as ours”.

Furthermore, Belk (2014) distinguished four types of pseudo-sharing:

- long-term renting and leasing;
- short-term rental;
- online sites “sharing” your data;
- online-facilitated barter economies.

According to Belk (2014), the true forms of sharing are ephemeral intentional online sharing, online-facilitated offline sharing, peer-to-peer online sharing and, online facilitated sharing.

Botsman (2013) argues that the terms collaborative consumption, collaborative economy, sharing economy, and peer economy have different meanings, but they also have common essential ideas that explain the overlap. Hamari et al. (2013) state that the concept of the sharing economy is derived from the collaborative consumption concept. Botsman and Roo (2010) attempt to define the concept of the collaborative consumption by describing it as “traditional sharing, bartering, lending, trading, renting, gifting and swapping, redefined through technology and peer communities”. In the author’s view, the collaborative consumption can be divided into three systems: product service systems, redistribution markets, and collaborative lifestyles. Product service systems are characterized by allowing members to pay for the benefit of using a product without the need of owning it. Redistribution markets are redistributing things from someone who does not need them to someone who does. eBay was founded more than twenty years ago, in 1995 and can be described as the first widely known marketplace for the redistribution of things. eBay is “dedicated to bringing together buyers and sellers in an honest and open marketplace” (<https://www.ebayinc.com/>). This sentence describes the essence of the sharing economy platforms: linking people who have goods, which are no longer needed or wanted, with people who need them. And the third system of collaborative lifestyles can be described as sharing and exchange of intangible assets such as time, skills, and experience. Schor (2014) takes a similar approach arguing that the shar-

ing economy activities fall into four broad categories: recirculation of goods, increased utilization of durable assets, exchange of services, and sharing of productive assets. Schor and Fitzmaurice (2015) expanded the categories described above by adding one more, i.e. building social connections.

Botsman (2013) defines the collaborative consumption as part of the collaborative economy, which she describes as “an economy built on distributed networks of connected individuals and communities versus centralized institutions, transforming how we can produce, consume, finance, and learn”. The collaborative economy involves collaborative finance, collaborative consumption, collaborative education, and collaborative production (Fig. 1).

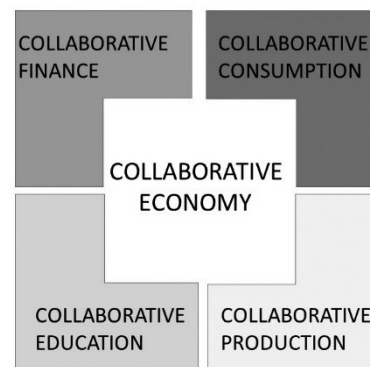


Fig. 1. Collaborative economy components

Source: authors’ elaboration based on (Botsman, 2015).

It should be noted that the collaborative economy is transforming the way people produce, consume, finance, and learn. The collaborative economy is transforming businesses and society by leveraging technology efficiently by matching supply and demand in a trusted environment. Botsman (2013) describes the sharing economy as an economic model based on sharing underutilized assets for monetary or non-monetary benefits. Besides, Botsman (2013) characterizes peer economy as person-to-person marketplaces that facilitate the sharing and direct trade of products and services built on peer trust. As shown in Figure 2, the collaborative consumption is a part of the collaborative economy. The collaborative consumption involves product service systems, redistribution markets, and collaborative lifestyles.

As noted above, the concept of the sharing economy is derived from the collaborative consumption concept. Accordingly, Botsman (2015) says that the sharing economy embraces “sharing underused assets or services”. Botsman (2015) defines the sharing

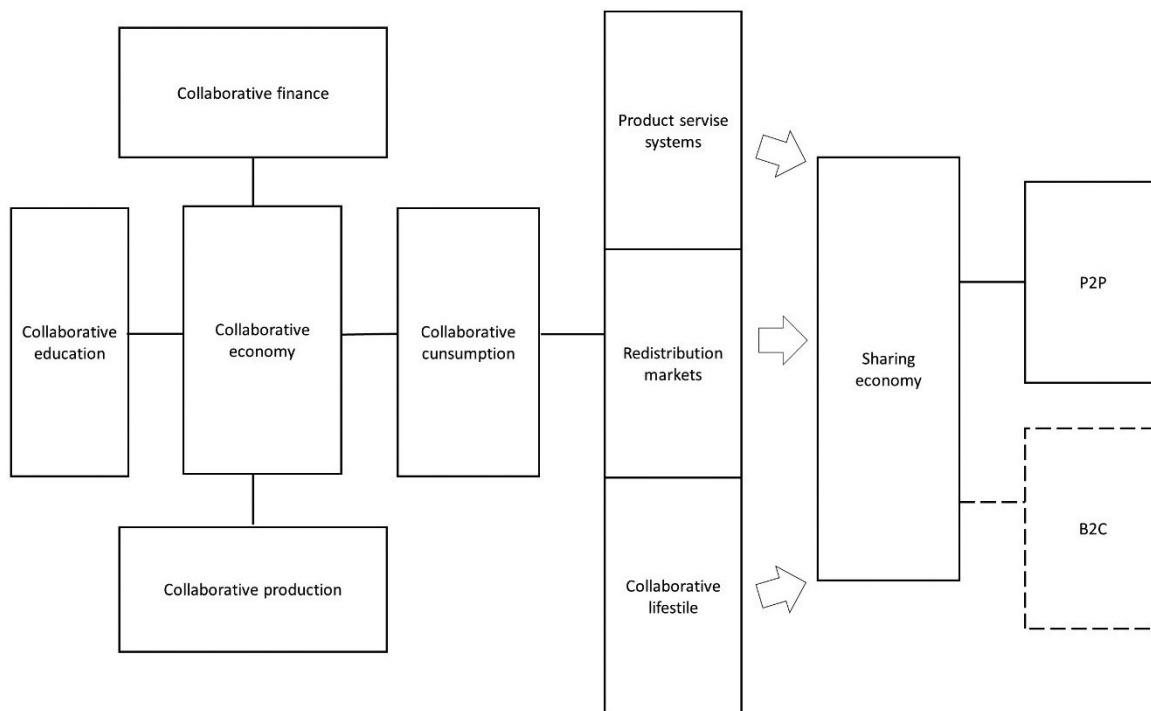


Fig. 2. Sharing economy in the context of the collaborative economy

Source: author's elaboration based on (Bostman, 2013).

economy narrowly, only as trading between individuals. De Grave (2014), Derojeda et al. (2013), Woskowiak (2014) and others take a similar approach and focus only on the peer-to-peer business model.

The authors of this paper propose a broader concept of the sharing economy, including not only private individuals but businesses as well. Furthermore, the authors propose peer-to-peer, business-to-peer, and business-to-business models. It is noted that new technologies, such as the Internet are the main drivers for the expansion of the sharing economy. New technologies have enabled the emergence of new multi-sided platforms, where people or organisations can share assets, skills, time, etc. The authors would like to underline, that the term “sharing” should not be understood in an altruistic way as helping others or charity. It is a matter of convenience, a fast and simple way to serve consumers who need products or services. They “share” those products or services via digital platforms.

In authors' view, the sharing economy could be defined as multi-sided digital platforms that create an open market for services and products and act as an intermediary between users and service providers. Members of the sharing economy can be individuals as well as businesses.

2. EMERGENCE OF THE SHARING ECONOMY

The sharing of unused goods for free or for money is not a revolutionary innovation. Today, the Internet and mobile technologies provide new forms and opportunities. It should be pointed out, that the most important factor that influenced the development and expansion of the sharing economy are digital technologies since they changed the traditional market behaviour, which was not previously possible. Even though the Internet is more than 20 years old, there has been a recent rapid development of the new technologies that enable changes in human behaviour and allow new opportunities. The rise of social media networks, the development of smart devices, and innovative technologies have had an enormous impact on business (Kaplan & Haenlein, 2010; Delina & Tkáč, 2015). Digital technologies are advancing at a very fast rate. They are not only transforming the way people interact but are also inventing a new way, in which people consume and what they consume (Hosu & Iancu, 2016; Wang & Zhang, 2012). As Sundararajan (2016) points out, a confluence of digital enablers created by wireless broadband, mass market smartphones, digitalized social networks, i.e. the development of digital technologies, is one of the

main factors that influences the emergence and growth of the sharing economy. Furthermore, Sundararajan (2016) defines three fundamental forces that distinguished digital technologies from other GPT (general purpose technologies). These forces are: rendering things as information and presenting information digitally; the growth of hardware power, the storage and miniaturization of digital devices; and increased programmability and modularity of devices. Digital technologies enable new types of sharing services. It should be stated, that Internet platforms and smartphone applications connect people who need services with those who can provide them (Schor, 2014; Smith, 2016). The sharing economy platforms differ from single-sided platforms where a single seller offers his/her products to buyers. The sharing economy platforms are peer-to-peer decentralized platforms where two members interact directly with each other without the need of a third-party intervention. Sundararajan (2014) describes the platforms as a person-to-person marketplace, which facilitates the exchange of goods and services between peers. Individuals or small businesses supply goods and services to these marketplaces and individuals (called consumers) buy, rent and consume.

On the other hand, the Internet and technological progress are not the only factors leading to the emergence and popularity of the sharing economy. According to Parson (2014), the economic downturn and other aspects, such as government austerity and environmental concerns, influenced the new paradigm of the shared use of resources. Botsman and Roo (2010) take a different approach and assert that the sharing economy no only responds to the economic downturn or consequence of the global financial crisis, but that it is a growing movement with millions of members who participate in the movement and receive benefits from it.

The benefits of the sharing economy are that it provides a greater range of services, gives users more options to choose from, and can offer a higher quality of service at a better price. New types of services based on digital platforms bring together users and service providers, satisfying user expectations to the best possible extent and, furthermore, contribute to the promotion of innovation and the increase in transparency. Information technology allows the sharing of goods for a short period, quickly, conveniently, and at an attractive price. It fundamentally

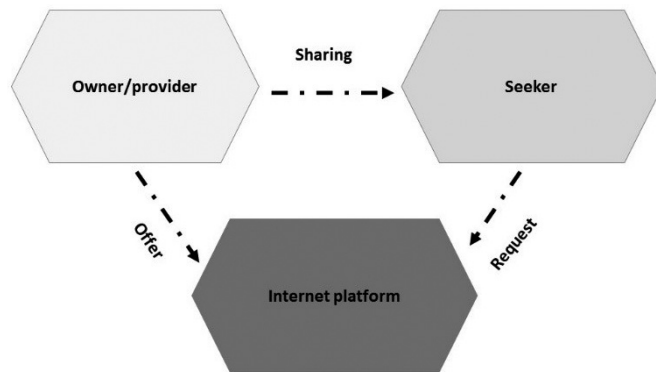


Fig. 3. Model of the sharing economy model

changes consumer habits since it provides the opportunity for people to consider and evaluate the pros and cons of purchasing the items. The sharing economy model contains three parts: sellers (or owners of assets), buyers (or seekers for goods and services) and developers of digital platforms (Fig. 3). Collaborative or sharing Internet platforms create an open market for services and products.

3. BENEFITS OF THE SHARING ECONOMY

The proponents of the sharing economy indicate the following benefits for the consumers: adjusting to the needs of individuals rather than reacting to changes in demand; offering unique experiences that commercial providers cannot ensure; and lower prices compared to commercial providers (Olson & Kemp, 2015). Sundararajan (2014) believes “that peer-to-peer business enabled by digital platforms will constitute a significant segment of the economy in the coming years. It is likely that this transition will have a positive impact on economic growth and welfare by stimulating new consumption, by raising productivity, and by catalyzing individual innovation and entrepreneurship”.

It should be noted, that the sharing economy creates new networks within societies. It creates trust and builds community, people feel connected to neighbours or co-workers. The success of the sharing economy is based on people’s trust in one another. So the reputation and the ability of market participants to sell their services is especially important. If the user is not satisfied with service provider’s work, he gets a low rating on the Internet, and other potential customers may decide not to use services from that service provider.

The sharing economy is believed to be advantageous to the environment because it makes greater use of existing resources and the potential energy savings that would result from car sharing and bike sharing. Schor (2010) talks about environmental crisis that humanity faces and suggests that it can have a radical change in people's values, how they think about consumer goods and how they live. It is believed that social innovations and new technologies can simultaneously enhance peoples' lives and protect our planet. Furthermore, Schor (2010) believes that economics based on sharing could help rebuild the social ties that have been lost through hyper-consumer culture.

It can be argued that benefits of the sharing economy correspond with the dimensions of sustainable development: economic, social and environmental (Table 2).

Tab. 2. Benefits of the sharing economy

ECONOMIC BENEFITS	ENVIRONMENTAL	SOCIAL BENEFITS
<ul style="list-style-type: none"> - raising productivity - catalysing individual innovation and entrepreneurship - cost savings 	<ul style="list-style-type: none"> - resource efficiency - potential energy savings 	<ul style="list-style-type: none"> - make meaningful connections - re-emergence of community - social inclusion

It should be mentioned, that the sharing economy could contribute to the achievement of sustainable development goals. Therefore, considerations should be given to the incorporation of new indicators to the current set of indicators that measure sustainable development goals.

4. INTENTION TO PARTICIPATE IN THE SHARING ECONOMY

The sharing economy depends on people's intention to share. Therefore, Nielsen (2014) conducted a global survey of how people in different parts of the world are willing to participate in sharing communities (% of online consumers willing to participate in the sharing economy). The results of the survey are shown in Figure 4.

The Nielsen survey also reveals the kind of products people are willing to share. People around the world are most willing to share or rent electronic devices for a fee (28%), 26% of global respondents are keen to share intellectual property, 23% – power tools, 22% – bicycle, 22% – clothing, and 22% – household items (Nielsen, 2014).

Another survey conducted by Hamari et al. (2015) investigated the main drivers for participating in the collaborative consumption. Hamari et al. (2015) gathered information from people registered on the Collaborative Consumptions site. The findings reveal that sustainability, enjoyment of the activity and economic gains were the main factors encouraging people to participate in the collaborative consumption.

In 2014, Havas Worldwide partnered with Market Probe International and surveyed 10574 people, aged 16 and older from 29 countries. 46% of respondents agree they would rather share things than own them. The survey reveals that the most appealing aspects of the sharing economy are: saving money (32%), feeling active and useful (13%), reducing

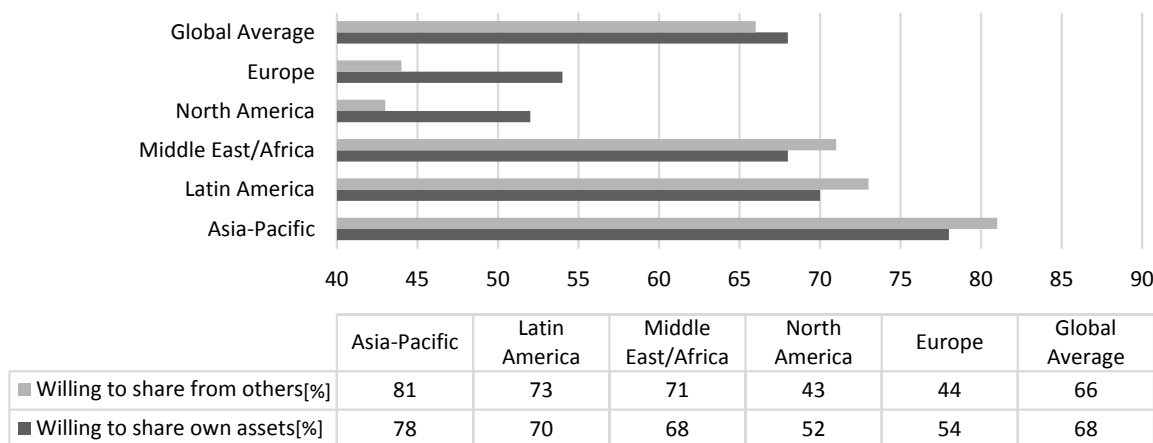


Fig. 4. Participation in the sharing economy

Source: authors' elaboration based on (Nielsen, 2014).

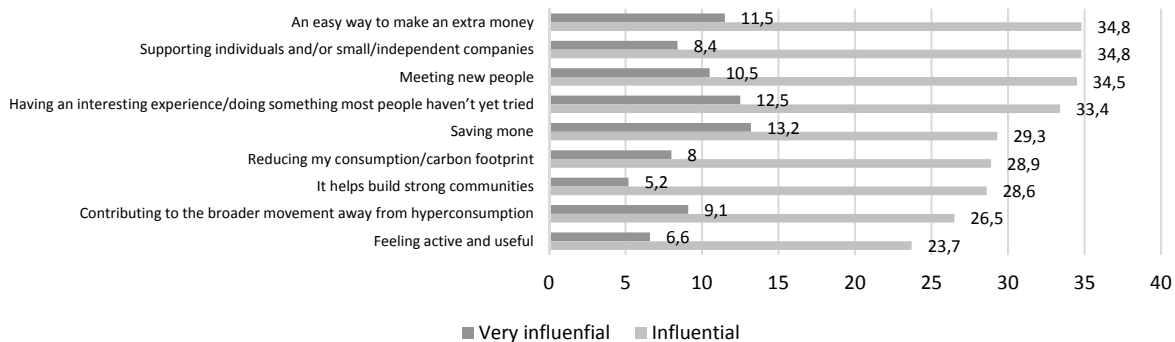


Fig. 5. Factors that influence participation in the sharing economy [%]

consumption/carbon footprint (13%), contributing to the broader movement by staying away from hyperconsumption (10%), supporting individuals and/or small/independent companies (9%), having an interesting experience/doing something most people have not tried (8%), and meeting new people (6%).

The authors of this paper conducted a survey in Lithuania. To learn more about the motives of Lithuanian people to participate in the sharing economy, a survey of 287 persons aged 18-25 years was conducted. The survey revealed that 32% of respondents have not heard about the sharing economy and even though 68% of respondents were aware of the sharing economy, only 33.8% of them have used the sharing economy services. 52.6% of respondents did not know if they would participate in the sharing economy in the future, and only 20.6% answered, that their participation will increase. Only 15.7% of respondents agree they would rather share things than own them and 36.6% of respondents disagreed with the statement.

The respondents were asked to select factors that influence their participation in the sharing economy. The leading factors for using the sharing economy platforms were an easy way to make extra money (34.8%), supporting individuals and/or small/independent companies (34.8%), meeting new people (34.5%), and having an interesting experience/doing something most people haven't yet tried (33.4%), (Fig. 5).

Respondents were asked if they would consider sharing things or paying someone to borrow their things in the next 12 months. Figure 6 shows what respondents consider sharing in the next 12 months, and Figure 7 shows what respondents consider paying someone to borrow their things in the next 12 months.

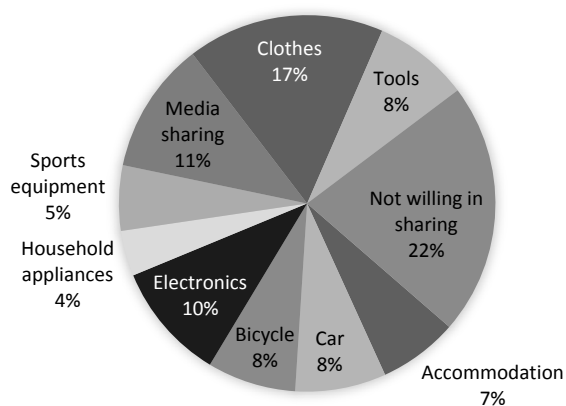


Fig. 6. Consider sharing things for money in the next 12 months

As shown in Figures 5 and 6, 16% of respondents are not willing to borrow from others, and 22% are not willing to share their goods with others. Despite the widespread popularity of the sharing economy platforms in the world, this phenomenon is in its infancy in Lithuania. The author's survey produced a unique response in the sharing of items. While most literature indicate that people are willing to share

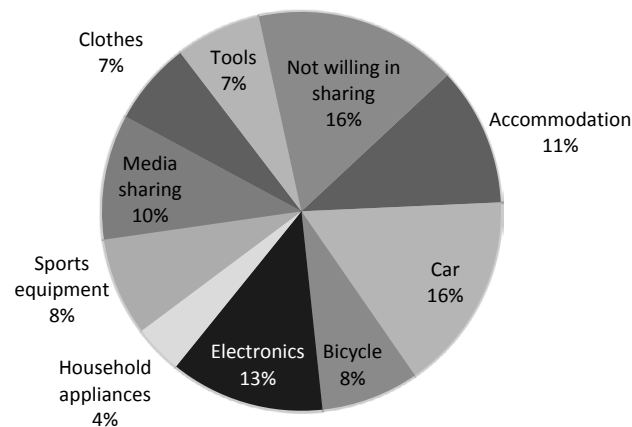


Fig. 7. Consider paying someone to borrow their things in the next 12 months

electronics, bikes, and similar items, in Lithuania, the most common item was clothing.

The survey reveals that only 33.8% of respondents in Lithuania have used the sharing economy services, and 52.6% of respondents did not know if they would participate in it in the future. As Sundararajan (2016) emphasizes, wireless broadband, mass market smartphones, digitalized social networks are the crucial elements of the sharing economy. If people do not have Internet access or a smartphone, they are not able to participate in the sharing economy through the sharing economy digital platforms. It should be noted, that in terms of the technological development, Lithuania does not lag behind the most developed countries. As shown in Figure 8, in mobile phone subscriptions per 100 inhabitants, Lithuania is ahead of such countries as the USA, Germany, the United Kingdom and France.

As shown in Figure 9, Lithuania does not lag far behind the more developed countries in terms of

individuals using the Internet. In 2015, Lithuania had 71.38% of individuals using the Internet, while the USA had 74.55%, France – 84.69%, Germany – 87.59%, and the UK – 92%. Furthermore, Lithuania is far ahead in the EU in terms of its broadband speed and fibre-to-premises penetration.

In Lithuania as well as other developed countries, the requirements for creating and using digital platforms and participating in the sharing economy are present. However, no legal restrictions exist for the sharing economy companies in Lithuania. Thus, one can say that Lithuania has all the possibilities for creating and using digital platforms. Therefore, one must look elsewhere for the reasons why people are not engaging in the sharing economy. There might be many reasons such non-participation, such as the lack of information about the sharing economy, its benefits, opportunities, etc. One can conclude that it could be very informative and beneficial to conduct a survey on such a subject.

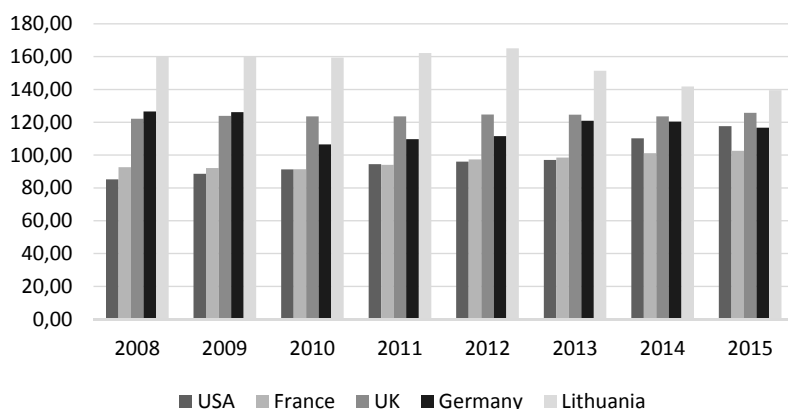


Fig. 8. Mobile-cellular telephone subscriptions per 100 inhabitants
Source: (ITU).

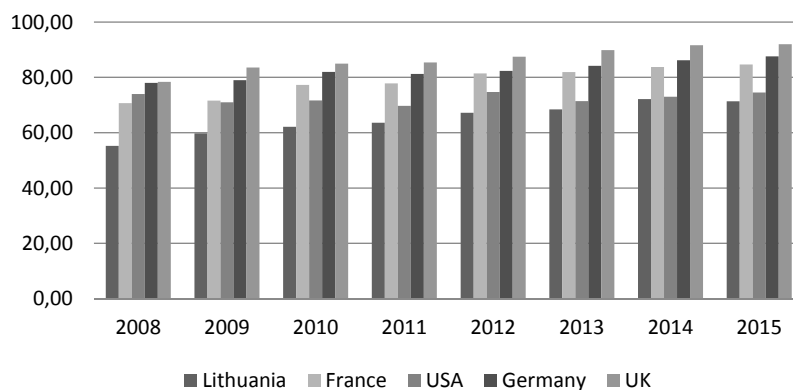


Fig. 9. Percentage of individuals using the Internet
Source: (ITU).

CONCLUSIONS

The sharing economy is a new phenomenon, and there are still many unanswered questions concerning its impact on traditional businesses and the labour market or its future directions. Consequently, it is important to analyse the sharing economy's impact on employment. What are its opportunities or challenges to the labour market? The sharing economy aspects, such as the impact on GDP should be explored. However, the authors of the article note the lack of statistics concerning the sharing economy. Consequently, further research is necessary to have a meaningful debate about its benefits.

It should be noted that there is no consensus on the definition of the sharing economy. Usually, the sharing economy is defined rather narrowly, highlighting trade

between individuals. The authors propose a broader concept of the sharing economy and state that the sharing economy could be defined as multi-sided digital platforms that create an open market for services and products and act as an intermediary between users and service providers. Members of the sharing economy could be individuals and businesses.

Surveys available in the literature and that the survey conducted by the authors reveal that the most important factors that influence participation in the sharing economy are economic: saving money and an easy way to make extra money. However, social factors, such as being useful to society and supportive to local communities are noted as well.

Future research should emphasize the contribution of the sharing economy to the sustainable development. The question of how much sharing economy contributes to the sustainable development should be raised.

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CONDITIONS OF COOPERATION BETWEEN ENTERPRISES AND BUSINESS ENVIRONMENT INSTITUTIONS USING THE PODLASIE REGION AS AN EXAMPLE

ANDRZEJ DANILUK

ABSTRACT

Cooperation in the field of innovation activities means active participation in joint projects with other companies and business environment institutions. Some of these institutions are involved in cooperation with entrepreneurs to a very limited extent, which makes the help ineffective.

The aim of this article is to define the impact of this kind of cooperation in in the context of innovation development in the Podlasie region. According to the author of this article, the research problem is the low level of cooperation between companies and institutions of the business environment. There are not many publications regarding the identification of the degree of readiness to cooperate by companies in the regional context.

The article uses the method of critical analysis of literature and statistical analysis of data. The results show the degree of interest in taking up cooperation between entities. Aiming to improve the level of cooperation, a more proactive and specific approach of the business environment institutions is recommended.

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KEY WORDS

cooperation, business environment institutions, innovation, entrepreneurship

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INTRODUCTION

Under contemporary performance conditions, companies are not able to implement significant innovations. Innovations rarely occur in isolation, as they constitute a highly interactive process of collaboration in a growing and diverse network of stakeholders. Companies aiming to develop new technologies, products, and services are forced to learn from multi-

ple sources and establish contacts with several external partners. Cooperation becomes a tool for the expansion of the scope of development projects and a way for building competences in the company. Supporting entrepreneurship and innovation processes includes the provision of specific services and development of economic-social environment favourable to entrepreneurs and conducive to inde-

pendent business (Pietruszewska-Cetkowska & Zygmunt, 2014, p. 8; Hillebrand & Biemas, 2003). Activities in this regard include establishment and development of specialized support institutions.

A literature review indicated the presence of several research trends in the research of business environment institutions. A diversified scale and scope of on-going research demonstrate the importance of the studied subject and confirm the existence of research gaps in this area. Today, studies of national and regional range can be distinguished, mostly relating to the situation in individual provinces. Some of the factors that can positively affect a high inclination to cooperate by companies from one area do not have to be as important for actors at the other end of the country or the community of regions. Research carried out at regional levels seem to be important for this (Szostak, 2008).

Although, among the available Polish studies there are reports on these issues at the national level, there is a small number of analyses regarding the individual provinces, including the Podlaskie province, which takes one of the last places in innovation rankings. This situation shows the importance of cooperation between companies and business environment institutions, local government units, research and development institutes (R&D) for regional development. Business environment institutions (BEI) offer entrepreneurs the assistance in the formation, operation, and development of companies. For research purposes and this article, it was assumed that the institutions from the business environment are non-profit organisations that do not work for profit. The identification of barriers to cooperation between the spheres of business is important from the point of view of measures to be taken in order to overcome the difficulties (*Bariery ...*, 2006; Gnyawali et al., 2006).

The business environment institutions are the important elements of the efficient innovation system. They support companies and facilitate the flow of knowledge and technology between science and businesses entities. These institutions strongly complement the contemporary logic of building the competitiveness of companies and socio-economic development of regions. They are such organisations whose activity is significant because of the direct contacts with local entrepreneurs. The cooperation of business environment institutions would enable presenting coherent and comprehensive services of business environment institutions to investors, as well as strengthening regional institutions in the

domestic market (Leight & Blakley, 2013; Patel et al., 2012).

The goal of this article is to present the results of studies, which consider factors affecting the level of cooperation between companies and the institutions of the business environment, in the context of implemented innovations in the Podlasie region. The methods of critical literature analysis and statistical analysis of data have been used. The results were derived from a study on industrial and construction companies in the north-eastern Poland.

1. LITERATURE REVIEW

The company development is determined by various factors associated with the entrepreneur in person, internal resources of the company, and the environment, in which the enterprise operates. With the development of globalization, we can see the simultaneous occurrence of cooperation and rivalry between companies (Cygler & Soroka, 2016). Modern company development processes increasingly take place in a specific system of mutual network interconnections. These include networks of enterprises, research institutions, non-government organisations, public administration, and civil initiatives, which facilitate the penetration of ideas and exchange of information. The cooperation between companies is becoming increasingly important, and network organisations are a common form of functioning in the business world (Sroka & Cygler, 2014). The specificity of cooperation development in the last two decades was the creation of cooperation between competitors rather than vertical cooperation or integration (Cygler, 2009).

Literature defines cooperation as a relationship, in which individuals, groups, and organisations interact with each other by sharing or transferring complementary skills and resources, and their development to achieve benefits on both sides (Gnyawali & Madhavan, 2006). Cooperation is an action that involves coordination of partial tasks resulting from the division of work or from the links between economic entities based on concluded contracts, agreements that prevent or facilitate the execution of specific tasks (Połomska-Jasieniowska, 2010). The ability to create collaboration between businesses may lead to future joint problem solving, joint control over processes, and mutual learning. A large part of alliances fails to achieve both the goals and the assumed bene-

fits by the cooperating companies (Kale & Singh, 2009; Lunnan & Haugland, 2008; Das & Teng, 2000; Keasler & Denning, 2009).

The main tasks of the business environment relate to a variety of activities aimed at increasing creativity, entrepreneurship, and innovation. This leads to a more efficient use of regional and local growth factors. Different motives for innovation implementation by companies are presented in the economic literature. One of the most important is to create a competitive advantage of both cost and the company's proposal resulting from differentiation (Porter, 1998; Tu et al., 2014; Nurullah et al., 2012). This is possible thanks to innovations introduced in various functions of the company as well as in the sphere of relations with partners. The concept of innovation includes both the effect and the process, due to which it is possible to achieve this effect. In management practice, the motifs for innovation should, therefore, be included in the form of objectives that would be the effects of the innovation process.

The development and absorption of innovations constitute the key elements of the policy of economic and social cohesion (Barska, 2014). Polish companies rarely undertake to carry out research and development activities. The value of the EBRD index remains at a low level (0.43% of GDP in 2014), (*Działalność ...*, 2015). We can observe a low percentage of Polish companies engaged in innovation activities. The total number of innovative enterprises in technological and non-technological innovation situates Poland on the last places (Zadura-Lichota, 2015). The increase in innovativeness of Polish enterprises is necessary to improve their competitiveness in the market (Ejdys et al., 2015). The role of regions has been growing in recent years because of the European Union policy, and this increases the importance of regional conditions in the development of enterprises. The regional environment includes entities supporting economic activity, entrepreneurship, and innovation. Support instruments are offered by the business environment institutions including centres of entrepreneurship support, organisations of entrepreneurs, service

companies, and financial institutions (Lisowska, 2013, p. 192).

Support offered by institutions of the business environment usually covers the following areas (Lisowska, 2014, p. 14):

- activation of academic entrepreneurship and cooperation between science and business;
- improvement of company management and better use of resources;
- establishing contacts with foreign partners;
- information and advisory activities;
- establishing cooperative relations with large companies;
- providing or facilitating the acquisition of financial support;
- encouraging entrepreneurs to organise themselves into producer or distribution groups and create a system of cooperation and subcontracting;
- improving the competitiveness through absorption and implementation of new technologies;
- technology transfer and providing pro-innovation services.

Business environment institutions affect mainly local and regional environment outside the company. They form a support infrastructure that can be

Tab. 1. Types of support offered by business environment institutions

SUPPORT OFFERED BY BUSINESS ENVIRONMENT INSTITUTIONS		
FINANCIAL	NON-FINANCIAL	
	"HARD"	"SOFT"
provided by any type of loan, guarantee funds, non-refundable grants, organisations acting as managers of aid for the SME sector	provided by entrepreneurship and innovation incubators, science and technology parks and industrial parks; in the form of offers for office space, buildings or land with all the appropriate services connected	offered by, among others, advisory and training institutions as well as technology transfer centres; it includes mainly information service, consulting, educational activities (training, workshops), cooperative interaction (exchange offers cooperation or technology)

Source: author's elaborations based on (Markiewicz, 2010, p. 35).

divided into few types (Tab. 1).

The latest paper presenting data on the number and spatial distribution of business environment institutions in Poland is the PARP report "Innovation centres in Poland". The results of this study indicate that in 2014, Poland had 176 active innovation centres and business incubators (including 130 innovation centres). In Podlaskie, five innovation centres and business incubators were identified in the PARP report. This ranks the region on the penultimate place

in the country, one position higher than the Opolskie province. Most centres are located in the southern provinces of Poland: Śląskie – 23, Małopolskie – 20, and Dolnośląskie – 17 (Bąkowski & Mażewska, 2014, p. 14).

The Podlaskie province is characterized by low saturation of BEI, and their offered support is not fully adequate to the needs reported by entrepreneurs. Professionalization of BEI should translate into an increase in the ability of the SME sector to participate in the processes of growth and thus increase the transfer of knowledge, innovation, and technology. In the poorly developed region with a low level of entrepreneurship, such as Podlaskie region, it is necessary to further develop the BEI operating in support of initiation and incubation of companies as well as those strengthening the existing businesses by providing capital in the early stages of operation (*Zapotrzebowanie ...*, 2015).

2. RESEARCH METHODS

The further part of this article presents some results of research carried out as the international research project, conducted under the agreement between the Polish Academy of Sciences and the National Academy of Sciences of Belarus in 2014-2016 “Readiness of enterprises to create cross-border networking”. Quantitative research carried out in the late 2014 and early 2015 covered 381 Polish companies of industries leading in the Podlaskie province. The main goal of the research was to examine the relationships between business entities and the institutions of the business environment in the perspective of innovation development in the Podlaskie province. The survey was addressed to the owners or members of senior management and the paper was limited to the analysis of chosen results.

As a result of the literature analysis and on-going discussions, the factors shaping cooperation between the operators have been determined. It should be noted that the study was not of a representative nature. In respect of the conducted analysis, the results cannot be generalized to the entire population. The purposeful selection was used, limiting the research to specific entities, whose opinion may be authoritative and most desirable. Considering the literature, it was assumed that taking certain forms of cooperation with business environment institutions can increase the chances of positive implementation

of innovation. The construction of the research questions included the importance of different reasons for the willingness to start cooperation between competitors. In addition, the impact of various factors on decisions about potential cooperation in implementing joint projects was considered. In this part of the study, the attention was first of all focused on the factors of a strategic nature, which have an impact on various aspects of making decisions about getting engaged in joint projects.

Defining the strategic factors for particular sectors has allowed for the identification of areas of potential cooperation and the importance of these factors for the development of technological entrepreneurship.

The research problem was formulated in the form of the following questions:

- How do respondents assess the current level of cooperation between the studied companies and institutions of the business environment?
- What is the degree of interest of the studied companies in strengthening the cooperation with institutions of the business environment in the near future?
- To what extent do the individual factors influence the current level of cooperation between the respondent companies with business environment institutions?
- To what extent may positive changes in various factors contribute to the improvement of cooperation in the near future?
- Is there a correlation between the assessment of the areas of existing cooperation and the evaluation of possibilities for improving it in the future?

The results of the survey were coded, and primary data obtained was subject to organising, grouping, and analysis using statistical tools such as the tabular form of data presentation, descriptive statistics, and nonparametric statistics. The analysis was performed using the statistical package STATISTICA, version 12.5.

The following areas of cooperation were evaluated:

- The possibility of joint research and development projects;
- Access to research centres/research infrastructure;
- Access to financial institutions and support programs;
- Consultation/Business Consulting;
- Commercialization of research results;
- Access to databases;
- Help in business development;

- Assistance in technology transfer;
- Past experience with cooperation.

The Desk Research analysis was applied for realization of the objectives. As a result of the literature analysis and on-going discussions, the factors shaping cooperation between enterprises and institutions of the business environment were determined in the context of strengthening the development of innovations. Based on the available statistical data and source materials, the analysis was carried out regarding factors affecting the level of cooperation. Identification of factors affecting the establishment of cooperation was based on the analysis of literature (Strzyżewska, 2011; Górczyński, 2006; Bengtsson & Kock, 2014; Ford & Håkansson, 2013). It also resulted from discussions with experts representing both academia and business. The respondents assessed the phenomenon on a seven-point scale, where 1 meant the complete lack of impact and 7 – a very big impact. The following statistical measures were used to interpret the results of the research: measures of the central tendency – the dominant, mean, and median, and the measure of dispersion – the coefficient of variation. The Spearman's rank correlation was used to indicate the strength of interdependence between the assessments, and with t-Student test, its significance was examined. To identify statistically significant differences between assessments of companies, the U Mann-Whitney test was used.

In the group of industrial companies, the highest participation of respondents per company size, was among small and middle companies (40.33%). In the construction sector, the biggest group of respondents per company size, were middle companies (30.26%). Small and medium-sized enterprises together represented 67,34% of respondents from the industry and 65.79% of respondents from the construction sector. Most companies have existed on the market for more than ten years (77.05% of industrial companies and 63.16% of construction companies). They are, therefore, well-established companies, although the majority of them are still in the group of small and medium companies (Tab. 2). It was assumed that certain forms of cooperation between companies and the institutions of the business environment could increase the propensity for development of innovative activities. It may, therefore, be beneficial to the development of entrepreneurship in the individual

entities within the framework of cooperative relations.

The cooperation in different types of structures can increase the effect of mutual support by providing options in the form of the potential of other companies. The research questions included the importance of different conditions for the willingness

Tab. 2. Characteristics of the studied companies

COMPANIES	INDUSTRIAL COMPANIES N (%)	CONSTRUCTION COMPANIES N (%)
SIZE OF THE STUDIED COMPANIES (NUMBER OF EMPLOYEES)		
Up to 9 people	65 (21.31%)	20 (26.32%)
10–49 people	123 (40.33%)	23 (30.26%)
50–249 people	83 (27.21%)	27 (35.53%)
250 people and more	34 (11.15%)	6 (7.89%)
AGE OF THE STUDIED ENTITIES (NUMBER OF YEARS ON THE MARKET)		
Up to 1 year	2 (0.66%)	1 (1.31%)
1–3 years	16 (5.24%)	12 (15.79%)
4–10 years	52 (17.05%)	15 (19.74%)
More than 10 years	235 (77.05%)	48 (63.16%)

to undertake cooperation between companies and the institutions of the business environment. Defining the key factors led to the identification of potential cooperation spheres and the importance of these factors for the development of innovations.

3. DISCUSSION OF THE RESEARCH RESULTS

In terms of the evaluation of conditions for innovation development in the construction and industry companies operating in the Podlaskie province, an important element of the study was the question of the assessment of the current level of cooperation and the degree of interest to increase it in the future. The researched companies were asked for self-evaluation through the prism of the indicated factors on the seven-point scale (Tab. 3).

Respondents assessed the level of the existing cooperation between their companies and the institutions of the business environment and gave it a rather low ranking. The ranking was higher in the case of industrial enterprises, where the dominant and the median were ranked at 3 and 4. It is surprising because in the case of construction business it is often

Tab. 3. Current and future cooperation with business environment institutions in the opinion of respondents

SPECIFICATION	\bar{X}	ME	D	N_b	V
Industrial companies Construction companies					
Declared level of cooperation with business environment institutions	3.12 2.84	3,00 3,00	3 1	77 18	48,95 53,61
Degree of interest in strengthening the cooperation within the next 2-3 years	3.69 3.68	4,00 4,00	4 3	65 21	44,29 40,43
Correlation of Spearman's rank ($p < 0.05$)					
Assessment of the current level of cooperation and possibilities of its strengthening in the future				0.630760 0.646695	

required to establish cooperation with other institutions for investments. This situation can be explained by the fact that for decades, political, social, and economic conditions were unfavourable for collaboration and cooperation in any area of the public sphere, and the dominant attitude – natural in the reality ruled by a repressive apparatus of power – was great precaution, egoism, and low confidence in contacts with others (Wasiluk, 2013; Tomaszuk, 2016). Little optimism can also be observed in assessing the level of interest of the companies in cooperation with the institutions of the business environment in the near future. In the case of both groups of companies, poor differentiation of the respondent assessments can be observed, although, in the case of industrial companies, it is slightly higher for the current state.

Conducted Spearman's rank correlation indicates a high dependency between the assessment of current cooperation and the possibility of strengthening it in the near future. The higher the companies assessed the current level of contacts with the institutions of the business environment, the higher level of readiness for its strengthening in the future they demonstrated in their declarations. The increase in the evaluations of the current level of cooperation is accompanied by a significant increase in the degree of interest in strengthening this cooperation in the next 2-3 years. The increase of interest in the strengthening of cooperation may be affected by its results so far, felt directly and indirectly by cooperat-

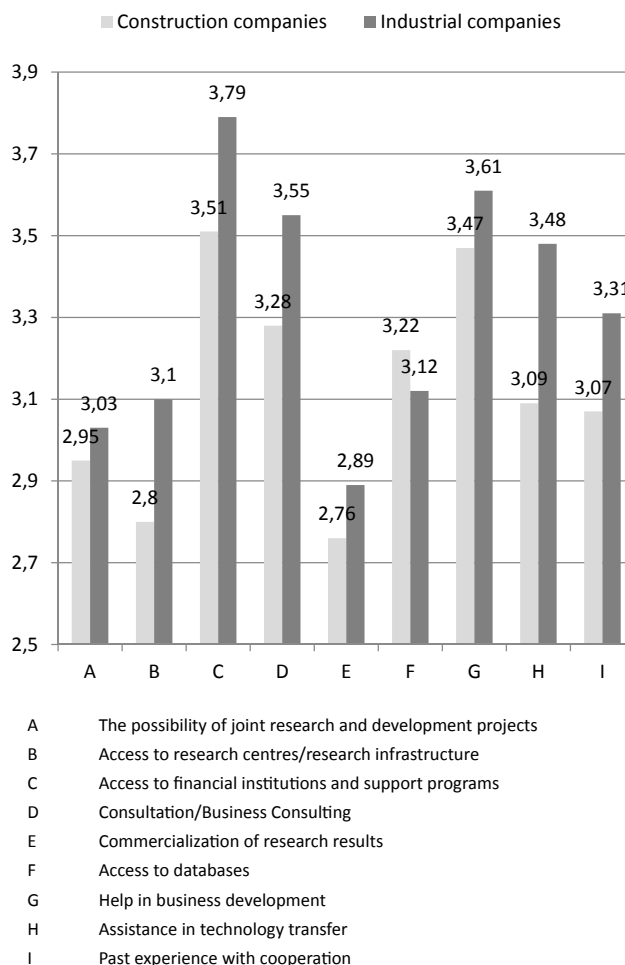


Fig. 1. Average rating of the impact of various factors on the level of existing cooperation

ing entities. This depends largely on mutual expectations and the expected and actually received benefits from the cooperation.

Considering the earlier analyses of the discussed issues, conducted by the author of this text in frames

of other projects (Wasiluk & Daniluk, 2013), it appears that companies in Podlaskie focus on immediate actions that allow for survival and achievement of even a slight increase. Identified were the interacting factors that constitute the mechanism of cooperation between companies and the business environment institutions.

Examined was also the extent, to which various factors affect the evaluation of the current level of cooperation between the respondent companies and the institutions of the business environment. The results are shown in Fig. 1.

Analysing the average values, we can notice that there are no indications of above 4. The higher notes apply to aspects of cooperation related to the access to financial institutions and support programs, business consulting and help in business development for both construction and industrial companies. These are the areas that do not require a mutual commitment to business cooperation. Low ratings in areas that have a particularly significant impact on the development of entrepreneurship in the framework of joint actions can raise anxiety about the mechanisms of cooperation. The indicated evaluations might suggest a lack of willingness on the part of companies to engage in deeper cooperation relationship, characterized by engaging their own resources.

Fig. 2 shows the results of examination of the positive changes in the identified areas of cooperation to its improvement in the near future.

In the opinion of respondents from the construction sector, the positive changes in the access to financial institutions and support programs, business consulting and help in business development have again had the greatest impact on the improvement of cooperation of their businesses with the business environment institutions. Whereas little effect was made by the changes in the area of commercialization of research results, past experience with cooperation and access to databases. Companies in the Podlaskie province do not trust their potential partners and are afraid of losing

technology, customers, and employees. A small percentage of entrepreneurs in Podlaskie province confirmed the use of the BEI offer in the past. Those who engage in cooperation, do it sporadically. Entrepreneurs do not undertake cooperation with BEI because they fail to see the benefits of such cooperation.

These conclusions are largely consistent with the results of other studies conducted in selected provinces (Kamińska, 2011; Bąkowski & Mażewska, 2014; Pietruszewska-Cetkowska & Zygmunt, 2014). These institutions specify their offer, but do not make the effort to get to know well a potential customer and, thereby, the offer often reaches an accidental recipient. Therefore, the promotion of BEI services is ineffective, and messages targeted to entrepreneurs are incomprehensible. To change this, the information activities promoting BEI services should be given in the language of business benefits. Often, information on the scope of BEI activities does not reach potential

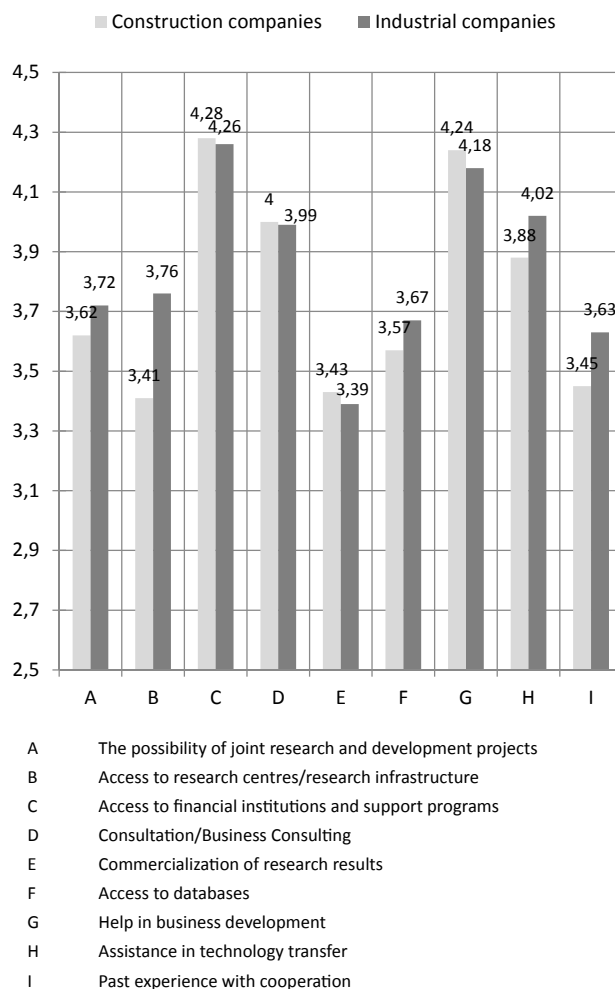


Fig. 2. Average rating of the impact of positive changes in various factors on the degree of strengthening cooperation in the near future (2-3 years)

recipients of services, due to the excessive amount of information. The average entrepreneur is not able to select independently the most valuable information that would allow him to cooperate with the BEI and other entities. Entrepreneurs also point to the excessive level of generality and the lack of specialist offers addressed to representatives of specific industries. Therefore, elimination of services targeted at a mass recipient is recommended, reallocation of resources in the areas that need the most support and personalization of the offer.

There is a high positive correlation between the assessment of the impact of various factors on the existing cooperation and the evaluation of the possi-

to strengthen it in the near future. Although the analysis pointed to areas, in which cooperation exists most often, and where the positive changes have an impact on the strengthening of cooperation in the future, it should be noted that the influence of these factors did not exceed level 4 on the seven-point scale for the current cooperation. Therefore, their power to affect the readiness of companies to cooperate with the institutions of the business environment should be assessed as rather weak. The results are not optimistic.

Companies do not recognize the need for cooperation and show no awareness of the benefits of cooperation. There is no clear will for cooperation among entrepreneurs, and they lack the sense of common purpose for the development. Entrepreneurs expect mainly tangible economic benefits from cooperation. A possibility of expansion into new markets and the improvement of their product and service quality are also viewed as important. Entrepreneurs believe that cooperation with institutions of the business environment could be better and more efficient. They do not benefit fully from what the existing institutions offer. Some business environment institutions are involved in cooperation with entrepreneurs to a very limited extent, which makes their help ineffective. They mostly provide

Tab. 4. Spearman's rank correlations for the impact of various factors on the existing level of cooperation and the possibility of improving it in the future resulting from positive changes in the factors

FACTORS	CORRELATIONS OF SPEARMAN'S RANKS	
	INDUSTRIAL COMPANIES	CONSTRUCTIONS COMPANIES
The possibility of joint research and development projects	0.705	0.771
Access to research centres/research infrastructure	0.677	0.720
Access to financial institutions and support programs	0.685	0.674
Consultation/Business Consulting	0.662	0.677
Commercialization of research results	0.701	0.646
Access to databases	0.669	0.647
Help in business development	0.655	0.681
Assistance in technology transfer	0.690	0.644
Past experience with cooperation	0.748	0.793

bility of improving it in the future, in both construction and industrial companies (Table 4).

Spearman's rank correlation conducted for the respondent assessments leads to the conclusion that the increase in the level of evaluation of the impact of individual factors on the current level of cooperation is accompanied by an increase in the average value of the evaluation level of the impact of positive changes in these factors on the establishment of cooperation in the future.

CONCLUSIONS

The carried out analyses show some deficit in terms of both the existing cooperation and readiness

general information and carry out general training. They have nothing to offer for specialized services, and if they do, the services are very difficult to access due to a large number of applicants. Poor cooperation between business environment institutions and other participants in the regional innovation scene is a barrier to the creation and functioning of the regional innovation system. The necessity for commitment and cooperation of numerous actors of the innovation processes is largely due to the specific nature of these processes, their interactivity, and penetration of many branches of knowledge.

Initiating and strengthening cooperative activities between the actors of the regional innovation scene should be one of the main tasks of the institutions and consequently lead to the formation of cooperation networks. There should be a closer

cooperation between business environment institutions and integration of numerous centres from the whole region on the collaboration platform, and stronger cooperation with local government units. Cooperation with business environment institutions should be improved, especially at the local level, through inviting them to and engaging in joint projects. This cooperation may take many forms, including: consulting, professional consultations, promotion of municipalities (city, county, sub-region), common organisation of trade fairs, trade missions, other assistance in establishing business contacts, public-private partnership projects, etc.

We can see the lack of cooperation between BEI. The crucial role in this regard can be played by provincial governments. These units, using funds from the Regional Operational Programmes, can initiate and supervise the implementation of major initiatives for connecting BEI, R&D, and entrepreneurs. Only cooperation on many levels, focused on comprehensive support for entrepreneurs and in cooperation with BEI can bring positive effects resulting in the increase in the competitiveness and innovativeness of the economy.

The establishment of structures for the cooperation with companies, for example, in the context of regional and local production organisation systems, would better respond to the needs of entrepreneurs. Creating more effective programmes to support entrepreneurship, innovation, and development of small and medium businesses at the national, regional, and district levels, based on the past experience and the needs of the target groups, should support innovation and entrepreneurship centres in smaller towns, where the number of potential customers does not allow for financial self-sufficiency. The cooperation of the centres at the regional level must be stimulating in the framework of regional innovation systems that form networks of cooperation between the administration, research institutions, and centres of innovation and entrepreneurship.

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LITERATURE

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CONSUMER PARTICIPATION IN THE HEALTH TOURISM INNOVATION PROCESS

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ABSTRACT

The aim of the study is to compare the level of innovation of companies introducing innovations with consumer participation with that of other innovative providers of health tourism services. The following hypothesis was formulated: Companies benefiting from the participation of consumers in the process of innovation represent a higher level of innovativeness than other innovative providers of health tourism services.

The following methods were used: a comparative analysis, a questionnaire (CAWI and PAPI), a standardized interview, and the ranking method. 461 providers of health tourism services participated in the research.

The value and implications of the paper for the economic sciences contribute to the development of innovation theory. The hypothesis has been positively verified. The research shows a much higher level of innovation in companies cooperating with consumers (patients) than that of other respondents.

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innovation, process of innovation, consumers, health, tourism

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INTRODUCTION

Innovativeness is one of the most important management issues. Innovativeness is defined as the ability of organisations, sectors, regions or countries to seek, implement and disseminate innovations, i.e. this means doing something new or introducing significant changes, which can be measured and assessed (Hilami et al., 2010). With respect to an organisation,

innovativeness involves its ability to place new products on the market or to open new markets by combining a strategic orientation with innovative behaviour and processes (Danneels & Kleinschmidt, 2000). In the Polish legislation, innovation is defined as an activity related to the preparation and launch of the manufacture of new or improved materials, products, equipment, services, processes or methods

intended to be placed on the market or for another use in practice (Ustawa (Act), 2015).

The research problem addressed in this paper was an innovation process. The research area is companies providing health tourism services in Poland. Health tourism is defined as a type of tourism, the main purpose of which is to improve or maintain health (Boruszczak, 2010). The aim of the study is to compare the level of innovation of companies introducing innovations with consumer participation with that of other providers of health tourism services.

Why health tourism? The issues were chosen based on three main premises. Firstly, the growing demand for the development of health tourism services, which is related to the ageing of society and the increasing leisure budget of certain customer groups. This has been indicated by the research done by Deloitte. Although the research covered the United States market, still it may provide guidance for other areas, including the countries of the European Union. As a result of the research, it was diagnosed that the tourism movement related to health tourism doubled in the USA in barely five years (from 2007 to 2011). The drivers of changes should be considered to include economic growth and the related higher per capita revenues (Rudawska, 2009).

Secondly, the dynamic development of medical sciences and enhanced international linkages. This development is a consequence of globalisation processes and a changed perception of medicine as no longer only services with healing functions (helping those in need) but also services with modelling and aesthetic functions. This change results from a holistic and optimistic understanding of the term “health”, i.e. a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (according to the World Health Organization (WHO)), ensuring a socially productive life in social, economic and mental terms, also in the spiritual dimension. Responses to the globalisation processes in medical services include e.g. the signing of multilateral contracts on medical care (Reismann, 2010), the liberalization of medical regulations (Lunt & Carrera, 2010; Morgan, 2010) and, in consequence, the efforts taken by certain countries to specialise in health tourism services (Brazil, India, Hungary, Costa Rica).

The third premise encouraging one to address the issue of innovativeness of health tourism is the emerging possibility of co-financing from the European funds (in the programming perspective of 2014-2020) for projects which are most important from the

point of view of the social demand and enhanced innovativeness of the economy.

461 providers of health tourism services participated in the research, and the following methods were used: a comparative analysis, a questionnaire (CAWI and PAPI), a standardized interview, and the ranking method.

The research has an interdisciplinary character and covers two research areas, specifically, medicine and the tourism economy.

1. LITERATURE REVIEW

1.1. INNOVATIVENESS OF ENTERPRISES AND INNOVATION PROCESSES

Innovation is perceived as the major driver of economic growth. The term “innovation” comes from Latin and means the introduction of something new, a reform – based on *innovatio*, which means “renewal”, or *innovare*, which means “to renew” (Kopaliński, 1978, p. 433). Therefore, the innovation issues have been discussed in many publications. The most important publications include those by Schumpeter, considered to be the father of innovation theory, along with his outstanding work *The Theory of Economic Growth* (1932). Drucker (1998) was another eminent researcher on these issues. Many studies emerged as part of the innovation studies carried out by the OECD and Eurostat (*Oslo*, 2005).

The main issues of interest to the researchers in the world who deal with the issues of innovativeness in the economy include:

- innovation policy (Furman et al., 2002; Grupp & Moge, 2004; Balezentis & Balkiene, 2014);
- the innovation drivers in the economy (Hollenstein, 2003; Gault, 2011), including users (Urban, 2013);
- the innovative activity of enterprises (mainly production enterprises), (Tuominen et al., 2004; Perunovic & Christiansen, 2005) with particular consideration given to technological progress and R&D expenditure as well as their roles in the innovation process (Aw et al., 2011; Urban & Czerska, 2016);
- sector-specific research on the innovativeness of the economy (Garcia & Hollanders, 2009); Gallouj (2002), Gallouj & Windrum (2009) and Gault (2011, 2013) should be regarded as the leading researches on the issues of the innovativeness of services at the international level;

- the innovativeness of chosen sectors, e.g. tourism enterprises (Hjalager, 2010; Szymańska, 2009, 2013);
- innovativeness in the context of a knowledge-based economy and in the globalisation process (Rycroft, 2003; Ejdys et al., 2015);
- attempts are also taken to seek innovation in different areas of social activity and to link completely different phenomena (Deshpande & Farley, 2004; Ejdys, 2015) or spatial planning of the city (Hajduk, 2015).

The innovativeness processes proposed as the research theses were designed on the basis of the considerations reported in the literature. As a result of these considerations, eight different models of innovativeness processes were developed. They are presented in Table 1 in the order, in which they appeared in the economic literature regarding the innovation theory, from the 1950s (linear systems) to the last decade (UDI and diffuse systems).

jugated innovation process. Later, studies were substantially more complex and all of them, starting from the 1990s, have involved advanced computer technologies. The concept of *open innovation* (Chesbrough, 2003) began a new look at the innovation processes. It enabled ideas to go outside of the organisation and for the latter to be open in the process of creating innovations. This turned out to be a factor, which greatly stimulated innovation. The UDI concept was created on this basis. Active participation of customers, even consisting of the co-creation of innovations (new products and services), seems to be the optimum option both for the customers who, in the course of the creation process, notify their needs and ideas, and for entrepreneurs who seek to meet these needs, as this enhances their certainty of sales. In light of the research conducted in Sweden, UDI helps to develop proactive technology that meets the needs and demands of today's senior citizens (Hollenstein, 2003). The researchers show that the concept

Tab. 1. Innovation processes

NO.	INNOVATION PROCESSES	CHARACTERISTICS OF MODELS
1.	Science pushed	A linear model of the innovation process <i>pushed by science</i>
2.	Pulled by the market	A linear model of the innovation process <i>pulled by the market</i>
3.	Conjugated	Interaction models where the connections among the individual elements result from the couplings between science, market, and enterprise
4.	Integrated and networked systems	Integrated systems based on networked connections – flexible, based on the system of a response related to the consumer, continuous innovation
5.	Parallel	Parallel-internal integration of the company and cooperation with suppliers and consumers, with emphasis placed on linkages and alliances
6.	Open innovation	The concept is based on the conviction that companies may, and even should, seek ideas and ways of creating innovations, not only within their structures but also their environment – among external partners (companies, organisations, and customers)
7.	User-driven innovation (UDI)	Demand-based approach to innovation – based on the conviction that consumers (users) have an increasingly large influence on the available commercial offers, participating in the process of creating products and services which they purchase
8.	Diffuse innovation process	Focus on open innovations inside and outside the organisation. Innovation is created (higher value is generated) by establishing an efficient knowledge flow system (inside and outside)

Source: own elaboration based on own research and (Szymańska, 2013).

The diffuse innovation process is one of the eight processes (also called systems), which can be distinguished in the literature concerned with innovation theory. Initially, the innovation processes were perceived as a simple consequence of change (the market needs or the results of research) – items 1 and 2 in Table 1. They can be called linear. However, Kline and Rosenberg (1986) noticed that these processes could be more complex and developed the model of a con-

of the co-creation by customers does not apply only to the creation of innovations, but it can be used, for example, to improve the quality of services (Urban & Czarska, 2016). It should be noted that the present change consists of the transition from technology-driven innovation to innovation driven by customers and other entities outside the enterprise.

This development has continued until today, starting from the first stage, covering the 1950s and

the first half of the 1960s, when the innovation processes unfolded linearly, through more complicated systems, until the contemporary process, which began after 2000, and is characterized by a large focus on knowledge management, for example, a diffuse one. Three of the processes described in the table emphasise the important role of consumers in the innovation process: open, UDI, and diffuse.

1.2. HEALTH TOURISM AS A RESEARCH AREA

The health tourism market based on health resort-based, spa & wellness, aesthetic medicine, and medical services (Szymańska, 2015; Panfiluk, 2016) develops dynamically as a result of the continuously increasing availability of the services listed above as well as cheap and fast means of transport (Garcia-Altes, 2005). On the one hand, this relates to changing social needs and lifestyles. The change in lifestyles from passive to active rest is based on the enhanced awareness of the significance of health in human life and, at the same time, the launch of actions to improve health and to regenerate the physical, mental, and spiritual strength stressed by the technicised civilisational development (Zuzda et al., 2013). Active rest often entails preventive rehabilitation delivered by visits to health resorts or relaxing activities during visits at spa and wellness clinics, as well as in recent years even medical services. As a result, health improvement is the purpose of tourist travels and, at the same time, the basis for the development of the health tourism market. The demand for health services has become a global phenomenon related to economic growth, increasingly good education, and enhanced revenues (Rudawska, 2009). On the other hand, significant changes can be seen in medicine. A wide offer of high-quality medical services is a response to the globalisation of health services (Lunt & Carrera, 2010; Morgan, 2010). Moreover, the causes of travels for health purposes are considered to include the availability of cheaper, alternative procedures conducted outside of the country of residence (Hazarika, 2010), and the unavailability of services in the country of residence, caused, among others, by procedural barriers to availability and long waiting lists (Burkett, 2007), (in particular, medical services). An important driver of the development of this market is also the incorrect health policy of countries, e.g. 47 million Americans live without health insurance (Amodeo, 2010), and it also results from the signing of multilateral intergovernmental agreements on medical care (Reismann, 2010). Moreover, medical

services have gone beyond the traditional perception of medicine based on its healing functions, understood to mean helping those in need, to include modelling or aesthetic functions. Its broader meaning derives from a holistic and optimistic understanding of the term "health", according to the World Health Organization (WHO, 2016) "a state of complete physical, mental and social well-being, ensuring a socially productive life in social, economic and mental terms, also in the spiritual dimension". The actors on the health tourism market include not only persons suffering from specific disease symptoms, but also physically healthy persons who wish to change the everyday rhythm of their lives, to experience new challenges or to improve their current health condition. Because of the factors listed above, health tourism already develops in more than 35 countries in the world (Amodeo, 2010). The main destination markets are the countries which can ensure the care of foreign patients, easy and relatively cheap access to medical procedures, including cardiological, orthopaedic, dental and plastic surgery procedures (Untii, 2009), as well as health resort-based or aesthetic medicine procedures.

In conclusion, it can, therefore, be said that the health tourism market develops as it goes beyond the institutional boundaries in the cooperation between tourism and medicine.

1.3. INNOVATIVENESS OF HEALTH TOURISM

The innovativeness of the tourism sector services has been explored only slightly (Szymańska, 2009; Hjalager, 2010; Camison & Monfort-Mir, 2012). Detailed research on the innovativeness of the tourism services indicates that this is a sector with a low innovativeness level (Hjalager, 2002). No research has been carried out, either, to analyse the factors that drive this negative result (Hjalager, 2009; Szymańska 2009). Therefore, innovations in medicine (Jończyk, 2014) contribute to the growth of tourism and new preferences in the field of tourism affect the search for medical products and their commercialisation. Thus, the development of medicine can be one of the drivers of tourism, while, medical innovativeness can be an indicator for the activities of enterprises operating in the tourism market (Hjalager, 2002).

The research on the innovativeness of health tourism has been carried by few researchers since only recently (Boruszczak, 2010, 2011; Panasiuk et al., 2016), including studies on the innovativeness of the market of health tourism and its forms (Hjalager,

2009; Szymańska, 2015; Panfiluk, 2016). In contrast, the innovativeness of the medical sector has been widely described, mainly in specialist medical journals and also in economic publications. A review of these issues was carried out, among other publications, in the *Report on Innovativeness of the Health Sector in Poland in 2012* (Baczko, 2012). The American, Hungarian and French experiences can turn out to be particularly useful in this respect.

The measurement of the innovativeness of health tourism processes is particularly important given the fact that this is a new tourism segment whose services develop based on two separate sectors, i.e. tourism and medicine. In this combination, the health tourism segment represents an innovative, specialised form of tourism, which counteracts the effect of seasonality and contributes to the growth of the tourism movement. In consequence, it can significantly help stabilise the tourist demand out of season.

In conclusion, a distinct shortage of scientific publications on the innovativeness of health tourism should be noted. Therefore, the exploration of these issues is a pioneering challenge facing researchers.

The following research hypotheses were verified:

H1 – Companies benefiting from the participation of consumers in the process of innovation represent a higher level of innovativeness than other innovative providers of health tourism.

Fig. 1 shows the elements covered by the research. Health tourism services were divided into four basic segments: the health resort-based segment, the spa & wellness segment, the aesthetic medicine segment, and the medical segment – conservative treatments and procedures. Consideration was also given to innovation types, distinguishing product, process, organisational, marketing and social innovations.

2. RESEARCH METHOD

Market research was carried out on providers of health services since it seems that this group of providers should be most interested in comments and suggestions of customers (patients, persons using health resort-specific services). The entities to be examined were selected on the basis of the Polish Classification of Activity (Section Q, Parts 86 and 87; Section Q, Part 86; Section I, Part 55; Section N, Part 79). The whole size of the examined population was determined based on the local data bank (BDL, 2014) as consisting of 241 393 entities. The size of the representative sample was calculated using the calculator and the research sample. The following parameters were adopted for the calculation of the size of the examined sample: the confidence level of 0.95, the expected fraction size of 0.5 and the maximum error

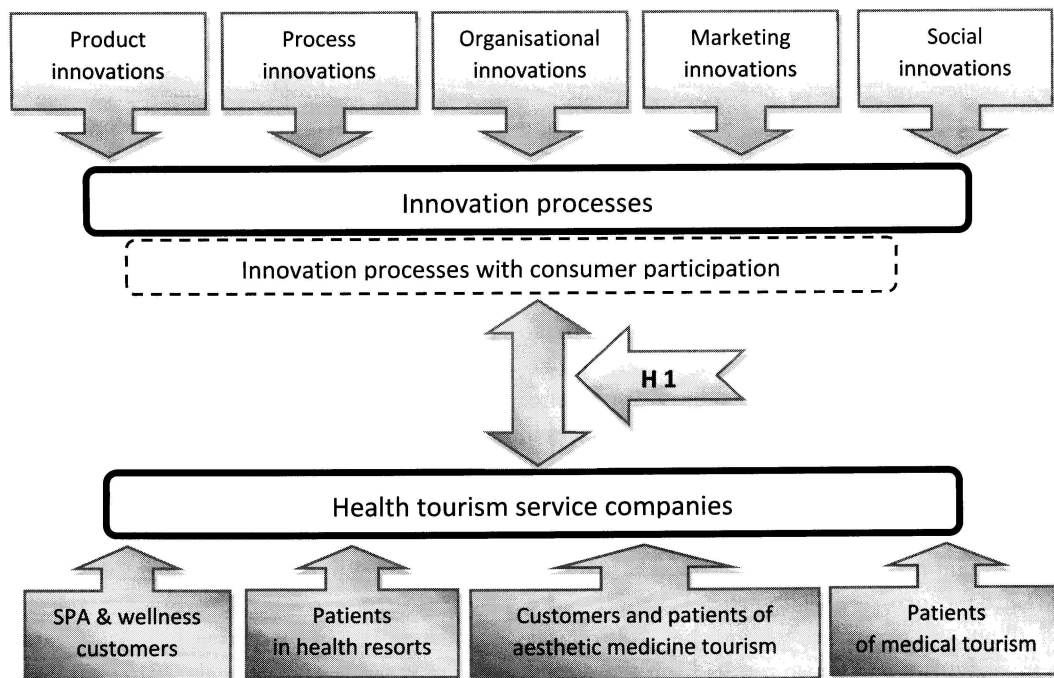


Fig. 1. Theoretical framework

of 0.05. As a result of the calculations, the minimum sample size was determined as 384 entities. The research material was collected using a survey questionnaire as a tool. The research was carried out from November 2015 to March 2016. Three techniques were applied to collect data: CAWI, PAPI, and a telephone interview. The CAWI technique, consisting in the Internet-based mailing of electronic survey questionnaires, proved to be hardly effective, despite the purchase of 35 000 e-mail addresses and the sending out of the link to the questionnaire (placed at the address: ankietka.pl). Ultimately, as a result of the research (with a simple random selection, taking into account the number of entities in particular provinces) carried out from November 2015 to 2016, questionnaires were collected from 461 entities. The interviewers used both tools: a questionnaire in the form of a paper and pencil interview (PAPI), which they filled in during the interview and the CAWI questionnaire, which they filled in after the conversation.

The respondents' task was to indicate the innovations which they had implemented over three years, in the period from 2013 to 2015. To assess the importance of innovations, they were divided into four groups: with a worldwide range (innovations with an absolute character), with a national or regional range or innovation for the firm. The providers of health tourism services could choose one or two out of eight options representing examples of innovation process models (Table 1).

3. RESEARCH RESULTS

The participation in the particular health tourism segment was varied: the health resort-based segment was represented by 79.44% of the investigated entities, the spa & wellness segment by 54.16% of the investigated entities, the aesthetic medicine segment by 41.67% of the investigated entities and the medical segment by 45.83% of the investigated entities. Certain respondents implemented more than one form of health tourism, therefore, the results did not sum up to 100. Over three years, 361 out of 461 respondents implemented at least one innovation, representing 81.87% of the research sample. The successive Figures (Figs. 2–6) show the research results (in absolute numbers) for the innovation processes applied, considering the ranges of the innovations introduced (worldwide, national and regional, and innovation for the firm).

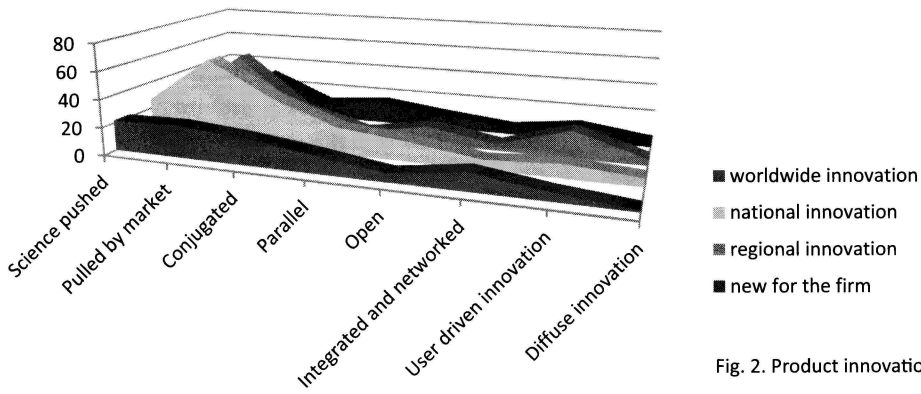
A comparison of the Figures indicates that the largest number of innovations implemented are product-related. An analysis of the results in terms of the range of the implemented innovation demonstrates that in general, the largest number of implemented innovations has a national range. However, a detailed analysis shows that new solutions for the organisation dominate among process innovations, whereas the largest number of social innovations has a regional range.

In the case of product innovations, the largest number of entities implemented innovations having a national range (30.70% of the entities investigated). Innovations of a regional range were implemented by 27.53% of the investigated entities, whereas 24.68% of the investigated entities implemented innovations at the level of the organisation. The largest number of marketing innovations also had a national range (25.63% of the entities investigated).

Innovations for the organisation were implemented by 20.89% of the entities, whereas innovations of a regional range were implemented by 18.53% of the investigated entities. The smallest number of entities (6.96%) implemented innovations that had a worldwide range. An analysis of process innovations shows that most often, they had a national range (6.03% of the investigated entities). Almost twice as few entities implemented innovations having a regional range (3.82%), whereas 1.86% of the entities investigated implemented innovations of a worldwide range.

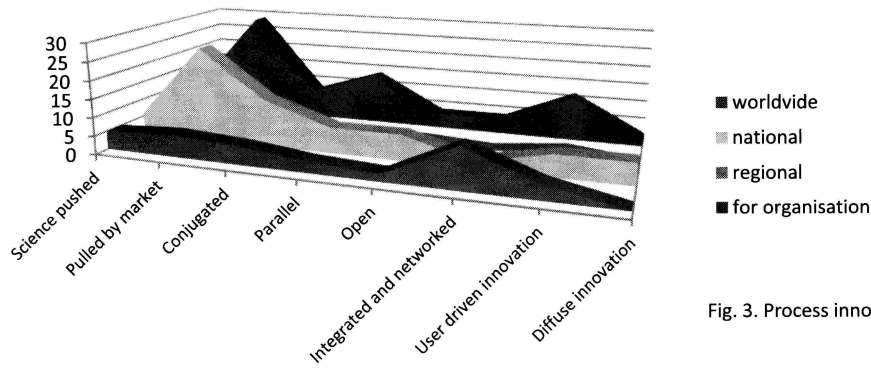
Summary results are presented in Figs. 7 and 8.

One model of the implementation of innovations clearly dominates: it is the innovation pulled by the market. A certain pattern can be discerned in innovation process models; specifically, as innovation processes open the number of service providers, their use diminishes. Therefore, the more open is a model, the fewer enterprises use it; perhaps apart from the user-driven innovation process. Innovation processes, which require cooperation are not popular and diffuse innovation was the least often indicated (Fig. 7). In turn, a comparison of innovativeness levels indicates that exactly this process is much more effective than the others, since, in the investigated period, the entities that used it implemented 4.55 innovations on average; whereas 3.36 innovations on average were implemented due to a more frequently applied pulled-by-market approach.



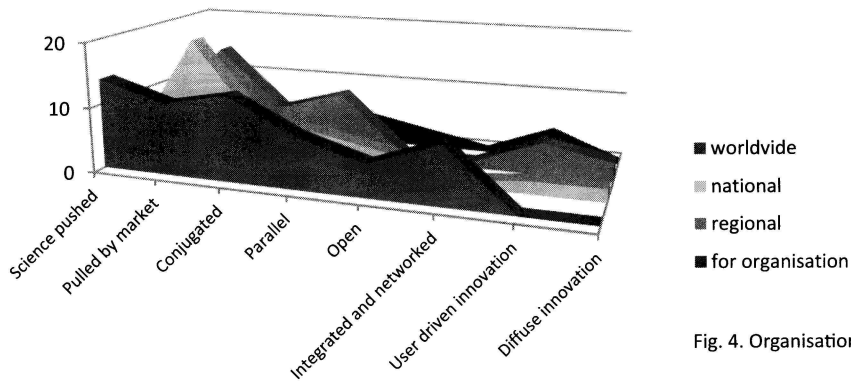
■ worldwide innovation
 ■ national innovation
 ■ regional innovation
 ■ new for the firm

Fig. 2. Product innovations



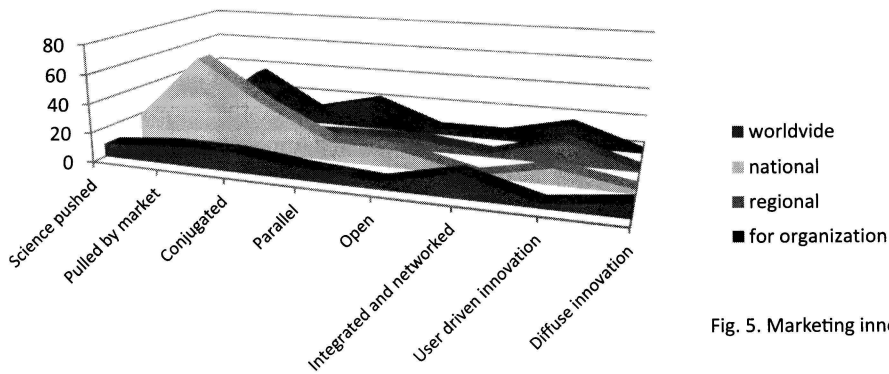
■ worldwide
 ■ national
 ■ regional
 ■ for organisation

Fig. 3. Process innovations



■ worldwide
 ■ national
 ■ regional
 ■ for organisation

Fig. 4. Organisational innovations



■ worldwide
 ■ national
 ■ regional
 ■ for organization

Fig. 5. Marketing innovations

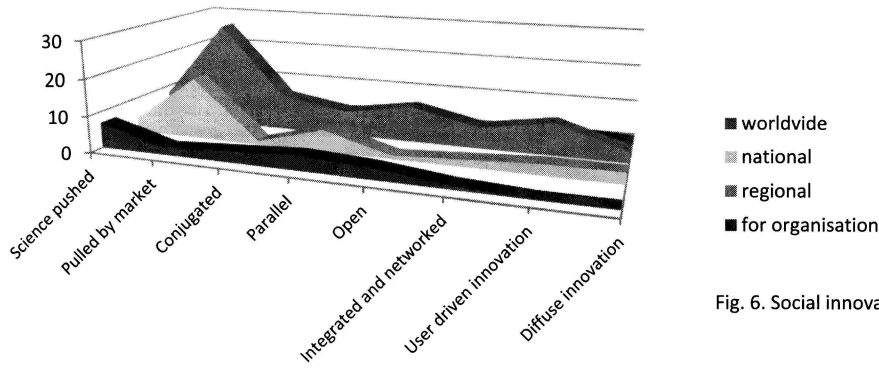


Fig. 6. Social innovations

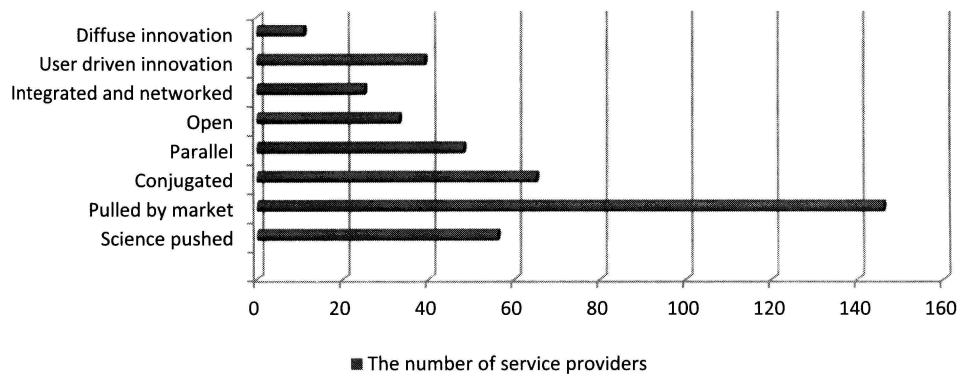


Fig. 7. Innovation processes conducted by health tourism providers

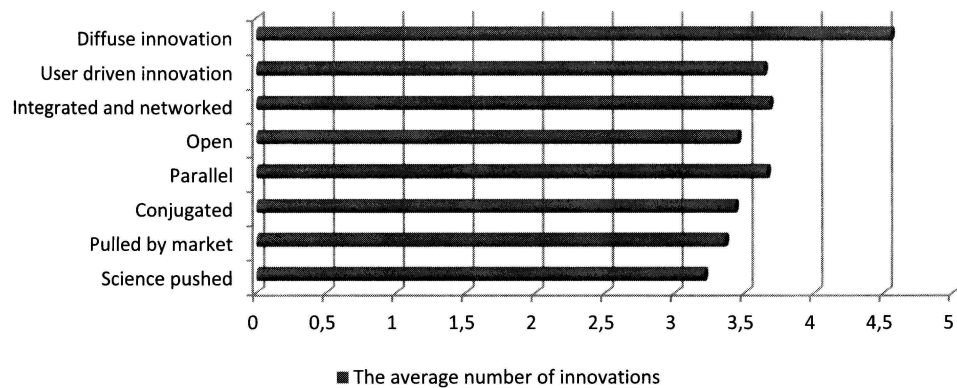


Fig. 8. Average number of innovations by innovation processes

4. DISCUSSION

The results of this research should be subjected to a deep discussion. It was indicated in publications by Panasiuk et al. (2016), and Jończyk (2014). It should be considered why enterprises providing services that are so important for society, do not follow their customer opinions in the innovation process. Knowing that there is a large demand for health services, the

employees and entrepreneurs do not see the need to engage patients in the process of creating their offer, organisational processes or interactive forms of marketing. The research by Szymańska (2009) indicated that each type of innovation (product, organizational innovation, process including technology innovations) in tourist companies is stimulated by management or owner most of all.

To answer the questions which arose in the course of the research, its scope would have to be expanded. And, perhaps, an extensive study of the needs of customers (patients) would pave the way for their broader cooperation.

CONCLUSIONS

Based on the research, it can be stated that the objective laid down in the Introduction has been achieved. This research enables the formulation of the following conclusions of a theoretical nature, which may make a certain contribution to innovation management theory. First of all, providers of health tourism, working with consumers while creating innovations, perform significantly better in terms of their number and the importance attributed to innovations. This allowed for the positive verification of the hypothesis.

Based on the research results, the following conclusions of an implementing nature can be drawn:

- Innovation processes that require cooperation are popular, but the most popular is the linear process "pulled by market";
- The diffuse innovation process was the most innovative but the least frequently indicated;
- This is particularly important when introducing product innovations, where the voice of users in the process of developing the concept of innovation is extremely important;
- The study of innovation processes should be deepened to enable the implementation of the model by the entities using other, less advanced models in practice.

Summing up, this study was conducted to create a new way of looking at health tourism innovativeness. The researchers hope that this study will build foundations for both innovation theory and practice for entrepreneurs operating at the interface between tourism and medicine for the results of the research to be applied in their economic activities.

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ANALYSIS OF THE EFFECTIVENESS IN THE DISBURSEMENT OF THE EUROPEAN REGIONAL DEVELOPMENT FUND FOR SELECTED ENTITIES IN THE TOURISM ECONOMY

EUGENIA PANFILUK

ABSTRACT

The aim of the article is to analyse the effectiveness of decision-making in the disbursement of funds from the ERDF for the selected tourism services. In the theoretical part of the article, the model for the assessment of the effectiveness of the ERDF management system was developed. This model is built based on the Propensity Score Matching (PSM) method, used to assess the effectiveness of community programmes. In the empirical part of the article, the verification of the model was carried out following the example of the tourism sector of the NUTS 2 region of Podlasie.

The obtained results allow concluding that the developed deadweight assessment model can be used in practice for the evaluation of the efficiency of the ERDF management. The conducted research indicates that the method of Propensity Score Matching (PSM), using the Neyman-Rubin model based on counterfactual studies, allows assessing the decision-making effectiveness in the disbursement of funds from the ERDF. Creating counterfactual situations in the models of evaluation of infrastructural actions serves for the identification of the effect of an independent event. The effect of an independent event measures the negative, unintended consequences of the undertaken decisions. It informs about the loss of alternative possibilities of allocating funds for other purposes.

KEY WORDS

European funds, deadweight evaluation model, public subsidies, management system

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INTRODUCTION

European Regional Development Fund is one of the most active regional policy instruments, including tourism policy. The effects of its implementation are measured in terms of both financial categories and the achieved socio-economic results. Experience shows that the most difficult part of the process is its evaluation. Assessment can be made using the finan-

cial outlay indicators, as well as quality indicators (Panfiluk, 2015). The advantage of qualitative indicators is the ability to capture the socio-economic changes, which are not analysed by the financial measures. With the use of qualitative measures, research was conducted on the ERDF's impact on the local tourism economy and the competitiveness of the tourist enterprise in relation to the selected effect

adopted in the political agenda. However, the conducted studies have focused on the analysis of the effects experienced by the environment; assessment from the point of view of efficiency of the ERDF management system was not attempted. The basic research problem focuses, therefore, on the need to answer the question whether, from the point of view of managerial decisions, the allocation was the best possible. Such a situation is best described by the measurement of the effect of the independent event. The effect of the independent event measures the negative, unintended consequences of the made decisions. This indicates the range of changes that would occur without bearing the costs of the realised activity. Loss of alternative possibilities of the allocation of funds for other purposes is an undesirable effect (Górniak & Keller, 2008). It occurs when the target group has been improperly identified, for which the system of management of the ERDF resources is directly responsible. The aim of the article is to analyse the effectiveness of decision-making in the disbursement of the ERDF funds for the selected tourism services. To carry out the measurement of the effect of the independent event and, consequently, the assessment of the efficiency of decision-making the *Propensity Score Matching* (PSM) method will be used.

1. LITERATURE REVIEW

EU funds are among the active tourism policy instruments. Their use leads to the development of the tourism economy in the region and increase of its importance in the economic structure of the region (Panasiuk, 2014). They constitute a significant factor stimulating investment activity of investors, both in the public and the private sector (Panfiluk, 2013a; Bondareva & Zatrochová, 2014). The co-financed investments include accommodation facilities (Panfiluk, 2016b), recreational, sports and a small tourist infrastructure, such as bike paths and hiking trails (Panfiluk, 2015b). These investments have contributed to the increase in the access to recreational services, high growth opportunities for the realization of tourist and recreation activities, and transport accessibility within the region (Panfiluk, 2016a). Also, they raised the tourist attractiveness of the subsidised facilities (Nash et al., 2006). Research confirms that they have also contributed to the increase in the attractiveness of the region (Panfiluk, 2016c). They

have a direct impact on the growth of the tourist attractiveness of the co-financed facilities; however, tourism companies that could contribute to the development of tourism, have not always arisen around these tourist attractions (Nash et al., 2006). The co-financed tourist investments have created new workplaces, influencing the employment growth (Panfiluk, 2015b). It should be noted, however, that only the investments related to the construction or expansion of facilities generate jobs. Among the infrastructure facilities of public benefit, new recreational facilities have the greatest importance for employment (Panfiluk, 2013b), in particular, the ones of a supra-local and supra-regional range (Panfiluk, 2015b). Research shows that the largest number of jobs is generated by businesses (Panfiluk, 2015b).

Attempts were undertaken to study the impact of subsidies on the local tourist economy and the competitiveness of the company considering specific effects adopted by the political agenda. The results are inconclusive. Some researchers have suggested that grants produce benefits from the resulting advantage only for a short term (Branzini & De Blasio, 2006), and a positive impact on the employment effects is undermined (Gabe & Krajbik, 2002) as well as the efficiency and productivity of workers (Griscoloni, 2009). However, there is also evidence of the positive impact of investments from non-repayable grants on employment (Carlucci & Pellegrini, 2005). A detailed study of the impact of subsidies on the condition of business is conducted for the four identified outcomes, i.e. employment, profit, the productivity of work, and entrepreneurship. It confirms the positive impact on employment and short-term profits but indicates that entrepreneurship and labour productivity show a downward trend (Bernini & Pellegrini, 2011, 2013).

It should be noted that the available studies indicate that the project/objective, and, therefore, the effect of the subsidy, generates a different level of efficiency and influences the development of the tourism sector to a different degree (Crouch, 2007). On the one hand, it is pointed out that an increasing touristic attractiveness of a facility does not always automatically translate into an increase in touristic attractiveness of the region, and does not always translate into the development of tourism in the region (Nash et al., 2006). On the other hand, there are results of research that state a significant effect to the growth of the tourist attractiveness of the tourist region (Panfiluk, 2016c). In the areas of high public intervention, the growth in the dynamics of the crea-

tion of the added value and the positive influence on the inhibition of the general declining trend in employment is observed (Panfiluk, 2016b). It has also been proven that the subsidised investments generate not only direct economic effects in the form of the development of the tourism sector but also positive indirect economic impact, contributing to job creation in the para-touristic service sector (Spencer & Nsiah, 2013).

2. METHODOLOGICAL ASSUMPTIONS FOR THE ANALYSIS OF THE DISBURSEMENT EFFICIENCY OF THE ERDF RESOURCES

1.1. ASSUMPTIONS FOR THE PROPENSITY SCORE MATCHING (PSM) METHOD

The *Propensity Score Matching* (PSM) is a method classified as one of counterfactual methods, largely used to assess the social effects of the public interventions, particularly recommended for carrying out the evaluation of programs and projects implemented under the ERDF (*The Programming Period 2014-2020*, 2014; Austin, 2011; Trzciński, 2009) This method is based on causal inference, which is based on the Neyman-Rubin model (Denkowska, 2015). The basic aim of the method is to determine the impact of the measures on the status of an individual or a community after the impact of these instruments (e.g. the impact of training on employment). The hypothetical assumption states that as an individual has been subjected to the impact, it is impossible to determine the state reached by the individual following the impact that would have been impossible to achieve without the impact of the intervention. Therefore, the method assumes that two individuals with the same characteristics and performances,

behave identically under identical conditions. This means that the effect that would arise in the absence of intervention would be the same in the group of individuals subjected to the impact and the control group. This assumption was the basis for the creation of the control group, i.e., the counterfactual situation (Fig. 1).

A counterfactual situation is defined as a situation, in which the analysed impact (public intervention) would not be realized. It could, therefore, be said that the counter-factual situation tells us how many entities subjected to the intervention would have implemented their actions if they had not been affected by it. Such a situation is called the result of the effect deadweight (Fig. 2).

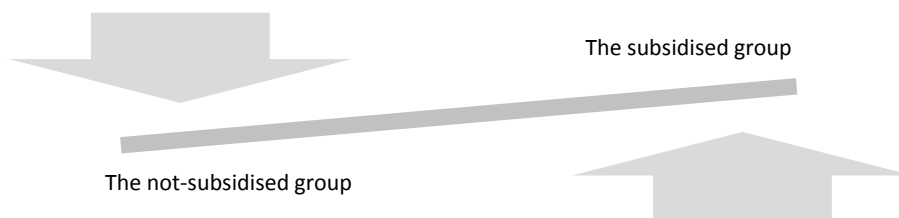


Fig. 1. Assumptions for the counterfactual situation

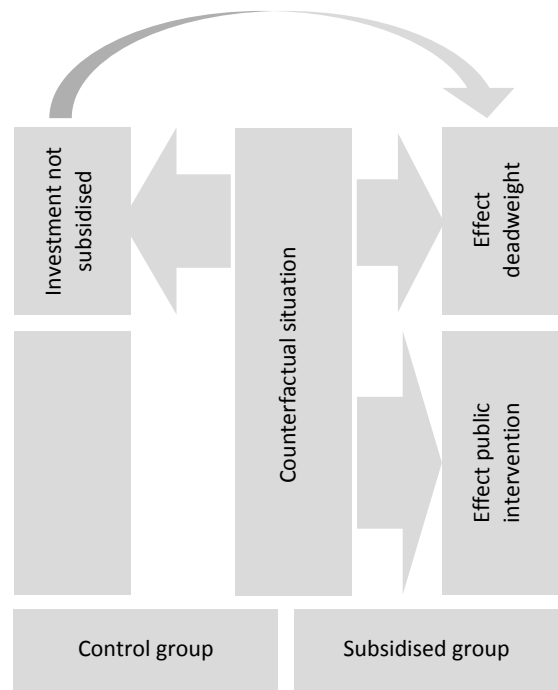


Fig. 2. Effect deadweight of the counterfactual situation

In statistical terms, the situation can be described by the following Formula 1 (Denkowska, 2015):

$$X_{ij} = E = D_1 Y_1 + (D - 1) * Y_0 \quad (1)$$

Where:

- X is a vector of observed characteristics of an individual;
- Y_1 – the effect in the case of implementation of the intervention;
- Y_0 – the effect in the absence of implementation of the intervention;
- D – the impact ($D \in \{0,1\}$);
- D = 1 means that the unit has been subjected to the intervention;
- D = 0 means that it was not subjected to the intervention;
- i – number of individuals with j – in elemental population only one of the two results of the output variable is possible.

Difficulties with the application of this method to social systems result from a strong differentiation and heterogeneity of the study group on the grounds of the characteristics and parameters of an individual. In the case of the ERDF management system, where intervention concerns grants for infrastructural tasks, the situation is less complex. Firstly, the support group is usually homogenous because of the purpose of the action and the assumed results. Secondly, the population can create a control group with the same characteristics and parameters with the identified same purpose of the action, the business activities, and the same area where the business operates. In addition, the control group may derive from the group of ineffective companies or the group of companies, which have not applied for a grant, or both groups of companies. Furthermore, due to the known quantity of finances, the effective enterprise is also able to determine how it would behave if it had not been subjected to the impact. The most important feature of the used method is the fact that it allows specifying the highest possible result that can be achieved due to the use of a particular instrument. Consequently, we can fully indicate a degree or level of the implementation efficiency of an organisation's objectives.

1.2. PROCEDURE TO BE FOLLOWED IN THE PROPENSITY SCORE MATCHING (PSM) METHOD

The procedure consists of six main phases (Fig. 3):

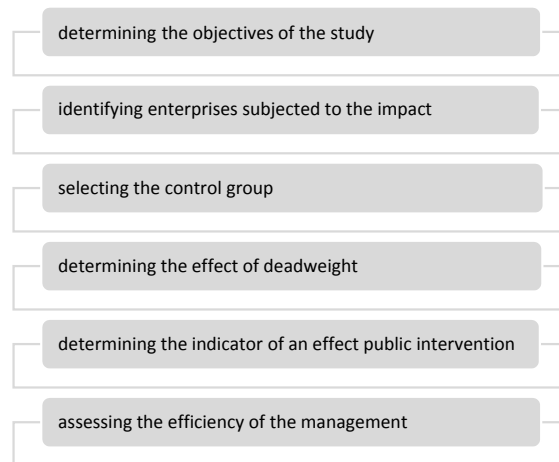


Fig. 3. Model for the evaluation of the ERDF management efficiency – the procedure to be followed

The starting point for the research is the formulation of the research objective. It sets the direction of the conducted analyses. In the second stage of the study, the subject of the research should be identified. According to the accepted research concept, the group should consist of entrepreneurs included in a public subsidy, operating in a homogeneous industry or a sector. It is important to include the entities that operate under similar socioeconomic conditions in the research. Consequently, the study should include the entities operating in regions with similar spatial and socioeconomic conditions. The control group should meet identical conditions: work in the same industry or sector, and operate under the same spatial and socioeconomic conditions. An important feature of the control group must be its uniformity and comparability with the group subject to the study. The control group is identified to determine the deadweight. The effect of an independent event determines the investment opportunities of companies in the industry, which operate in a specific socioeconomic area. Deadweight determines the counterfactual situation of the examined group. The final stage of the research procedure is the evaluation of the decision-making managers managing the ERDF. The assessment is carried out in accordance with the adopted assessment scale.

1.3. ASSUMPTIONS FOR THE IDENTIFICATION OF THE CONTROL GROUP IN THE PROPENSITY SCORE MATCHING (PSM) METHOD

In assessing the effectiveness of the disbursement of ERDF resources, the objective of the analysis is reduced to examining whether the ERDF resource

allocation was the best possible from the point of view of managerial decisions in achieving the objectives of the Regional Operational Programme (ROP). The analysis can be carried out considering the entities subjected to the influence of public intervention

subsidies. The second variant concerns entities subject to the impact of the ERDF intervention. The study consists of identifying the hypothetical behaviour of the entity in the event of not receiving the grant from the ERDF (Fig. 4).

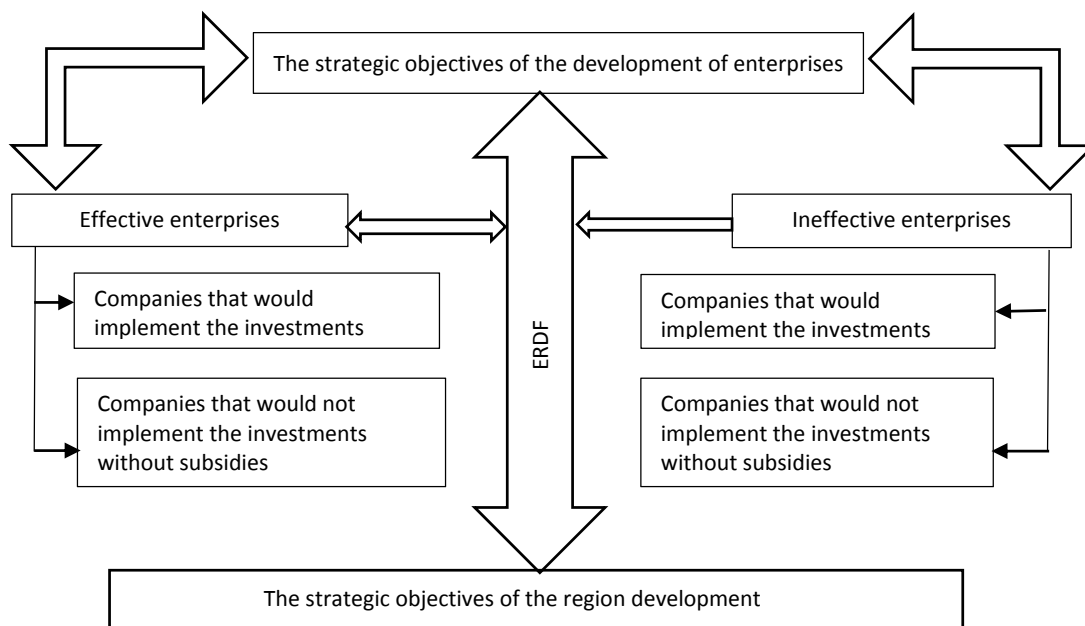


Fig. 4. Model of evaluation of the ERDF management efficiency – identification control group

of a particular sector, industry or a type of entities. Theoretically, the entities subjected to the impact due to the implementation of the ROP objectives, form a homogeneous group. Their objectives are compatible with the objectives set out in the ROP. For the identified homogeneous group of entities subject to the impact of the ERDF, a control group is selected. The control group must meet three basic criteria: the entity of the control group should pursue the same economic objectives, do business in the same industry, and operate in a similar or the same economic space. The control group is used to measure the negative effect of the independent event. The independent event is the behaviour of market actors, independent from the public intervention. On its basis, the hypothetical number of entities that would realise their goals regardless of public intervention is determined.

As a result of the theoretical analysis, it is concluded that the control group can be created in two variations. The first variant of the control group is formed by companies that applied for a grant but did not receive it (the so-called ineffective entities). In this case, the study consists of identifying whether the entity that applied for a grant for a specific purpose (the project) realised the intended purpose without

Theoretically, the third variant of the control group can also occur. The control group consists of entities that did not apply for a grant and meet the criteria of the control group. Selecting that group is carried out in several stages. The first step is the creation of a database of entities operating in the examined industry. The second stage is the compatibility analysis of provisions pertaining to the strategy objectives or the company's development programme and public intervention objectives set out in the strategy document (ROP). The control group should include only the entities whose development goals were compatible with the ROP. Then, the number of entities that have achieved objectives falling within the support from the ROP during the impact of the programme was examined in this group. Creating the control group in practice may be impossible to realize. This is because companies do not have the obligation to have a strategy or the company development programme, and, moreover, investment plans are protected. Besides, usually, companies do not provide such information.

1.4. EVALUATION OF THE ASSUMPTIONS REGARDING THE DECISION EFFICIENCY USING THE PROPENSITY SCORE MATCHING (PSM) METHOD

The decision efficiency was evaluated using a five-grade scale.

Values were assigned to the % result of the study of the counterfactual situation. The value of 5 indicated a situation where more than 81% of the entities subject to the public intervention would not achieve their objectives. In this case, the effect of the independent event (independent negative effect) was from 1 to 20%. To a very great extent, the public intervention contributed to acquiring the positive socioeconomic effect. Management decisions on the selection of the target group were the best possible. This situation corresponded to the very high efficiency of the ERDF management. A value of 1 meant that only 1% to 20% of the entities subject to public intervention would not achieve their objectives. In this case, the effect of the independent event (independent negative effect) is from 80 to 100%. The public intervention did not contribute to acquiring the positive socioeconomic effect. From the point of view of resource allocation, management decisions on the selection of the target group were not properly made. This situation corresponded to the lack of effective ERDF management. The undesirable result of such a situation was a loss of alternatives for the allocation of funds for other purposes (Table 1).

Tab. 1. Assessment scale of the management system performance

SCALE	THE RESULT IN %	EFFICIENCY
1	1 – 20	Lack of efficiency
2	21 – 40	Low efficiency
3	41 – 60	Average efficiency
4	61 – 80	High efficiency
5	81 – 100	Exceptionally high efficiency

2. SELECTION OF A RESEARCH SAMPLE

Verification of the assessment model of the ERDF management system was carried out using the example of management applied to the Regional Operational Programme for Podlaskie Voivodeship 2007-2013 by the Department of Regional Develop-

ment of the Podlaskie Voivodeship Marshal's Office. The effectiveness of the ERDF resource disbursement was calculated for one of the six RPOWP 2007-2013 goals, namely the development of tourist facilities in the region, which was implemented by strengthening the tourism industry in the region as a result of the expansion and construction of accommodation facilities. The goal is recorded in the Detailed Description of Priority Axes RPOWP 2007-2013 as measure 3.2: *Investment support of tourism enterprises* of priority III *Development of tourism and culture*.

In 2015, this region was selected for the study by the European Commission as a representative region of Poland for the *Ex-post evaluation of Cohesion Policy Programmes 2007-2013 – WP9: Culture & Tourism* study. Analysis of the tourism potential of the Podlaskie region compared to EU regions showed that for 283 EU regions at NUTS 2 level, Podlaskie is situated among 68 regions with the lowest tourist potential. The analysis of the position of the Podlaskie Voivodeship against the background of the regions of the European Union was prepared using the method cluster analysis, the Ward method, and k-means. The analysis covered 283 European regions at the NUTS 2 level, for which data was available in the Eurostat database, concerning the following variables: the number of establishments, number of beds, total nights spent by residents, and total nights spent by non-residents. The data concerned the year 2013. The tourist potential of the Podlaskie Voivodeship was compared to the domestic and foreign regions. The focus was on the impact of projects in the field of tourism and culture on the socioeconomic development of the region. The position of the Podlaskie Voivodeship was compared to the background of the country and Europe (Dębkowska & Szymańska, 2015). It should be emphasized that comparative statistical analyses alone, without perceiving a wider range of conditions and specificity of the tested region, are not enough to draw clear conclusions. Rich in natural resources, this region is the most valuable region of Poland. Natural areas are particularly valuable worldwide and protected by law. The region boasts four national parks, three landscape parks, 83 nature reserves, NATURA 2000 sites, 13 protected landscape areas, 262 ecological grounds, a nature-and-landscape complex, three documentary stations and 1932 natural monuments. A high rank of the region is illustrated by the international status given to four of them: Białowieża National Park – the area of strict protection, including the biosphere reserve, which is the natural object of the UNESCO World

Heritage Site; and the Biebrza National Park, Narew National Park, and Wigry National Park – all protected under the international Ramsar Convention.

The Podlaskie Voivodeship has the least transfigured nature, but in terms of the proportion of the protected area, it occupies the 8th position in the country (although the percentage of the area of national parks and the SACs is the highest, and in the case of SPAs, it comes second).

Naturalness (non-substitutability) of natural resources, uniqueness, preciousness, rarity, and the impossibility of imitation causes them to be a significant resource for creating a competitive advantage of the region (Barney, 2001). According to studies conducted in the region, high natural values, clean air, low noise, attractive tourist routes, high quality of public catering establishments, low rental prices of recreational equipment and guide services are the

i.e. the so-called effective entities. The control group consisted of entities that applied for a non-refundable grant for the development of the company and did not receive it, i.e. the so-called ineffective entities. In total, the first group of entities consisted of 44 companies, while the second group of entities consisted of 68 companies. The entities were verified on account of the investment objective (expansion, construction of accommodation facilities). Further, the study concerned companies that applied for grants for the purpose associated with the development and construction of accommodation facilities, i.e. 36 successful companies and 48 ineffective businesses. The comprehensive sample was included in the study. The research material used in the analysis was collected using a questionnaire, telephone interview, and the CAWI questionnaire. The achieved rate of return of surveys is presented in Table 2.

Tab. 2. Size of the research sample

SPECIFICATION	NUMBER OF COMPANIES OPERATING IN THE AREA OF ACCOMMODATION, OVERALL	NUMBER OF COMPANIES COVERED BY THE STUDY	NUMBER OF COMPLETED SURVEYS	RETURN RATE IN %
Effective entities, which received a grant from action 3.2 (effective entities, which received a grant from the activity 3.2)	36	36	25	69.44%
Ineffective entities, which did not receive grants from action 3.2 (ineffective entities that applied for a grant from the activity 3.2 and it did not receive it)	48	48	45	93.75%

components of the tourism potential, basing on which the competitive advantage of naturally precious areas of the Podlaskie Voivodeship can be built (Borkowska-Niszczota, 2014).

In this region, the total value of the investment funds invested in tourism and culture for the projects co-financed by the ERDF amounted to 10% of the total value of the funds invested in the projects co-financed by the ERDF in the years 2007-2013 (Panfiluk, 2015b).

The study included private entities working in the area of accommodation (PKD Section I, Chapter 55) from the list of competition results announced by the ERDF, i.e. the Department of Regional Development of the Podlaskie Voivodeship Marshal's Office, the managing authority at the regional level. The starting point for the research was the creation of the database of entities. Two groups of entities were created. The first group of entities was comprised of the companies, who applied for a non-refundable grant for the development of the company and received it,

The comparability of the results and the homogeneity of the control group, were obtained through the verification with respect to the object and area of activity.

The comparability of the results and the homogeneity of the control group was achieved through the verification on account of the business activity and space of activities.

3. RESEARCH RESULTS

3.1. RESEARCH RESULTS: VARIANT 1 – CONTROL GROUP – NON-SUBSIDISED ENTERPRISES

Detailed studies have shown that the public intervention covered 36 entities providing services related to housing. The support was granted for the implementation of the objective connected to the expansion of tourist facilities in the region. Invest-

ments connected to the expansion and construction of accommodation facilities in the region were co-financed. This means that Y_1 (the effect in the case of the investment implementation) is 36 entities. The control group in this variant was made from ineffective entities, i.e. those who applied for support, but did not receive it. The examination of the control group allowed determining the effect of the independent event. It was estimated that of the 45 entities from the control group, 8 entities who applied for a grant but did not receive it, realized their goals. This means Y_0 is equal 8 (Table 3).

The support was granted for the implementation of the objective connected to the expansion of tourist infrastructure in the region. Investments connected to the expansion and construction of accommodation facilities in the region were co-financed. This means that Y_1 (the effect in the case of the investment implementation) is 36 entities. The control group in this variant was made from effective entities, i.e. those who applied for support and received it. The successful entities were asked whether and to what extent the ERDF resources made it possible to achieve the objective. 25 (69.44%) subsidised entities took part in

Tab. 3. Research results: variant 1 – control group – non-subsidised enterprises

SPECIFICATION	NUMBER OF SUBSIDISED ENTERPRISES	CONTROL GROUP, NON-SUBSIDISED ENTERPRISES
Number of researched enterprises	36	45
Effect of subsidies	36	0
Effect of deadweight	0	8
Structure	100%	17.77%
Effect of deadweight	17.77%	
Effect public intervention	82.23%	
Assessment of the efficiency of the management system scale	80 – 100%	Very high efficiency

The effects of public intervention were calculated using the following formula:

$$E = D_1 Y_1 + (D-1) * Y_0 \quad (2)$$

Where:

- $Y_1 = 36$ (100%) entities that have made the expansion or construction of tourist accommodation as a result of the support from the ERDF;
- $Y_0 = 8$ (17.77%) out of 45 entities carried out investments connected to the extension or construction of accommodation without co-financing from the ERDF (the effect of the independent event).

Given the scale of the efficiency assessment of the management system (Table 1), the obtained result fits into the fifth class. This means that 82.23% of the entities subject to public intervention did not achieve their goals. The public intervention contributed to the achievement of the positive socioeconomic effect to a very great extent. Management decisions regarding the selection of the target group were reasonable and optimal. This situation corresponds to the very high efficiency of the ERDF management.

3.2. RESEARCH RESULTS: VARIANT 2 – CONTROL GROUP – SUBSIDISED ENTERPRISES

Detailed studies have shown that the public intervention covered 36 entities providing services related to housing.

the study. It was found that for 16 out of 25 respondents (64%), the grant enabled the realization of the full objective, to 32% (8 entities) the obtained grant allowed to realise a part of their objectives, and in the case of one subject (4%), the grant did not affect the implementation of objectives. This means that one of the surveyed companies would carry out the investment even without the subsidy, i.e. the effect of the independent event is: $Y_0 = 1$; $Y_0 = 1$ (4%), (Table 4).

The effects of a public intervention were calculated using the following formula:

$$E = D_1 Y_1 + (D-1) * Y_0 \quad (3)$$

Where:

- $Y_1 = 36$ (100%) entities that have expanded or constructed tourist accommodation facilities as a result of the ERDF support;
- $Y_0 = 1$ (4.00%) per 25 surveyed entities that would implement the investment concerning the extension or construction of accommodation facilities without the ERDF co-financing in whole or in part (due to the independent event).

Given the scale of the efficiency assessment pertaining to the management system (Table 4), the result obtained fits into the fifth class. A public intervention contributed to the achievement of a positive socioeconomic effect to a very great extent. Management decisions on the selection of the target group

Tab. 4. Research results: variant 2 – control group – subsidised enterprises

SPECIFICATION	NUMBER OF ENTERPRISES SUBSIDIES	CONTROL GROUP, SUBSIDIES ENTERPRISES
Number of researched enterprises	36	25
Effect of subsidies	36	0
Effect of deadweight	0	1
Structure	100%	4%
Effect of deadweight	4%	
Effect public intervention	96%	
Assessment of the efficiency of the management system scale	80 – 100%	Very high efficiency

were reasonable and optimal. This situation corresponds to the very high efficiency of ERDF management.

CONCLUSIONS

The conducted research indicates that the method of Propensity Score Matching (PSM), using the Neyman-Rubin model, based on counterfactual studies, allows assessing the decision-making effectiveness in the disbursement of funds from the ERDF. Creating counterfactual situations in the models of evaluation of infrastructural actions serves for the identification of the effect of an independent event. The effect of an independent event measures the negative, unintended consequences of the undertaken decisions. It informs about the loss of alternative possibilities of allocating funds for other purposes.

A small variation of the control group is the essence of the construction of counterfactual situations in the models for the evaluation of infrastructural actions. The result is that the assessment must be carried out in a homogeneous group of entities, i.e. a sector, industry, or a type of entities. The basic features of the control group for the entities undertaking infrastructural activities constitute one and the same items of economic activity according to PKD and the area/space of its business activities as well as the similar size of enterprises. As a result of research, it was found that a counterfactual situation may be created by three categories of participants:

- entities subjected to influence, as knowing their financial potential may indicate the manner, in which a unit would have acted had it not been subjected to influence;
- entities not subjected to influence, and showing the need to support their business activities with an ERDF instrument;

- entities not subjected to influence and entities not interested in the participation in ERDF support.

The proposed concept of the assessment of the ERDF management system in a short period of time allows estimating the effectiveness of the management system for the implemented instrument.

From the point of view of empirical research, it was found that the best possible management decisions were made on the allocation of funds foreseen for the achievement of the objective: the development of the tourist base in the region through strengthening the tourism industry in the Voivodeship as a result of the expansion and construction of accommodation facilities in the region. The target group subjected to the influence of the ERDF was identified properly. A remarkably high efficiency of the ERDF management system was noticed in the framework of the measures envisaged for the implementation of the objectives set in the Regional Operational Programme of Podlaskie Voivodeship 2007-2013, Action 3.2. *Investment support for tourism enterprises of the Priority III Development of tourism and culture.*

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THE MODELS EVALUATING COURIER AND MESSENGER COMPANIES IN POLAND

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ABSTRACT

Data Envelopment Analysis (DEA) is a well-established, popular, and often used method for efficiency evaluation of units from all sector, both commercial and non-profit organisations, of any scale of operations. Network DEA models are a relatively recent approach used to examine the efficiency of decision-making units (DMUs) having an internal structure of sub-processes. The article presents the concept of DEA network models in estimating the efficiency of courier and messenger companies with relations to their business clients. The considerations are supported by an example of data concerning leaders from the sector of couriers and messengers in Poland and one of the biggest and most popular online stores. The results are compared with the traditional DEA approach. In addition, to measure reliability for DEA scores, the jack-knife procedure was performed. The author proves the usefulness of network DEA as a research and management tool.

KEY WORDS

courier and messenger companies, network DEA, efficiency, evaluation

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INTRODUCTION

Increased market competition, changing customer requirements and the provisions for the management of product lifecycle mean that many companies are searching for new operational models. To a great extent, this process applies to logistics systems in companies. A growing number of firms focus on their core competency and begin to outsource the logistics

activities, contributing to the increasing popularity of third-party logistics (3PL) and fourth-party logistics (4PL) services. It is worth emphasizing that in many cases the operational efficiency of the chosen logistics system can be the factor that determines the competitiveness of a company. Data Envelopment Analysis (DEA), since its introduction, has become widely used for measuring the efficiency of logistics provid-

ers as well as whole logistics systems. The following section of the article provides some literature that supports this statement. The article focuses on the efficiency of courier and messenger companies. A case study includes the courier market in Poland.

1. LITERATURE REVIEW

Based on a literature review on the subject of the application of the DEA method in logistics, it can be noticed that the majority of the publications focused on the comparative efficiency of enterprises providing logistics services. Among others, DEA was used for benchmarking of the operational efficiency of major 3PLs in the USA (Min & Joo, 2006). The proposed approach allowed to evaluate the prioritization of the use of financial resources and identify the potential cause for inefficiency. According to the researchers, DEA measures the operational efficiency better than traditional financial ratios, such as return on investments or assets.

There were also assessments of substantial components of supply chains and logistics operations. The work by Johnson & Mcginnis (2011) evaluating warehouses can serve as an example. According to the researchers, financial indicators, for example, revenue related to cost, are not fully appropriate because warehouses function to support the supply chain rather than generate revenue. Moreover, the settings and the general economic conditions of the warehouse owners have the major impact on the costs of the resources used by each warehouse. Researchers reviewed the literature on warehousing performance assessment and proposed the two-stage method that consists of estimating the efficiency in the first stage using DEA and identifying contextual variables correlated with high efficiency in the second stage using a regression model. The data were collected via the iDEAs-W website (<http://ise.tamu.edu/ideas/>). DEA found to be a useful method to evaluate both individual warehouses and groups of warehouses and to identify the operational policies, design characteristics and attributes correlated with technical efficiency.

Another example is a comparative analysis of the efficiency of Chinese and Korean major container terminals from the list of world top container ports published in 2010 Lu & Wang (2012). According to the work, DEA provided a more appropriate benchmark with insights into resource allocation and optimization of the operating efficiency, helped to identify

the returns to scale and the potential areas of improvement for inefficient terminals. Empirical results derived from DEA revealed that substantial waste exists in the production processes in the world's leading container terminals.

In addition to publications that treat companies or logistics departments as 'black boxes' where inputs are transformed into outputs, recent trends tend towards the analysis that looks inside the organisations using the network DEA approach. The network DEA considers the existence of several stages, each of which consumes its own set of inputs and produces its own set of outputs, in addition to consuming and producing intermediate products. One of the first works introducing and popularizing the network methodology were Färe & Grosskopf (2000) and Lewis & Sexton (2004). The first paper provided the general framework of the network DEA model. Lewis & Sexton (2004) presented some theoretical properties of the network DEA model and applied it to major league baseball. Kao (2014) conducted a comprehensive review of studies related to network DEA with regard to both the models and structures examined. Cook & Zhu (2014) provided a complete source for the state-of-the-art DEA modelling the internal structures and network DEA.

In the field of logistics, the advantages of network DEA were used in attempts to measure the performance of supply chains. Due to the network nature of many supply chains, DEA seems to be a suitable tool for the analysis of comprehensive supply chains.

Zhu (2003) presented a DEA-based supply chain model with four echelons: suppliers, manufacturers, distributors, and retailers to measure the efficiency of both the supply chain and its members. A provided numerical example in Microsoft Excel yielded a set of optimal values of the intermediate performance measures and indicated that two supply chains might have different input-output mix, and both might be efficient.

Liang et al. (2006) developed several DEA-based approaches for characterizing and measuring supply chain efficiency when intermediate measures are incorporated into the performance evaluation. The models were illustrated in a hypothetical seller-buyer supply chain context when the relationship between the seller and buyer is treated as leader-follower or is cooperative.

Chen et al. (2006) investigated the efficiency game between two supply chain members: a supplier and a manufacturer. They developed two efficiency functions for the supplier and the manufacturer and

showed that numerous Nash equilibriums efficiency plans exist for the supplier and the manufacturer.

Chen & Yan (2011) established the network DEA model for the efficiency evaluation of two stage supplier–manufacturer supply chain. Three theoretical network DEA models were introduced to the concept of centralised, decentralised and mixed organisation mechanisms. In a centralised control mechanism, the supply chain is supervised by a single decision maker who can arrange the supplier and manufacturer operations to maximise the whole supply chain efficiency. In a decentralised organisation, each of the division has its own missions and strategies. The conducted analysis proved that only for the centralised control mechanism it is possible to take the internal structure of supply chain as a ‘black box’ when evaluating the performance.

Wong & Wong (2007) adopted two DEA models (technical efficiency model and cost efficiency model) to measure internal supply chain performance. The output and input variables used for analysis were respectively revenue, on-time delivery rate and cost, internal manufacturing capacity, and cycle time. The concept integrates elements of the supply chain and evaluates them as one system. However, in contrast to the above-mentioned works, the proposed DEA-based approach was confirmed by a real data set from companies operating in the semiconductor sector of Malaysia. According to the researchers, the information obtained from the DEA models could help managers identify the inefficient operations and take the right remedial actions for continuous improvement.

The supply chain efficiency measured by the application of DEA was also presented by Mishra (2012). A case study included 29 enterprises from the pharmaceutical industry of India. Eight inputs (internal manufacturing capacity, supply chain cost, working capital, invested capital, the number of employees, wages to workers, material consumed and fuels consumed) and two outputs (net value added and net income) were considered. The obtained results indicated the scope for improvement of the pharmaceutical companies.

Momeni et al. (2014) took into account that the input and output data in real-world problems are often imprecise or ambiguous and proposed a fuzzy network slack-based DEA model for evaluating supply chain networks with imprecise data and reverse logistics. A case-study was presented to demonstrate the applicability of the proposed model in evaluating

the procedures of a supply chain in the semiconductor industry.

More awareness of the environmental damage caused by human activities, and increased attention towards the environment, resulted in the development of a methodology for assessing eco-efficiency in logistics networks.

Quariguasi Frota Neto et al. (2008) reviewed the main activities influencing sustainability in logistics networks and developed a framework for the design and evaluation of sustainable logistics networks, in which profitability and environmental impacts are balanced. The technique was based on the commonalities between DEA and multi-objective programming. They illustrated the approach in the European pulp and paper sector.

To sum up the brief review of the literature on DEA in logistics, DEA proved to be a reliable, flexible and efficient tool for measuring the performance of both supply chain members and the entire supply chain systems. However, because of unavailability of data in many organisations, the complex considerations of supply chains are impossible and necessarily limited to the context of direct relationships of selected tiers of the supply chain and its members.

2. COURIER AND MESSENGER COMPANIES IN POLAND

The sector of couriers and messengers in Poland is growing very rapidly. In 2014, courier companies provided 171.61 million of units of service and achieved the revenue of PLN 2462.65 million. For comparison, 2013 saw 132.46 million of units of service provided and PLN 2176.12 million in revenues earned. That gives an increase of 29.5% in terms of the volume and 13.1% in terms of the revenue. The development of the courier sector is linked to the market of e-commerce, which in Poland continues to remain at the early stages of expansion if compared to the level of e-commerce in the Western Europe despite its rapid growth that has been taking place for some years (Report..., 2014; Report..., 2013).

There are approaches to assess courier companies in Poland using the DEA, for example Kozłowska (2014) but the reliability of the comparison can be questioned due to arbitrary rather than a homogeneous set of data, including companies with a different core business, despite the same PKD (Polish Classifi-

cation of Activity) number. First at all, nine service providers of the courier sector in 2014, the largest in terms of volume and revenue, had the share of 84.63% of the total volume and the share of 94.62% of the total revenue generated from the provision of courier services (Report..., 2014). Table 1 provides their total operating revenue.

Tab. 1. Leaders in the courier segment in 2014

	COMPANY NAME	ABBREV.	TOTAL OPERATING REVENUE [MLN PLN]
1.	DHL Express (Polska) sp. z o.o.	DHL	1298.6
2.	DPD Polska sp. z o.o.	DPD	690.5
3.	FedEx Express Polska sp. z o.o.	FedEx	249.8
4.	Federal Express Poland sp. z o.o.	Federal	96.9
5.	General Logistics Systems Poland sp. z o.o.	GSL	378.8
6.	K-EX sp. z o.o.	K-EX	140.7
7.	Siódemka S.A.	Siódemka	337.9
8.	TNT Express Worldwide 'Poland' sp. z o.o.	TNT	429.6
9.	UPS Polska sp. z o.o.	UPS	1540.4

Source: on the basis of (Report..., 2014; EMIS).

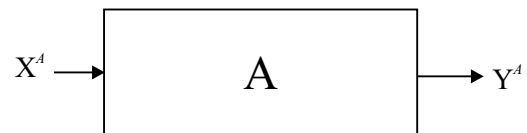
It is worthwhile mentioning that the market of couriers and messengers is highly dynamic. Mergers and acquisitions are also rather frequent. In 2012, FedEx bought the Polish *Opek Sp. z o.o.* In 2014, *DPD Polska*, which is owned by the French State Mail, bought *Siódemka*. In 2015, *FedEx* planned to take over *TNT Express*. For the analysis, the data about courier companies was collected from Emerging Markets Information Service (EMIS) database.

Traditionally, a courier is associated with the part of the delivery system that connects a retailer and a customer. However, in 2012, every third company in the European Union had something to do with electronic shopping. Polish companies exceeded the thresholds of 20% but ranked far below the EU average. In 2013, compared to the previous year, the percentage of firms ordering goods and services via computer networks increased by 2.4 percentage points and amounted 23.6%. Electronic commerce became the most popular among big companies involved in computer and communication equipment repairs as well as information and communication (The information society ..., 2014). However, services provided by external couriers mostly form the basis of logistic systems used by micro and small enterprises. The hypothetical system that consists of two members, i.e. a courier and another enterprise, is the subject of the analysis presented in this paper.

3. RESEARCH METHOD FOR EVALUATING COURIER AND MESSENGER COMPANIES

Firstly, the traditional DEA model to measure the relative performance of courier companies was applied. The analysed process included transforming two inputs in the form of a payroll plus social security and other benefits as a measure of labour costs and other operating expenses into output – the total operating revenue (Fig. 1). In the opinion of the author, labour costs are a better reflection of labour use in a company rather than the number of employees, even if converted into full-time jobs.

Labour productivity determined by the level of employment only partially expresses the personal abilities of employees and the intensity of their effort. Rather, it reflects how effectively their work is combined with other input factors in the production process. The chosen solution, to a greater extent, reflects the degree of the use of available resources and qualifications of employees. Still, the solution has some flaws. First at all, it is a derivative of the local labour market conditions and is associated with regional differentiation of salaries. Moreover, it contains additional costs, such as severance pays for dismissed employees, which are not directly associated with processes of the production/ services.



where:

- $X^A = (x_1^A, x_2^A)$,
- x_1^A – payroll plus social security and other benefits,
- x_2^A – other operating expenses,
- $Y^A = (y_1^A)$,
- y_1^A – total operating revenue.

Fig. 1. One-stage DEA evaluation of a courier company

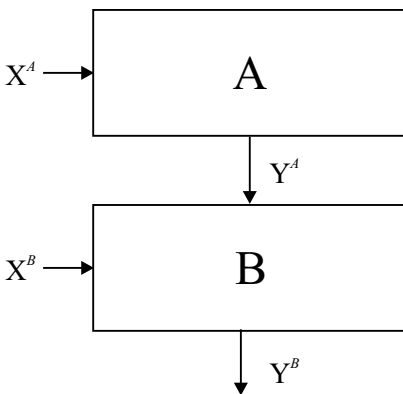
The efficiency in one stage DEA was obtained by employing the conventional DEA CCR-I model:

$$\begin{aligned} \Omega_A^* &= \min_{\Omega_A, \lambda_j} \Omega_A \\ \sum_{j=1}^J \lambda_j x_{ij}^A &\leq \Omega_A x_{ijo}^A \quad i = 1, 2, \dots, I^A \\ \sum_{j=1}^J \lambda_j y_{tj}^A &\geq y_{tjo}^A \quad t = 1, \dots, T \\ \lambda_j &\geq 0, \quad j = 1, \dots, J \end{aligned} \quad (1)$$

where:

- x_{ij}^A - i -th input for the DMU $_j$,
- y_{tj}^A - t -th output for the DMU $_j$,
- $j = 1, \dots, J$ - number of DMUs,
- λ_j - weighs.

Such approach would be appropriate and sufficient in the case of analysing and identifying the best practice among courier enterprises. When evaluating



where:

- $X^A = (x_1^A, x_2^A)$ - direct input vector of the courier,
- x_1^A - payroll plus social security,
- x_2^A - other operating expenses,
- $Y^A = (y_1^A)$ - intermediate output vector of the courier/input vector of the other enterprise,
- y_1^A - total operating revenue,
- $X^B = (x_1^B, x_2^B)$ - direct inputs to the other enterprise,
- x_1^B - payroll plus social security,
- x_2^B - other operating expenses,
- $Y^B = (y_1^B)$ - direct output vector of the other enterprise,
- y_1^B - profit.

Fig. 2. Two-stage network DEA model for evaluating courier and other enterprises

network processes, the outputs from one stage become the inputs of the next stage and other inputs can enter the process at each intermediate stage. Moreover, there usually is a conflict between chain members' interests. First member's objective to maximise, for example, the revenue can at the same time be the minimisation of costs for the next member. In order to evaluate courier and messenger companies, the following model presented in Fig. 2 was applied.

Presented in Fig. 2, the two-stage network structure with additional inputs to the second stage can be estimate by following equations adopted from Zhu (2003):

$$\begin{aligned} \Omega^* &= \min_{\Omega_A, \Omega_B, \lambda_j, \beta_j, \bar{z}} (\Omega_A + \Omega_B)/2 \\ \sum_{j=1}^J \lambda_j x_{ij}^A &\leq \Omega_A x_{ijo}^A \quad i = 1, 2, \dots, I^A \\ \sum_{j=1}^J \lambda_j z_{tj}^{A-B} &\geq \bar{z}_{tjo}^{A-B} \quad t = 1, \dots, T \\ \lambda_j &\geq 0, \quad j = 1, \dots, J \\ \sum_{j=1}^J \beta_j x_{ij}^B &\leq \Omega_B x_{ijo}^B \quad i = 1, 2, \dots, I^B \\ \sum_{j=1}^J \beta_j y_{rj}^B &\geq y_{rjo}^B \quad r = 1, 2, \dots, R^B \\ \sum_{j=1}^J \beta_j z_{tj}^{A-B} &\leq \bar{z}_{tjo}^{A-B} \quad t = 1, \dots, T \\ \beta_j &\geq 0, \quad j = 1, \dots, J \\ \Omega_A, \Omega_B &\leq 1 \end{aligned} \quad (2)$$

where:

- x_{ij}^A - i -th input to the A stage for the DMU $_j$,
- x_{ij}^B - i -th input to the B stage for the DMU $_j$,
- z_{tj}^{A-B} - t -th intermediate output from A to enterprise B (input to B),
- y_{rj}^B - r -th output to the B stage for the DMU $_j$,
- $j = 1, \dots, J$ - number of DMUs,
- $\Omega^* = 1$ means that there exists an optimal solution such as $\lambda_{jo}^* = \beta_{jo}^* = 1$.

The model (2) integrates the efficiency of each stage in the network via geometric averages. In the article, the models to obtain the efficiency scores were solved in Microsoft Excel, using VBA programming to automate it.

Figs. 3 and 4 illustrate potential extensions of the presented and empirically applied two-stage model.

The basic two-stage DEA model can be simply extended to the structure: producer–courier–another enterprise, as shown in Fig. 3. The interesting approach Liang et al. (2011) is the proposal to include the feedback to the serial network process. Fig. 4 presents the situation where the output from the second stage can be fed back as the input to the first stage.

Since DEA is a non-parametric method, changes in the data set may highly affect the final results. The reliability of DEA scores can be measured alter-

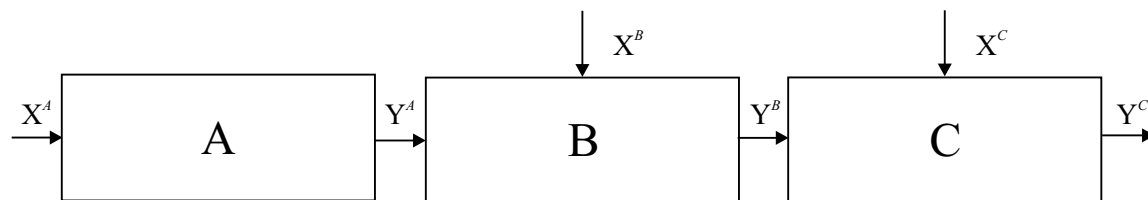


Fig. 3. Tree-stage process

Source: adopted on the basis of (Cook & Zhu, 2014).

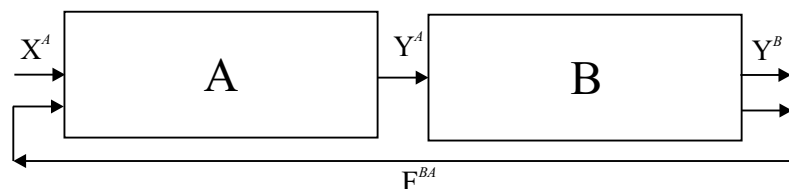


Fig. 4. Two-stage process with feedback

Source: adopted on the basis of (Cook & Zhu, 2014).

natively by the bootstrap technique or jack-knife procedure. In this work, because the sample set is small, the author proposes examining the sensitivity of DEA efficiency scores by the jack-knife procedure. Jack-knife is a resampling method that uses a subset of available data. The procedure involves the repetition dropping one DMU and using the remaining data to compute DEA scores. To test the robustness of DEA by jack-knife, it is enough to exclude only efficient units. The standard deviation of obtained efficiency scores provides information, for example, on the presence of outliers.

4. RESULT

The data about the courier companies for the analysis was collected from EMIS database. The hypothetical chain that consists of two types of members, i.e. leaders of the sector, is listed in Tab. 1. The bigger enterprise in the electronic shopping sector, that does not have stationary shops (Bonprix Sp. z o.o.) and has fixed values of profit of 56.89, operating expenses of 614.82 and the payroll of PLN 16 628 mln was the subject of analysis of this paper. Efficiency ratios relating to courier companies that evaluate how they transform operating costs to revenue and efficiency ratios relating to courier companies as members of chains differ significantly (Tab. 2). The efficiency of the second member of the chain (another company) was equal to one due to assumptions of the fixed values. The frontier plot and selected inputs and outputs of courier companies included in DEA are illustrated in Fig. 5.

Tab. 2. DEA scores

	Ω_A^* (ONE-STAGE COURIER EFFICIENCY)	Ω^* (TWO-STAGE PROCESS EFFICIENCY)	$\hat{\Omega}_A$ (COURIER EFFICIENCY IN TWO-STAGE PROCESS)
DHL	0.853	0.532	0.064
DPD	0.920	0.565	0.129
FedEx	0.777	0.651	0.301
Federal	0.724	0.862	0.724
GSL	1.000	0.628	0.256
K-EX	0.782	0.769	0.538
Siódemka	0.965	0.638	0.277
TNT	0.961	0.608	0.217
UPS	1.000	0.531	0.063

While analysing the efficiency of courier and messenger sector, it can be said that the average efficiency equals to 0.88 and is highly prevalent among the leaders of the sector. Additionally, it can be noticed that this set is highly homogeneous. Two companies are fully efficient: GSL and UPS. Not fully efficient companies should reduce their payroll (from the range of 0 to 45%) or/and increase their revenue (from 0% to 38%). In other words, compared to the best, there is the surplus in spending and deficits in results and, thus, it is possible to improve the efficiency. The evaluation of the systems (courier – another enterprise), where the outputs from one stage become the inputs of the next stage and other inputs are entered, is not as positive. The resulting scores are lower and vary between objects from 0.53 to 0.86.

It is obvious that improvements of individual chain members do not lead to the improvement of the chain as a whole. The compatibility of the ranking of

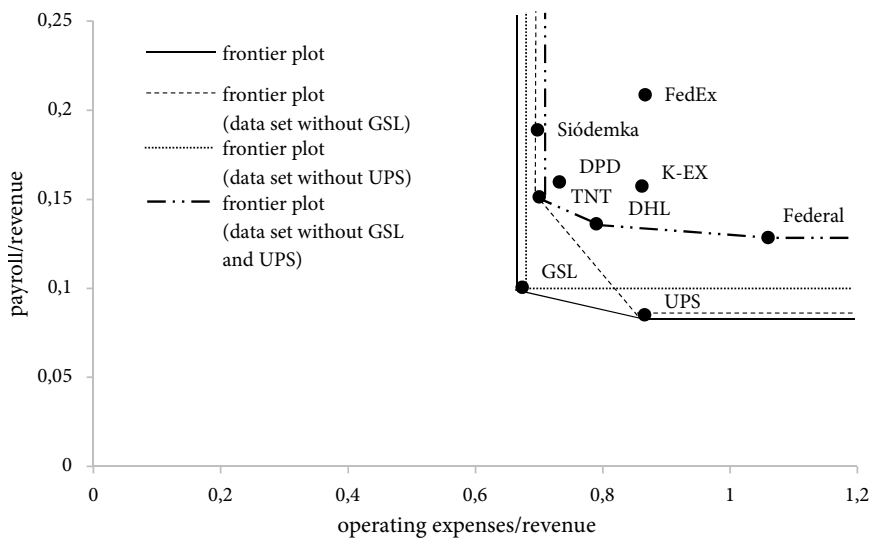


Fig. 5. CCR DEA model for couriers companies — the frontier plot

courier companies and ranking of the analysed chain is -0.64, as measured by the Spearman rank correlation.

The jack-knife procedure for checking the stability of the results that involve the exclusion of the efficient units moved the frontier, which could have been expected, and improved the average efficiencies. The new alternative efficiency frontiers are illustrated in Fig. 5. Detailed numerical results are presented in Table 3. Table 3 also summarises the results of the evaluations of the system in the case of removal of efficient units. All calculations were made in Microsoft Excel using Solver Add-in.

Implemented jack-knife procedure resulted in very slight changes, of course, on the positive side. Assessing the market of courier leaders with the exception of the best, resulted in the emergence of new leaders. This time they were: *Siódemka*, *TNT* and *Federal*. Similarly, the assessment of the designed logistics system also showed a surprising lack of sensitivity to the modification of the analysed set. In summary, a very limited assessment of courier and messenger companies using the DEA method seems to be a valuable alternative to the conventional analysis based only on financial indicators. The reliable, accurate evaluation of individual system components as well as the overall system should be the basis for

Tab. 3. DEA scores after the jack-knife procedure

CCR-I	(ONE STAGE COURIER EFFICIENCY)					(TWO STAGE PROCESS EFFICIENCY)					
	UNIT NAME	ALL	WITHOUT GSL	WITHOUT UPS	WITHOUT GSL AND UPS	AVERAGE	ALL	WITHOUT GSL	WITHOUT UPS	WITHOUT GSL AND UPS	AVERAGE
	DHL	0.85	0.95	0.85	1.00	0.92	0.53	0.54	0.53	0.54	0.53
	DPD	0.92	0.96	0.92	0.96	0.94	0.57	0.57	0.56	0.57	0.57
	FedEx	0.78	0.81	0.78	0.81	0.79	0.65	0.66	0.65	0.66	0.65
	Federal	0.72	0.78	0.78	1.00	0.82	0.86	0.89	0.89	1.00	0.91
	GSL	1.00		1.00		1.00	0.63		0.63		0.63
	K-EX	0.78	0.86	0.78	0.89	0.83	0.77	0.80	0.77	0.81	0.78
	Siódemka	0.97	1.00	0.97	1.00	0.98	0.64	0.64	0.64	0.64	0.64
	TNT	0.96	1.00	0.96	1.00	0.98	0.61	0.61	0.61	0.61	0.61
	UPS	1.00	1.00			1.00	0.53	0.53			0.53
	Average	0.89	0.92	0.88	0.95	0.92	0.64	0.65	0.66	0.69	0.65

managerial decision-making. Especially in the face of customer expectations conflicting with the pressure to earn profit. In the article, due to the hypothetical nature of the relationship, the derivation of conclusions and implications was abandoned.

CONCLUSIONS

Self-service transport and forwarding or the engagement of specialised external companies are questions asked by an increasing number of small, medium and large companies. This article does not provide answers on the best business model. It only shows and discusses an alternative, compared to traditional financial indicators, which is an approach for the assessment of the efficiency of courier companies. In contrast to the traditional performance measurement, which uses sets of single indicators and compares one output to one resource, DEA considers simultaneously multiple inputs and outputs that are correlated. The key issue is the selection of appropriate input and output variables. The article takes into account such indicators as: operating expenses, payroll plus social security, total operating revenue and payroll, operating expenses and profit of the company using the services of couriers. This choice of indicators was related to the availability of data. However, it is worth noting that in addition to the price of services translated into the cost/profit in the logistics system, an increasing popularity is gained criteria, such as the quality treated as the reliability, speed, delivery in a specific, narrow range of time, IT innovations that enable the monitoring and modification of the delivery on any stage of service or complexity of services, including, for example, packaging. Increasingly more attention is given to such issues as ecology in the transport sector and not only the CO₂ emissions but also organic and recyclable packaging.

DEA can be used in each case to evaluate DMUs on any selected criteria. The only limitation is the availability of relevant data describing the set. While selecting the criteria analysis, it should not be forgotten that it should be based on a thorough understanding of the fundamental economics relations.

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STRUCTURE AND DYNAMICS OF A PUBLIC BIKE-SHARING SYSTEM. CASE STUDY OF THE PUBLIC TRANSPORT SYSTEM IN BIAŁYSTOK

EWA DOBRZYŃSKA, MACIEJ DOBRZYŃSKI

ABSTRACT

The article presents the results of a research project referring to the dynamics of the public bike-sharing system BiKeR (Białystok, Poland) in 2014-2015. Identification of the dynamics of the system permits modifications that lead to the enhancement of the efficiency and help to determine the reasons for the choice of a location for new bicycle stations. The basic methodology used for compiling data were the statistical methods with special emphasis on network analysis and graph theory.

Analysis of the data allowed us to identify the mechanisms of changes in the system affecting its dynamics, especially in the area of network topology changes in conjunction with the location of network nodes (stations). The research and analysis showed the specificity of PBS as a transport network. The PBS network, the process of analysis, the value of network metrics and their distribution differ significantly from other types of transport networks (including municipal). The results improve decision-making processes related to the creation and modification of a PBS network, especially in the field of process support, the choice of station location and the impact of these choices on the networks dynamics (as a prognostic utility).

KEY WORDS

public bike-sharing system (PBS), network dynamics, network analysis

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INTRODUCTION

The study of transport networks has a long history. One of the features of this type of research is the interdisciplinarity. In recent years, we have seen a growing interest in this field of study due to the development and implementation of methods for network analysis, mainly, the Internet research. Traditional studies of transport networks took flows of

people or cargos as their basis, and these flows were connected with the optimization of costs, maximization of flows and the determination of the shortest transport paths. The main direction of the research was static network associated with the structure topology. The prevalence of methods of the social networks analysis (SNA) has led to an increased interest in the dynamics of processes in the network

associated with changes in time and issues of evolution.

In the case of urban transport networks, the widest representation in the literature includes research of transportation by bus. Due to the relatively short period of existence of urban cycling systems, the study of their dynamics is understood as a variation of the system (organisation) in time and are at an early stage of development. This article is an attempt to fill this gap. The authors examine the changes, which were applied to the urban bike-sharing system BiKeR (Białystok, Poland) in its first two seasons of operation. The results were compared with studies by other authors on other personal communication systems of both urban and global character (airline network). The comparison of research results was also aimed at identifying tools and research methods that can be applied to urban bike systems.

1. LITERATURE REVIEW

In the literature, there are three (or rarely four) generations of PBS (Shaheen & Guzman, 2011). The standard first-generation system is called the White Bicycle system, which originated in Amsterdam in 1965. The system was free-of-charge, which led to numerous thefts and destruction. The implementation of the system was a failure; however, the PBS concept survived.

The introduction of city bikes in Copenhagen in 1995 is considered as the beginning of the second-generation systems. The system involved a fee and worked on a coin-deposit principle. Assumptions of this system have not changed in the next generations of PBS (distinctive design and colour of bicycles, special docking stations serving the basic operations on rent and return, paid rent). Experience in the operation of second-generation systems allowed gaining experience, which is used for systems of the third generation.

The introduction of BIXI in Montreal in 2009 (Faghih-Imani et al., 2014) should be considered as the beginning of the third-generation systems. BIXI offers new solutions and concepts for both technical and organisational sides, which became the basis for the third generation of PBS in Canada and the United States (Mahmoud et al., 2015; Ahillen et al., 2016). Basic features of this generation are the integration between transport and advertising functions, additional features of the docking station (user identifica-

tion and payment service) and the use of advanced information technology (mobile phones, magnetic stripe cards, smartcards). Most currently operating PBS belong to the third generation. All PBS operating in Polish cities are also the third-generation systems (Klimkiewicz, 2013; Kłos-Adamkiewicz, 2014).

Some authors (Shaheen et al., 2010) postulate the separation of the fourth generation of PBS. It contains all of the features particular to the third-generation systems, but also aims for the integration of cycling with other modes of public transport (especially car sharing). The basic method of integration is common in determining the locations of stations and stops for all modes of transport. It also increases the use of advanced technological solutions (solar systems and bicycles with electric drive in order to promote the principles of sustainable development).

Most publications consider transport networks as static systems. With such a perspective, the main objective is to determine the characteristics of the network structure based on the topology, geometry, morphology and transport flows (Ducruet & Lugo, 2013). Within the static perspective of research on transport networks, two directions of research dominate: at the global level, dealing with the network as a whole and on the local level of the network by separating individual groups of nodes (Lu & Shi, 2007).

Transport networks belong to the broad category of spatial networks because their structure is closely linked to sites connected to the physical infrastructure. The physical infrastructure is determined by the mode of transport. The nature and course of the transport processes affect the durability of the relationship between flows and infrastructure. Regardless of the type of transport, networks have a durable link with nodes in the form of terminals, ports, railway stations or bus stops and their locations. Flows between nodes are dependent on the specification of transport. In the case of urban transport (subway or bus) or rail link with elements of transport, through which the flows go (roads, bridges, railway lines), those links are strict in nature (Ibarra-Rojas et al., 2015). In some modes of transport (maritime, airlines) spatial location of flows is determined by the location of the nodes, whereas the flows between nodes can take place in almost any way (Lillo et al., 2016).

On the global level, most focus is given to the accessibility of a transport network. The planning of transport infrastructure is supported by topographic measures and their impact on the mobility in the city, the suburbs or the region. Transport networks with-

out the physical structure of the route (maritime, airline) analyse systems of cities at different levels (Dobruszkes, 2006).

On a local level, the main objective of the research is to analyse the position of each node in the network and discern node groups (clusters) within the network. Since the analysis of the whole network is complicated in terms of computing (and less useful in terms of pragmatics) there are definitely more papers and articles related to the analysis of the local transport network perspective (Farahani et al., 2013).

The development of a transport network requires analysis and understanding of the complexity and dynamics of the processes that cause changes in the transport system. The literature defines two major research problems: how the spatial organisation of the transport system changes over time and what mechanisms modify the structure. A number of techniques have been found that allow the simulation, and describe the changes (Colizza et al., 2006). A popular tool for the analysis of the network dynamics is an Agent-Based Model (Xie & Levison, 2009). ABM assumes the existence of independent components (called agents) having relationships with each other and the environment. Interactions between

agents are based on simple principles and cause complex changes in the networks on the global level. ABM is a good option as a method for the analysis of the dynamics of transport networks enabling the evaluation of the models and a large variety of theoretical approaches.

There are two main procedures for the analysis of dynamics. Generative methods explaining the formation of connections between nodes take the existence of nodes with no connections between them as the initial position, and in the development process of the system, the connections are formed (as a result of action, i.e. the principles of the lowest cost or the optimization of time of transport), (Newman, 2003). The degenerative method for analysis of the initial state considers the existence of the network, in which all nodes are connected to each other. Connections represent all possible variants of paths in the system, while process dynamics change their parameters (Yerra & Levison, 2005).

The literature review allowed us to identify the specificity of urban cycling systems distinguishing them from others. The summary of differences is reported in Table 1.

Tab. 1. Network characteristics of an urban bike transport system

PARAMETER	TRADITIONAL PUBLIC TRANSPORT SYSTEMS (BUS, METRO)	PUBLIC BIKE-SHARING SYSTEMS
Means of transport	Group	Individual
The influence of the user on transport move	Negligible	Significant
Route selection	Conditioned by organization and transport network topology	Any (including the possibility of returning to the original station)
Availability (by day)	As timetable	Full
Availability (per year)	Full-year	Limited by climate (usually in the summer period)
Interaction with other modes of transport	Imposed by the transport manager	Shaped by the user
The degree of the impact on user behaviour	Significant	Limited
Main substitutes of urban transport systems	Private cars	Private bikes
Possibility of transport system modification	Limited, dependent on urban infrastructure	Smaller limitations, integration with infrastructure of pedestrian flows

2. OBJECT OF THE RESEARCH – THE BIKER SYSTEM

The bike-sharing system was established in Białystok in 2014. The initiative to start the bike transport system came from the city authorities. In the beginning, the city held a contest to name the system. Residents chose the name of the project from among the following options: BIKESTOK, BICIKLO (Esperanto for a single track vehicle) BiKoMobil, BKMBike, BIKER (Białystok Bicycles Communication). Before the system began to function, two tenders for the operator of the urban bicycle-sharing system were held. Only two companies competed in the first tender. The bids submitted by the two companies were not attractive. In the second tender, only one company, namely Next Bike, made an offer. Next Bike

priced its offer at PLN 4.4 million. Although the offer was PLN 1.5 million higher than expected, it was selected.

In Białystok, on 31 May 2014, the first BSS was launched. In the beginning, 30 stations were in operation with 300 bikes. The locations of stations were established by administrative decisions. The first season of BiKeR lasted until the end of November. Bicycles were hired 347 797 times and the system registered 26 330 users.

The second season began on 24 March 2015. The system was enlarged by additional 15 stations. The locations of the stations were selected by resident votes on the system's website. These stations were equipped with 150 bicycles. The third season began on 1 April 2016. Users could choose from 46 stations and 460 bicycles. In the future, the system is expected to expand by 15 new stations.

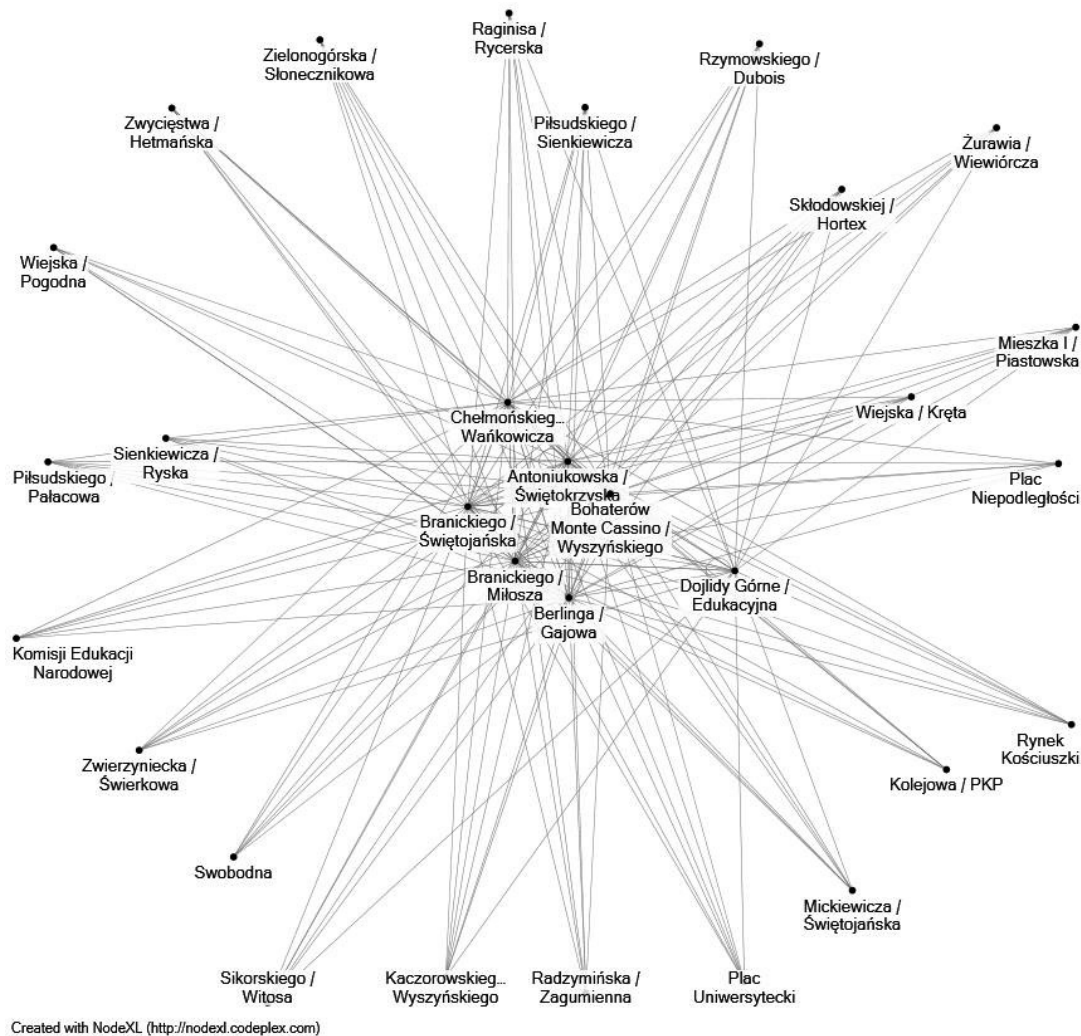


Fig. 1. Topology of the BiKeR system and flows between stations

Figure 1 shows the topology of the network BiKeR and the pattern of flows between stations. The empirical data confirm that this network has connections between two arbitrarily selected nodes (fully connected network topology or complete topology).

3. RESEARCH METHOD

Multiple metrics have been developed for the analysis of the dynamics of networks at local and global levels (Rocha, 2016; Tarapata, 2013). The most popular metrics of the global level are:

- Betweenness centrality – the number of possible positions on the shortest path; in research practice, other variants of this measure are also used (e.g. closeness centrality or distance);
- Eccentricity – the number of connections (edges) required to achieve the furthest node in the network (graph);
- Shimmel index (Shimmel distance) – the sum of the lengths of the shortest paths connecting all nodes in the network.

Taking into account the specificities of urban bike network, which results from the analysis of comparative literature in the research part, the BiKeR system was examined mainly from a local perspective. A set of indicators for the analysis at the local level is focused on the issues of the neighbourhood node. Most measures are:

- Degree (or degree centrality) – the number of adjacent neighbouring nodes;
- Hub dependence – the share of the path having the greatest flow in the total flow of the network; it is a measure of the sensitivity of the connections;
- Average nearest neighbour degree characterized by the importance of the nodes adjacent to the analysed node;
- Clustering coefficient: the ratio between the observed nearest threes and the sum of all possible coming of threes; it is a measure of proximity and density.

The choice of a set of measures of the transport network is largely conditioned by the specificity of transport. The authors of the publication freely choose

indicators depending on the purpose of research, so that the choice of indicators can vary considerably (e.g. for maritime (Wei-Bing et al., 2009), airlines (Wang et al., 2011) and the overall transport network (Sienkiewicz & Hołyst, 2005; Eagle et al., 2010). The dynamics of the bike system will be dealt with on a local level, the identification of this dynamic requires a selection of indicators grouped giving a deeper insight into this problem.

4. RESULTS

Basic data concerning the operations of bike hire and return in Białystok urban agglomeration for the respective seasons of 2014 and 2015 were obtained directly from the system BiKeR. Geographic data (location of stations) have been developed independently by the authors.

In this section, we present the results of statistical analysis of data on two levels of networks: local and global. At the local level, two features were considered: node-degree distribution and node clustering coefficient.

Figure 2 shows a graph of the validity of distribution network nodes of BiKeR, presented in a double logarithmic scale (note: individual points of the graph should be treated as multiple points). The distribution shows considerable differences in relation to similar ones calculated for other transport networks (can be compared with the distributions for the urban bus network (Chatterjee, 2005, Fig. 12) or airline network (Li et al., 2006, Fig. 2).

In Figure 2, the phenomenon of heavy-tailed characteristics can be seen. The chart does not pre-

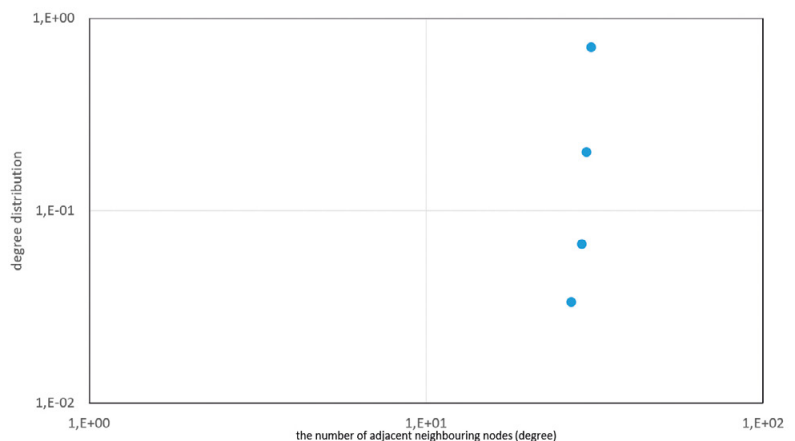


Fig. 2. Degree-distribution in the BiKeR network (double logarithmic scale)

serve the principle of power-law distribution¹. In the discussions found in the literature, transport networks in the real world follow the principle of slower decaying distributions. Typical class networks have exponential or power law tails. The graph in Figure 2 is not compatible with any of these rules. A noticeable difference of a general nature is also a gap for the degree in the range from 0 to 10¹, not found in similar graphs for other modes of transport.

Figure 3 shows a variation factor of clustering in relation to the validity of nodes (the chart was also

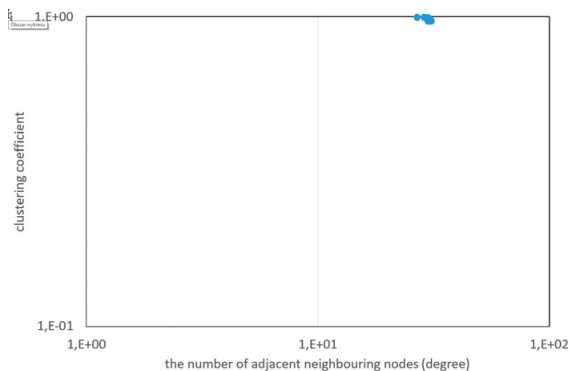


Fig. 3. Variation in clustering coefficient with the node degree in the BiKeR network (double logarithmic scale)

drawn up to a double logarithmic scale, and individual points are to be treated as multiple). There is no similarity between the graphs of these parameters prepared for other modes of transport (e.g. urban bus (Li, 2006, Fig. 15)). The chart reflects the hierarchical structure of the network. The nodes with a high degree of validity serve as hubs focusing transport flows both on a local level and in general. The nodes of the lower level of importance formulate usual local clusters, concentrating flows of a local nature. Usually, transport networks existing in the real world have both types of nodes. In the BiKeR system, hub stations (nodes) dominate, which are central agents that focus the flows and interact with each other.

For the analysis of transport networks on the global level (topology), the most common indicators are node centrality and connectivity. Figure 4 shows the distributions of two indicators: betweenness and closeness centralities (the results can be compared with the same indicators for the urban bus network (Chatterjee, 2015, Fig. 12).

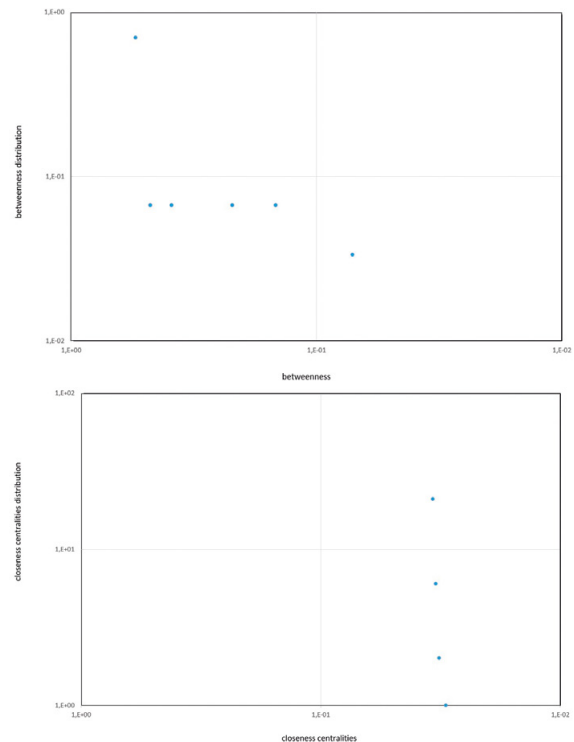


Fig. 4. Betweenness and closeness centralities for the BiKeR network (double logarithmic scale)

5. DISCUSSION OF THE RESULTS

The studies analysed the properties of the urban bike network using statistical methods. The analyses revealed significant differences between the characteristics of a bike network and networks of other modes of transport. The bike networks show similarities to other transport networks. From the geographical perspective, they belong to urban (agglomeration) transport, which suggests a resemblance to bus networks. From the perspective of the infrastructure functionality, bike networks should have characteristics that are similar to networks of sea or air transport (fixed hub locations, the ability to change routes between hubs). The comparison of characteristics of the network and their distributions (degree distribution, clustering coefficient, betweenness and closeness centralities) showed significant differences between cycling networks and other types of transport networks. The main observed differences:

- Lack of hubs in bike networks with a small number of connections (low degree coefficient); bike networks are almost exclusively hub nodes that generate a connection not only with neighbouring nodes (stations) but also with more additional stations (greater distances); the characteristic of

¹ In statistics, a power law is a functional relationship between two quantities, where a relative change in one quantity results in a proportional relative change in the other quantity, independent of the initial size of those quantities: one quantity varies as a power of another.

- the bicycle network is the creation of complete networks, in which the nodes are interconnected;
- In bike networks, we do not observe the typical distributions characteristic of other networks; in transport networks, two types of distributions dominate: the exponential and Poisson distributions; distribution network indicators in bicycle transport are chaotic in nature;
 - Nodes (stations) in the bike network tend to create a smaller number of strong clusters (steady state – low dynamics);
 - The dynamics of the network bikes is degenerative; the choice of the location of a station is made by administrative decision or by voting (e.g. a plebiscite); new nodes form connections with all existing nodes.

CONCLUSIONS

The study by the authors allowed reviewing the current state of knowledge about bike networks, tools used for the analysis and the determination of the network characteristics. Despite a significant increase in the interest of the problems PBS face and a significant increase in publications on the subject, this research area requires a greater exploration. The research enables the development of a series of demands regarding the future research.

The dynamics of the systems are related to their variation in time. PBS are a new phenomenon in the context of transport networks, historical data about their functioning only dates back to a few years at the most (in the case of the BiKeR system, the maximum period of two years, i.e. from 2014 to 2015, can be considered, which is similar to the situation in other Polish cities). The initial stages of the development of PBS are also characterized by changes in the infrastructure (adding new stations), which cause temporary disturbances in the network and variations in the characteristics. At the initial stage of development, the PBS network has a small number of nodes (stations).

Network analysis tools (especially in the dynamically developing field of social network analysis) focus on the issues of topology (configuration) of the surveyed network. The strength of connections (flow volume) between nodes is usually a secondary issue. The conducted analysis, as well as the value and distributions of the network characteristics, indicate the need for tool identification for a deeper analysis of

bike networks. It appears that in the case of PBS, it is necessary to use weighted indicators.

The analysis of transport networks is a prerequisite for their modifications and changes. The primary objective of the authors is to strive for the optimal configuration of transport networks. The results of the analysis should also be applied in field-level user support and serve for the improvement of the service. Previous work focused on the supply side (transport infrastructure); however, the demand side (users) requires a deeper and broader analysis.

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ASSESSMENT OF URBAN TRANSPORT – A COMPARATIVE ANALYSIS OF SELECTED CITIES BY TAXONOMIC METHODS

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ABSTRACT

This paper aims to perform comparative analysis of urban transport in selected global cities and to verify the existence of clusters. It was based on data source from the World Organization Data Urban. It used Indicators proposed in ISO 37120 Sustainable Community Development.

The test procedure exploited taxonomic methods as Ward's hierarchical analysis and the deagglomerating k-means analysis. The empirical analysis comprises four indicators: (I) high capacity public transport system, (II) light passenger public transport system, (III) annual number of public transport trips and (IV) number of personal automobiles.

Main results are the classification of selected global cities, identification and characterization of trends in the field of urban transport in each group. The empirical analysis confirms a substantial diversity of urban transport in selected cities. These differences arise from their past, geographical location, size, different reactions to the transition process and the different economic structures. The taxonomic analysis of the urban transport in selected cities separated five independent classes typological. This elaboration aims to examine the role of urban transport in city management based on a literature review, databases and reports of the European Union.

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KEY WORDS

urban transport, ISO 37120, smart city, taxonomic, city management

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INTRODUCTION

Urban transport is a significant component of city management used worldwide. Sustainable public transport prevents social exclusion, congestion, and air pollution in cities. However, so far there has been no standardized method to measure the quality of life and delivery of public services in cities. ISO 37120 Sustainable Community Development provides

a uniform and consistent approach to measurement methods of city performance. Urban transport is one of 17 thematic areas.

The main goal of the study is to determine trends in the field of urban transport, to classify global cities and to verify the existence of clusters. The article consists of four sections. The first part includes deliberations of the scientist concerning urban transport.

The next sections present the data and research methods. The last two parts of the study contain results and conclusions of the examination. The elaboration was based on literature studies and taxonomic analysis. The data obtained from the database of the Central Statistical Office – Local Data Bank, Eurostat Regional Statistics and the World Organization Data Urban.

1. LITERATURE REVIEW

A constantly growing number of urban residents makes access to public service more difficult and, consequently, reduces the quality of life (Mucha, 2012). Currently, 54% of the world's population resides in cities, whereas forecasts indicate an increase of up to 66% in 2050 (United Nations, 2015). Approximately 85% of the EU's GDP is generated in cities (Dobbs et al., 2012). The increase in road traffic as well as passenger and freight transport, cause congestion and air pollution. Urban transport became an important component of city management in international documents in the last decade (Table 1). Forecasts of the European Commission show that the intensity of freight transport will increase by 40% by 2030, and by more than 80% by 2050, when compared to 2005. At the same time, it is expected that passenger transport will also increase by about 34% by 2030, and by more than 50% by 2050, in comparison to 2005 (White Paper, 2011). Based on the result of a study conducted in seven major Polish cities, it is estimated that in 2013, costs related to congestion will reach PLN 3.5 billion (average of 2.905 per driver). Additionally, external costs of accidents in urban areas are estimated at EUR 80 billion per year, and the external costs of noise – at EUR 40 billion per year. Furthermore, CO₂ emissions in urban areas amount to 280 million tons per year (Rzepnikowska et al., 2014).

City management in the field of urban logistics is influenced by the regulations at the European Union level (Table 1). The European Commission has developed several documents imposing on the cities the obligation to take action towards the improvement of passenger and freight traffic in the city and to reduce environmental degradation. One of the requirements of the EU towards the member states is the necessity to develop sustainable mobility strategies, including passenger and freight transport. Unfortunately, many cities have not prepared this document (Allen et al., 2015; Przybyłowski, 2014).

Tab. 1. Transport on the background of domains of city management in international documents

DOCUMENTS	DOMAINS OF CITY MANAGEMENT
Pact of Amsterdam, 2016	Inclusion of migrants and refugees; Air quality; Urban poverty; Housing; Circular economy; Jobs and skills in the local economy; Climate adaptation (including green infrastructure solutions); Energy transition; Sustainable use of land and Nature-Based solutions; Urban mobility ; Digital transition; Innovative and responsible public procurement
ISO 37120, 2015	Economy, Education, Energy; Finance; Environment; Fire and emergency response; Governance; Health; Recreation; Safety; Shelter; Solid waste; Telecommunication; Transportation ; Urban planning; Wastewater; Water sanitation
Leipzig Charter, 2007	Energy efficiency; Environment; Labor market; Education; Urban transport
Bristol Accord, 2005	Well run; Well connected ; Well served; Environmentally sensitive; Thriving; Well designed and build; Fair for everyone; Active, inclusive and safe

Source: author's elaboration based on (*Urban Agenda ...*, 2016; ISO 37120 ..., 2015; *Leipzig Charter ...*, 2007; *Bristol Accord ...*, 2005).

Integrated city management requires specific knowledge of how to take effective strategic decisions. Effective city management is based on information that can be obtained through quick access to reliable data. A smart city should be built through the implementation of goals and decisions based on reliable data. ISO 37120 should be used to measure the city performance. The standard value does not include evaluation data and quantitative limits; it only provides a framework for the sustainable development of the city and its monitoring. It allows to compare cities in a global perspective and to benefit from the knowledge and skills of the leading urban centres. This is the right tool for reporting the state of city development. There are four levels of accreditation certificate. The minimum limit is to collect data for 30 obligatory indicators. World Organization Data Urban disseminates a new international standard for cities and coordinates efforts to obtain accreditation by sharing city data. It publishes information regarding 30 cities.

Sustainable urban transport improves the quality of life in urban areas. The results are a wide range of advantages, such as a more attractive public space, improvement in the city's image and increase in competitiveness, health improvement, better road safety, lower air pollution and reduced noise emissions (Komisja Europejska, 2014). Improving the

quality of urban space can be achieved through the promotion of public transport and alternative forms of movements within the cities (Ministerstwo Infrastruktury i Rozwoju, 2015). It may help to inhibit the process of suburbanization and revitalize city centres. Road investments should mainly focus on the construction of a basic transport system of the city and its functional area, which will enable the removal of excessive traffic through the ring roads of the city and exit routes to national roads. It is necessary to modernize the existing road system by eliminating bottlenecks and improving traffic safety, which is the priority of public transport and cycling.

Improvement of urban mobility can also be achieved through the appropriate coordination of timetables among different means of transport. The integration of railways, subways, buses, and trams requires, among other things, a rhythmic timetable, dynamic passenger information, and proper interchanges locations. This solution constitutes a part of the category of a multi-modal trip, which is to leave the personal means of transport in the car park and to continue the onward journey to the city centre by public transport. It is also worth mentioning here the existence of an Intelligent Transportation Systems, which allows for the management of road traffic, rail, public transport, fleet and cargo transport. These are devices that can investigate and inform drivers about traffic jams or vacant parking spaces.

The public transport measurement is rather challenging because of a diversified approach to this matter in the substantive literature and various international and national strategic documents (European Commission, 2013). However, it is possible to determine and select the indicators that are commonly and repeatedly applied in the very approach to the measurement of the progress of implementation of public

transport. The quantitative approach of the measurement applicable to the transport phenomena is generally easier to measure directly. Quantitative data refer to information measured numerically (Mingardo, 2008; Pindea, 2016). Quantitative data are recognized as more objective and easier to be analysed, e.g. the speed of moving vehicles and their communication delays. The qualitative approach measurement of specific phenomena of transport is more difficult to estimate. The qualitative data are related to a different type of information, e.g. convenience, comfort, and dynamism in the opinion of users (Nieuwenhuijsen, 2016). Qualitative data can be expressed as quantitative, using a rating system or different evaluation techniques used in economics. Another division of indicators is reflecting the economic, social and environmental influences. Economic dimension indicates the profitability of transport, as the cost per unit of travel (Fielbaum et al., 2016; Taylor, 2008; Medda et al., 2003). The social dimension reflects the relative mobility and financial burden of the population in connection with the use of transport. The environmental dimension shows different emissions caused by transport and field requirements (Table 2).

The great challenge in the field of urban transport is to reduce the use of cars in favour of alternative forms of movement, which have a positive environmental impact, such as a cycling or walking. Furthermore, alternative forms of movement reduce congestion, at the same time improving health and physical condition of travellers. Poles have about 9 million bicycles but in large cities, cycling remains at a low level, constituting 1–3% of total journeys. To compare, in some European cities, such as Kuopio, Cambridge, Stralsund, cycling amounts to 30% of total journeys (Fig. 1).

Tab. 2. Approach and domains of urban transport in scientific literature

APPROACH BASED ON QUANTITATIVE DATA		APPROACH BASED ON QUALITATIVE DATA	
<ul style="list-style-type: none"> – user preferences – convenience and comfort – the dynamics of community – aesthetic qualities 		<ul style="list-style-type: none"> – length of linear infrastructure – the number of kilometres travelled per vehicle and per person – traffic accidents and fatalities – expenses and revenues 	
MOBILE DIMENSION	ECONOMIC DIMENSION	SOCIAL DIMENSION	ENVIRONMENTAL DIMENSION
<ul style="list-style-type: none"> – the supply of transport service – the organisation of mobility inside city 	<ul style="list-style-type: none"> – cost incurred by community 	<ul style="list-style-type: none"> – the number of vehicles in the household – the distance flown individually – expenditure by households on transport 	<ul style="list-style-type: none"> – annual energy consumption and emissions of CO₂, CO, NO_x, hydrocarbons, particulate matter – se of public space for parking and transport infrastructure – noise – risk of accidents

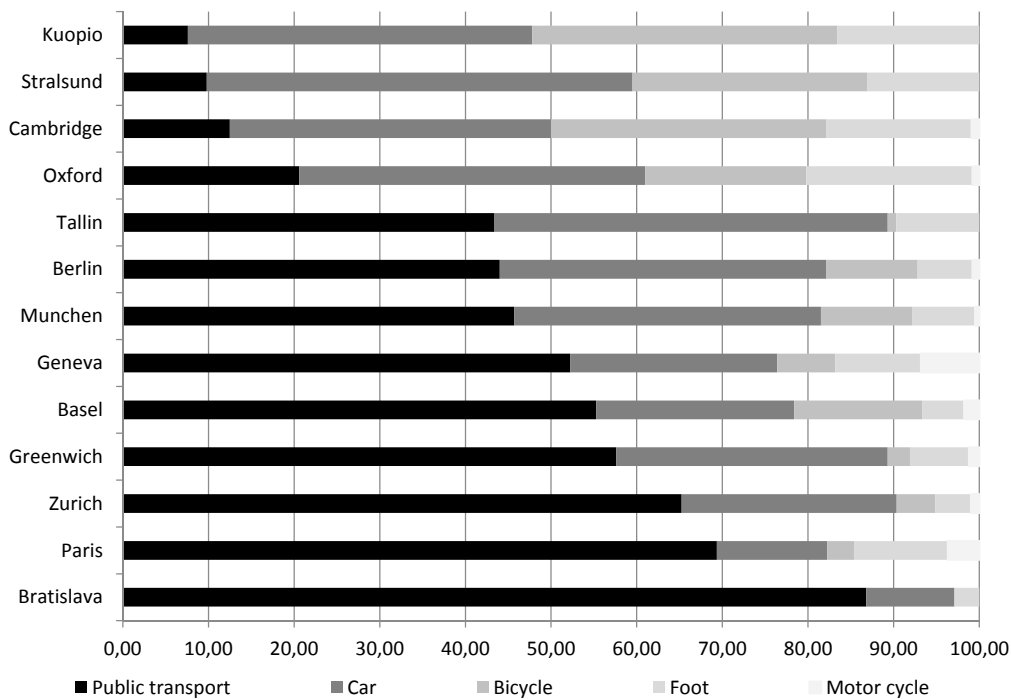


Fig. 1. Share of the use of transportation modes in European cities [%]

Source: author's elaboration based on (Eurostat, 2016).

The collective public transport uses several systems of transport: bus, tram, railway, trolleybus, and metro. In relation to passenger cars, it brings two important advantages – reduces traffic congestion and environmental impact. Compared to individual transport, a bus emits five times less pollution, requires three times less energy per passenger, and twenty times less road surface. A particularly advantageous solution in this respect is bus lanes. 24 Polish cities with powiat status have 196 km of bus lanes allocated for public transport vehicles (Table 3).

Tab. 3. Cities with powiat status with the greatest length of bus lanes

CITIES	LENGTH OF BUS LINES	NUMBER OF BUSES	BUSES LINES PER 100 BUSES
Kielce	15.3	576	2.66
Olsztyn	13.3	657	2.02
Białystok	12.8	857	1.49
Łódź	18.9	1 363	1.39
Kraków	25.2	2 458	1.03
Wrocław	21.5	2 129	1.01

Source: author's elaboration based on (Bank Danych ..., 2016).

Moreover, many scientists analyse transport in a national and regional approach (Czech & Lewczuk,

2016). There are only few publications that compare transport in cities. Urban transport often appears in case studies (Paradowska, 2012; Zimon & Gosik, 2015), analyses of the key success factors (Iwan, 2015) or benchmarking (Chojnacka, 2012; Szymczak & Sienkiewicz-Malyjurek, 2011; Kiba-Janiak, 2016). Scientists use the latest future-oriented methods to evaluate transport (Ejdys et al., 2015).

2. RESEARCH METHODS

The presented research focused on the assessment of urban transport. The scope of research has three steps: selection, evaluation, and classification (Fig. 2). Four indicators were selected from ISO 37120:2014, namely: (X_1) kilometres of high capacity public transport system per 100000 population; (X_2) kilometres of light passenger public transport system per 100000 population; (X_3) the annual number of public transport trips per capita; and (X_4) the number of personal automobiles per capita.

The study included 25 cities (Table 4) with different levels of certification according to ISO 37120:2014, i.e. aspiring (the cities), gold (three cities), and platinum (12 cities). They represent each continent: six cities were European, ten – North American, one –

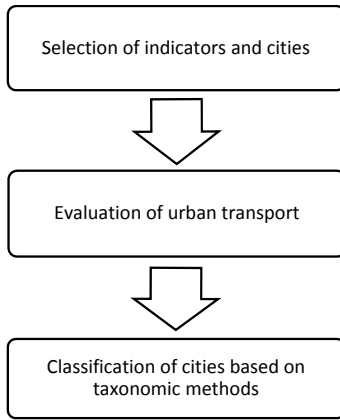


Fig. 2. Scope of the research process

South American, five – Asian, two – Australian, and one – African. Data for each city were collected from the website of the World Organization Data Urban (World Council ..., 2016).

Tab. 4. Certification level of cities per ISO 37120:2014

LEVEL OF CERTIFICATION IN ISO 37120:2014	CITIES AND ABBREVIATIONS
Aspiring	ES1 Barcelona; NL2 Rotterdam; US2 Los Angeles; CA1 Surrey; CA4 Toronto; CA5 Vaughan; AU1 Greater Melbourne; AE1 Dubai; VN1 Haiphong; TW1 Amman
Gold	NL1 Amsterdam; PT1 Porto; CA3 Shawinigan
Platinum	UK1 London; ES2 Valencia; US1 Boston; US3 San Diego; CA2 Saint-Augustin-de-Desmaures; MX1 Guadalajara; MX2 Leon; AR1 Bueno Aires; AU2 Melbourne; PH1 Makati; JO1 Taipei; SA1 Makkah.

Abbreviations of cities based on ISO 3166.

Source: author’s elaboration based on (World Council ..., 2016).

Each indicator was determined by measuring the position (arithmetic mean,) and variability (standard deviation, S_x ; variation coefficient, V). Indicators were standardized based on formula . The Pearson’s correlation coefficient matrix was used to determine the correspondence among indicators and to eliminated strongly correlated indicators. The classification of cities applied the Ward’s hierarchical analysis for the Euclidean distance based on formula. The number of classes was determined by using a graph of distance bond with respect to binding steps. Each aggregation was characterized based on the deagglomerating k-means method.

3. RESEARCH RESULTS

The most differentiated indicator (177.82%) is the length of high capacity public transport system. While the least differentiated variable (48.93%) is the number of public transport trips. Melbourne has the longest public transport system. Bueno Aires has the largest number of personal automobiles per capita (Table 5).

Tab. 5. Selected statistics of urban transport indicators

	X_1	X_2	X_3	X_4
	11.64	121.54	316.22	0.42
S_x	20.70	90.35	454.65	0.21
V	177.82	74.34	143.77	48.93
Max	AU2 102.87	AU2 293.57	PH1 2097.25	AR1 0.75
Min	CA1 CA2 PH1 TW1 SA1 0.00	PH1 3.25	TW1 2.29	VN1 0.01

Source: author’s elaboration based on (World Council ..., 2016).

Correlation among indicators was determined based on the Pearson’s correlation coefficient (Table 6).

Tab. 6. Pearson’s correlation matrix of urban transport indicators

	X_1	X_2	X_3
X_2	0.385836		
X_3	0.341173	-0.057860	
X_4	0.437447	0.348036	-0.162726

Source: author’s elaboration based on (World Council ..., 2016).

Values of the correlation coefficient were positive except for two pairs. The strongest correlation was between the length of high capacity public transport system with the number of personal automobiles. Negative values of the correlation coefficient were observed in the following relations: the length of light passenger public transport system vs. the annual number of public transport trips as well as the annual number of public transport trips vs. the number of personal automobiles.

Using agglomeration Ward’s method for the Euclidean distance, 25 cities were divided into five classes. Applying the chart that compares the binding distance chart to binding levels, the limiting distance was established at the level of 5.0. The taxonomic analysis of the urban transport in selected cities separated five independent typological classes. First and

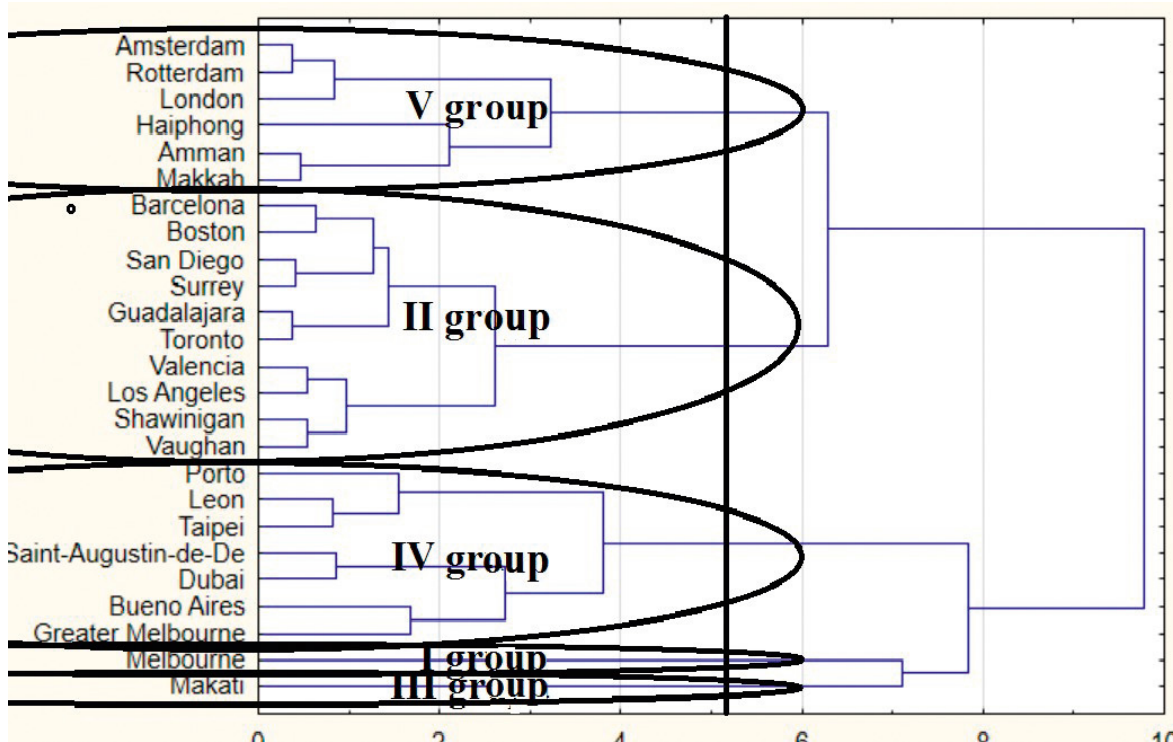


Fig. 3. Scheme of the cluster analyses

third class are constituted by a single element. The second group consists of ten mostly American and Canadian cities. The majority of European cities fall in the fifth class. The fourth cluster includes seven cities (Fig. 3).

Classes have been characterized using k-means methods. The first group has the highest capacity value of the public transport system, while the third cluster has the lowest. The first group has the highest value of the light passenger public transport system, while the third cluster has the lowest. The third cluster has the highest value of the annual number of public transport trips, while the second cluster has the lowest. The first group has the highest number of personal automobiles, while the third cluster has the lowest.

4. DISCUSSION OF THE RESULTS

The first group consists of one-element. Melbourne has a public transport system characterized by high levels of capacity. However, transport in Melbourne consists of an extensive network and a wide variety of transport services. The second class has ten objects, such as Barcelona, Valencia, Boston, San Diego, Los Angeles, Surrey, Shawinigan, Toronto, Vaughan, and Guadalajara. The cities have the lowest

value for the light passenger public transport system. The third cluster consists of one element. Makati is characterized by high levels of the annual number of public transport trips because of jeepneys (they were introduced after the World War II and made from leftover US military jeeps in the Philippines). The fourth class includes seven objects, namely Porto, Leon, Taipei, Saint-Augustin-de-Desmaures, Dubai, Bueno Aires, and Greater Melbourne. These cities are characterized by the average value of all indicators. The fifth group consists of six objects: Rotterdam, Amsterdam, London, Haiphong, Amman, and Makkah. These cities are characterized by the average value of all indicators (Table 7).

Tab. 7. Average values of urban transport indicators for each group

	x_1	x_2	x_3	x_4
Unites	km	Km	capita/yr	-
GI	102.87	293.57	1009.18	0.72
GII	6.49	88.56	146.70	0.51
GIII	1.10	3.24	2097.25	0.06
GIV	11.47	220.94	314.03	0.49
GV	6.99	51.58	188.98	0.21

Source: author's elaboration based on (World Council ..., 2016).

CONCLUSIONS

An efficient and effectively functioning transport in the city is important for residents and enterprises. As a part of the production and consumption, it is an integral part of the modern economy and society. However, apart from the positive impact transport also amounts to numerous social costs, including congestion, accidents, and negative impacts on the environmental.

The results obtained in this research show that selected cities are characterized by great diversity in the field of urban transport. These differences arise from their past, geographical location, size, different reactions to the transition process, and different economic structures. The taxonomic analysis of the urban transport in selected cities separated three independent typological classes (beyond the first and the third group, consisting of one element, respectively, Melbourne and Makai).

The author understands that due to the small sample and the huge variety of cities, generalised conclusions are hardly possible. However, the results of this study can be treated as guidance for reflection and further research.

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MULTIDIMENSIONAL ASSESSMENT OF THE EUROPEAN UNION TRANSPORT DEVELOPMENT IN THE LIGHT OF IMPLEMENTED NORMALIZATION METHODS

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ABSTRACT

Transport is considered a basis for socio-economic development. It is closely connected with the process of movement of products and humans. The main aim of the paper is to investigate the influence of different order normalization methods in the synthetic measure construction implemented in the assessment of the development of European Union member states in the area of logistic, especially transportation system. Moreover, the article attempts to investigate the influence of such methods on linear ordering in multi-criteria taxonomic approach.

The source of information in the research is the data drawn from Eurostat, the statistical office of the European Union. The main method in this study is the order synthetic measure constructed with Weber median in different forms due to implemented normalization methods.

The main result of the carried out analysis indicated that the development level of three main branches of a transportation system correlates with the socio-economic development of particular member states. Furthermore, the assessment process based on the synthetic measure construction can lead to differences in linear ordering due to the implemented normalization methods. The research on the transport development can bring a better understanding of the socio-economic development of particular areas of the European Union. Hence, the results can be helpful to European policy makers for the allocation of support funds.

KEY WORDS

transport, European Union member states, synthetic measure, normalization

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INTRODUCTION

As a European Union member state, Poland is a part of the structural policy. The main imperative of its activity is to increase the state, regional and local cohesion. It is caused by the fact that excessive spatial disproportions are considered a factor of negative external effects for the whole European Union. Moreover, it becomes much more important in the

face of globalization effects because the world economy has changed significantly and globalization needs new logistic dynamics (Kherbash & Mocan, 2015). Hence, transport plays an important role in the management process of logistics and has already been considered one of the cornerstones of the globalization process (Kumar & Hoffmann, 2002).

The economic growth and foreign trade determine the level and structure of transportation demand (Proniewski et al., 2005). Going further, the Gross Domestic Product, consumption level, the structure of household expenditures, technology innovations, fuel prices and other phenomena are considered factors of transportation demand. On the other hand, transport influences the economic growth and job creation (White Paper, 2011), which results in the demand for many products and services. The relationships in the area of transport and their links with economy and society are mutual and very hard to quantify. Thus, transport is considered as a complex phenomenon where different and directly unobservable interactions play a key role. Hence, the studies in that area are especially sophisticated and require special tools. Taxonomy brings many opportunities to improve the assessment process that ought to have a positive impact on the transportation policy. Nevertheless, multidimensional statistical analysis, such as linear ordering, is ballasted with arbitrary aspects. The properly constructed synthetic measure depends on the data set selection, normalization methods, distance measure, statistical measures, etc.

The aim of the paper is to investigate the influence of order normalization methods in the synthetic measure construction implemented in the assessment process of transportation development in chosen European Union member states. Moreover, the article aims to investigate the influence of such methods on linear ordering in multi-criteria taxonomic approach to compare and improve the previous research in that area.

1. LITERATURE REVIEW

The literature review showed that transport as a logistic branch is in the spotlight of different scientific fields and the analyses are carried out with many research tools. However, transport plays a key role in the process of reducing regional and social disparities in the European Union by strengthening economic and social cohesion (López et al., 2008).

On the one hand, transport is analysed because of its impact in the form of external effects on the environment and sustainable consumption (Gratiela & Viorela-Georgiana, 2013; Gratiela, 2013a, 2013b). Going further, the process of adaptation of the Polish transport system to the requirements of the European Union includes consideration of congestion, air pol-

lution, impact on the environment, etc. (Wojewódzka-Król, 2015).

Moreover, transport disadvantages are strictly correlated with social exclusion and well-being (Currie et al., 2010). Transport plays an important role in the strategy development for cross-border regions (Lewczuk & Ustinovichius, 2015). Furthermore, a transportation system has already been analysed with future-oriented methods like foresight (Ejdys et al., 2015). In addition, the same research technique has been used by an interdisciplinary research team in the process of the prediction of the development of future-oriented road technologies in the context of environmental protection (Radziszewski et al., 2016).

Infrastructure adaptation is considered the most important thing in the achievement of social and economic goals, which have to improve the competitiveness of Europe and its regions. This phenomenon is very complex because of technical, economic, and environmental barriers and limitations. Hence, multi-criteria methods play a more significant role in the decision-making process in the development and modernization of transport infrastructure (Pawłowska & Kozłak, 2014).

As one of the research fields of logistics, transport causes many difficulties because of its multidimensional and multi-criteria character. This sophisticated feature disables the clear-cut evaluation process of research objects. Taxonomy can be considered a solution because the implementation of these methods simplifies the assessment process of research objects described by many variables and creates a possibility for support in the logistics policy (Figura, 2013). The author argues that it can be performed by implementing the ordering and classification procedures.

As a result of literature research in the area of taxonomy, two main approaches emerged in the synthetic measure construction in the field of ordering methods due to implemented statistical measures.

One of them is known as a classical approach and uses arithmetic mean and standard deviation in its construction. It was introduced presented by Hellwig and implemented into the research in different fields (Hellwig, 1968). In the scope of transport development, empirical assessment has already been performed in relation to roads and voivodships (Cheba, 2011). Furthermore, the taxonomic development level has already been introduced into transport research in the context of sustainable development, where particular synthetic measures were constructed in the areas of four orders, that is environmental, social, economic, and transport investment (Przybydłowski, 2014).

On the other hand, international evaluation of the European Union transport development was presented as well (Tarka, 2012; Kauf & Tłuczuk, 2014). Most of the evaluations are mainly based on non-pattern methods of the synthetic measure construction and classical statistical measures like arithmetic mean and standard deviation.

The other attitude is called the order and implements the multidimensional median vector and *mad* (the median absolute deviation), (Lira et al., 2002). It was implemented for the first time in the area of logistics for the assessment of road transport development in voivodships (Czech & Lewczuk, 2016a). The further analyses are connected with three main modes of the European Union transport, i.e. roads, railways and air (Czech & Lewczuk, 2016b). Both analyses use the multidimensional Weber median account for interactions in the set of diagnostic variables and among three means of transport. It is worth mentioning that the issue of including indirect impacts is very important for transport, for example in the project appraisal (Ward et al., 2016; Hayashi & Morisugi, 2000). Moreover, this issue is widely discussed among experts, and a consensus has not yet been reached (Vörös et al., 2015).

The review of literature proved that available taxonomic analyses of transport development are usually based on normalization in the shape of standardization. Also, there are other linear transformations, such as unitarization or ratio transformation (Jajuga & Walesiak, 2000; Walesiak, 2011; Dębikowska & Jarocka, 2013). Nevertheless, the research is mainly based on the classical normalization methods.

In the light of literature review findings, the order version of normalization can be implemented not only in the form of standardization but as unitarization and ratio transformation (Młodak, 2006). The Weber median transformation methods have already been introduced into indirect consumption research (Czech, 2014).

To sum up, there is a lack of taxonomic analysis with other normalization methods, besides standardization, which accounts for the sophisticated character of the transportation system and mutual interactions among its elements. It should be emphasized that the research gap is also connected with the multi-criteria taxonomic analysis, which is based on the order synthetic measure construction. Hence, the analysis of synthetic measure construction with the implementation of different normalization methods could have an influence on the correctness of

taxonomic analysis in the field of logistic evaluation, especially in the area of transportation.

2. THEORETICAL BASIS OF IMPLEMENTED RESEARCH METHODS AND THE SELECTION OF THE DATA SET

The final set of diagnostic variables, which is implemented in the process of synthetic measure construction usually must be transformed to bring particular features into comparability. This process is called normalization and is implemented in the case of classification methods, multidimensional calibration or linear ordering. There are three main normalization methods, namely standardization, unitarization, and ratio transformation, which can be used in the construction process of different classical and order statistic measures. This situation may cause a problem in clear taxonomic assessment with the synthetic measure construction. Therefore, it would be helpful to investigate chosen normalization methods in the process of evaluation of the European Union transportation system.

In reality, transport is considered a complex phenomenon where mutual directly unobservable interactions have a crucial impact on the research field. That is why the wide range of normalization methods will be limited to those that implement the multidimensional Weber median.

Standardization, in its original order version, implements the median and *mad* (the median absolute deviation). It was first presented by a Poznań statistician, and the normalization process is expressed by the following formula (Lira et al., 2002):

$$z_j = \frac{x_j - \theta_j}{1,4826 * mad(X_j)} \quad (1)$$

where θ_j is considered the Weber median vector and *mad* (the median absolute deviation) is expressed:

$$mad(X_j) = \text{med}_{i=1,2,\dots,n} |x_j - \theta_j| \quad (2)$$

The history of the Weber median and its construction is widely discussed in the literature (Młodak, 2009).

On the other hand, there are other versions of the normalization process. It is worth mentioning that all forms of transformations were proposed by Młodak (2006).

Another form of order standardization uses only the median absolute deviation, and the transformation process is in accordance with the following formula:

$$z_j = \frac{x_j}{\text{mad}(X_j)} \quad (3)$$

Unitization is considered as the next form of normalization. The basis for this transformation is a range of a variable, and the order version of it is expressed by the following formula:

$$z_j = \frac{x_j - \theta_j}{R(X)} \quad (4)$$

where $R(X)$ stands for the range of a variable that is the difference between the higher and smaller value in the distribution of a particular feature. Besides, the presented form of order unitarization, there are other untypical forms expressed by the two following formulas:

$$z_j = \frac{x_j - \theta_j}{\max|x_j - \bar{x}|} \quad (5)$$

$$z_j = \frac{x_j - \theta_j}{\max|x_j - \theta_j|} \quad (6)$$

The last form of normalization is known as ratio transformation where the order form is expressed by the equation:

$$z_j = \frac{x_j}{\theta_j} \quad (7)$$

Furthermore, another form of this transformation, which introduces the multidimensional median vector is based on square values of diagnostic variables and expressed by the following:

$$z_j = \frac{x_j}{\theta_j(x_j)^2} \quad (8)$$

All presented normalization methods are called linear transformations and the synthetic measures constructed on their basis can have different values. Hence, the position of the research objects in the ranking can differ as well.

The basis of synthetic measure construction is a set of diagnostic variables that describe three different areas of transportation, namely, roads, railways, and air. This approach resulted from the terminology accepted in the logistic literature. The data was drawn from the Eurostat database for 2012. The set of twenty-one potential diagnostic variables was treated as a basis of taxonomic analysis with the implementation of different normalization methods for the spe-

cial assessment of the development level of the transportation system in different areas.

Roads as the first mode of transport is presented by the following variables: X_1 – length of motorways (km/100 km²), X_2 – length of state roads (km/100 km²), X_3 – number of motorcycles per 1000 citizens, X_4 – number of passenger cars per 1000 citizens, X_5 – number of lorries and road tractors per 1000 citizens, X_6 – goods transported by roads in 1 million tonne-kilometre per 1000 citizens, X_7 – number of killed in road accidents per 1 million citizens.

Railways as the second mode of transport includes the following features: X_8 – length of railway lines (km/100 km²), X_9 – number of passengers per one citizen, X_{10} – number of passenger-kilometre per one citizen, X_{11} – goods transported by railways in tonnes per one citizen, X_{12} – railways-goods transported in 1 million tonne-kilometre per 1000 citizens, X_{13} – number of suicides connected with railways per 100 thousand citizens, X_{14} – number of killed per 1 million passengers, X_{15} – number of injured per 1 million passengers, X_{16} – number of railway accidents per 1 million citizens.

Air is the third mode of transport and includes the following variables: X_{17} – number of airports (with over 15000 passenger units per year) per 10 000 km², X_{18} – number of airline passengers per one citizen, X_{19} – number of commercial aircraft fleet per 1 million passengers, X_{20} – freight and mail transported by air in tonnes per 1000 citizens, X_{21} – number of killed in commercial air transport per 1 million passengers.

It is worth mentioning that all three branches of transportation include variables that are related to cargo transport changes in the country. Moreover, there are some facts about these modes of transport. On the one hand, road transport plays a key role in the cargo transportation. Nevertheless, the transport absorption is decreasing due to economic growth. On the other hand, the railway transport is not efficiently used, and inland waterways cannot compensate for cargo transportation by railways or roads (Strojny, 2013). It is worth emphasizing the fact that all modes of transport are complex and generate external effects (Chruzik & Sitarz, 2014).

Furthermore, the inland waterways transport is not greatly significant that is why it was omitted from the research. On the other hand, the pipeline transport is considered to be specific and significant for the economy. Nevertheless, it is very difficult to access interdependence with other branches of the transportation system.

Tab. 1. Chosen statistical measures of particular variables and values of the main diagonal of inverted Pearson correlation matrixes

VARIABLE	MEANS OF TRANSPORT	MEAN	M _B	M _W	A _S	S _X	MAD (W)	R	V _S	V _W	MDIM
X ₁	Roads	1.37	1.12	1.38	0.85	1.17	0.90	3.79	85.18	65.20	2.11
X ₂		15.22	9.51	12.51	0.65	12.05	7.73	34.87	79.17	61.80	1.93
X ₃		33.11	21.03	34.89	1.46	29.91	19.94	104.72	90.36	57.16	1.87
X ₄		453.28	464.77	447.34	-0.57	108.22	82.31	400.99	23.87	18.40	2.13
X ₅		57.06	54.62	66.04	0.82	22.27	20.66	75.36	39.03	31.28	2.02
X ₆		4.20	4.04	4.62	0.58	1.84	1.31	6.33	43.90	28.47	1.82
X ₇		634.00	62.50	64.24	0.27	21.27	17.50	72.00	33.24	27.24	2.16
X ₈	Railways	5.51	5.06	5.26	0.94	3.03	2.26	10.38	54.90	43.01	4.78
X ₉		12.61	10.89	10.38	0.97	9.05	5.27	30.51	71.72	50.83	9.29
X ₁₀		612.47	471.94	502.80	0.73	396.56	261.99	1304.65	64.75	52.11	6.83
X ₁₁		8.16	5.39	6.97	1.88	9.57	5.07	33.63	117.22	72.69	5.16
X ₁₂		1.88	1.32	1.62	2.82	2.53	1.04	10.67	134.50	64.02	4.51
X ₁₃		0.63	0.44	0.54	1.81	0.51	0.24	2.02	81.17	44.73	2.98
X ₁₄		0.78	0.24	0.71	2.34	1.13	0.64	4.47	145.22	90.08	4.80
X ₁₅		0.60	0.39	0.54	1.27	0.70	0.50	2.28	116.43	91.67	6.62
X ₁₆		7.57	7.73	7.59	0.28	5.44	4.31	17.76	71.91	56.84	3.41
X ₁₇	Air	0.70	0.62	0.64	1.03	0.44	0.30	1.70	63.23	47.00	1.67
X ₁₈		1.90	1.82	1.87	0.85	1.31	1.10	4.87	69.18	59.04	2.20
X ₁₉		9.91	6.74	9.35	2.07	7.11	3.61	29.63	71.75	38.59	3.05
X ₂₀		16.65	12.97	11.91	1.11	15.32	8.72	53.94	92.01	73.21	2.01
X ₂₁		0.29	0.00	0.30	4.24	1.21	0.30	5.14	421.38	100.00	3.17

Notation: M_B – border median, M_W – Weber median, A_S – skewness, S_X – standard deviation, mad (W) – median absolute deviation (Weber Median), R – range, V_S – classical variation coefficient, V_W – order variation coefficient based on Weber median, MDIM – main diagonal of inverted Pearson correlation matrixes.

It is worth mentioning that the objective causes of railway disasters and railway accidents were the basis for treating this variable as a separate one. However, suicides are considered as a specific form of death, which results from personal decisions, and that is why this variable should not be combined with the number of killed.

All potential diagnostic variables were put under statistical investigation due to variation as well as correlation analysis. The chosen statistical measures of particular features are presented in Table 1.

The investigation of classical and order form of variation coefficients proved that all diagnostic variables have a strong differentiation, which results in their inclusion into the process of the synthetic measure construction.

In the scope of dealing with correlation analysis, three inverted matrixes of Pearson correlation coefficients have been constructed (Malina & Zeliaš, 1997). The values located on the main diagonal of particular inverted matrixes in three areas of the transportation system are presented in Table 1. The analysis of correlation measures proved that all potential variables could be taken for the further analysis.

To sum up, it should be mentioned that all three investigated areas are described by the features connected with infrastructure, equipment, people, and freight transport as well as safety. Moreover, there are mutual interactions among these three areas as well as in the whole set of diagnostic variables. Furthermore, some of the diagnostic features have strong skewness, which encourages to use order statistic measures instead of the classical ones. Hence, the process of synthetic measure construction of transport development should be based on normalization methods, which implement the multidimensional Weber median.

3. RESEARCH RESULTS

To bring the variables to comparability, seven presented normalization methods were introduced into the analysis in the form of standardization, unitarization, and ratio transformation. Additionally, these forms of transformation implemented the Weber median to take into account the sophisticated

Tab. 2. Positions of countries in the ranking according to different normalization methods

COUNTRY	ROADS							RAILWAYS						
	S(1)	S(2)	U(3)	U(4)	U(5)	RT(6)	RT(7)	S(1)	S(2)	U(3)	U(4)	U(5)	RT(6)	RT(7)
Bulgaria	14	15	15	15	16	12	12	15	14	15	15	14	15	12
Czech Republic	12	13	13	13	13	15	17	8	16	14	13	13	13	18
Germany	5	3	4	4	4	2	2	3	6	6	5	5	5	11
Estonia	11	14	14	14	14	16	14	17	10	12	12	12	11	13
Ireland	13	9	9	8	9	9	9	13	9	9	9	9	9	2
Spain	9	2	1	1	1	3	3	9	8	8	8	8	8	4
France	7	5	5	5	5	6	6	1	4	3	1	2	4	6
Italy	1	12	10	10	10	11	16	5	5	5	4	4	6	3
Latvia	17	17	17	17	17	17	15	12	1	4	6	6	1	1
Lithuania	3	11	12	12	12	13	11	18	17	17	17	17	17	17
Hungary	16	16	16	16	15	14	13	6	13	13	14	15	14	16
Austria	4	6	6	6	6	4	5	2	2	1	3	3	2	9
Poland	8	7	8	9	8	8	8	10	12	11	11	11	12	8
Romania	18	18	18	18	18	18	18	16	18	18	18	18	18	15
Slovenia	6	1	2	2	2	1	1	14	11	10	10	10	10	10
Slovakia	15	10	11	11	11	10	10	11	15	16	16	16	16	14
Finland	2	4	3	3	3	5	4	7	7	7	7	7	7	7
United Kingdom	10	8	7	7	7	7	7	4	3	2	2	1	3	5
	AIR							TOTAL MEASURE						
Bulgaria	16	14	14	15	15	14	14	17	15	16	16	17	13	11
Czech Republic	15	12	13	13	12	13	13	13	14	14	13	13	14	18
Germany	1	3	3	3	4	2	1	1	1	2	2	2	3	3
Estonia	7	7	9	9	9	9	10	8	10	11	11	14	16	17
Ireland	4	1	1	1	1	1	2	6	4	4	4	9	15	7
Spain	11	9	5	5	5	7	7	10	5	6	6	1	2	2
France	6	5	6	6	6	6	5	5	6	5	5	4	4	10
Italy	10	13	12	12	13	12	12	7	9	8	8	8	8	6
Latvia	8	6	8	8	8	8	8	12	8	9	10	11	10	8
Lithuania	12	10	10	10	10	10	11	11	12	15	15	15	17	16
Hungary	14	15	15	16	16	15	15	16	17	17	17	16	12	13
Austria	5	2	2	2	2	3	4	4	2	1	1	5	6	12
Poland	17	17	18	18	18	17	17	14	13	12	12	10	5	4
Romania	18	16	17	17	17	16	16	18	18	18	18	18	18	15
Slovenia	9	18	16	14	14	18	18	9	16	10	9	7	1	1
Slovakia	13	11	11	11	11	11	9	15	11	13	14	12	11	14
Finland	3	4	4	4	3	4	3	2	3	3	3	3	9	5
United Kingdom	2	8	7	7	7	5	6	3	7	7	7	6	7	9

Notation: S(1) – standardization I, S(2) – standardization II, U(3) – unitarization I, U(4) – unitarization II, U(5) – unitarization III, RT(6) – ratio transformation I, RT(7) – ratio transformation II.

character of particular branches of the transportation system. Furthermore, the multidimensional median allowed making the taxonomic analysis immune to the skewness of particular features. The values of synthetic measures for railway transport development, which were put together with different normalization methods, are presented in Figure 1.

limitation of the Pearson's coefficient, which can incorrectly indicate the character of interdependence (Luszniewicz & Słaby, 2008). To assure adequate results of carried out research, box and whisker plots were put together and presented in Figure 2.

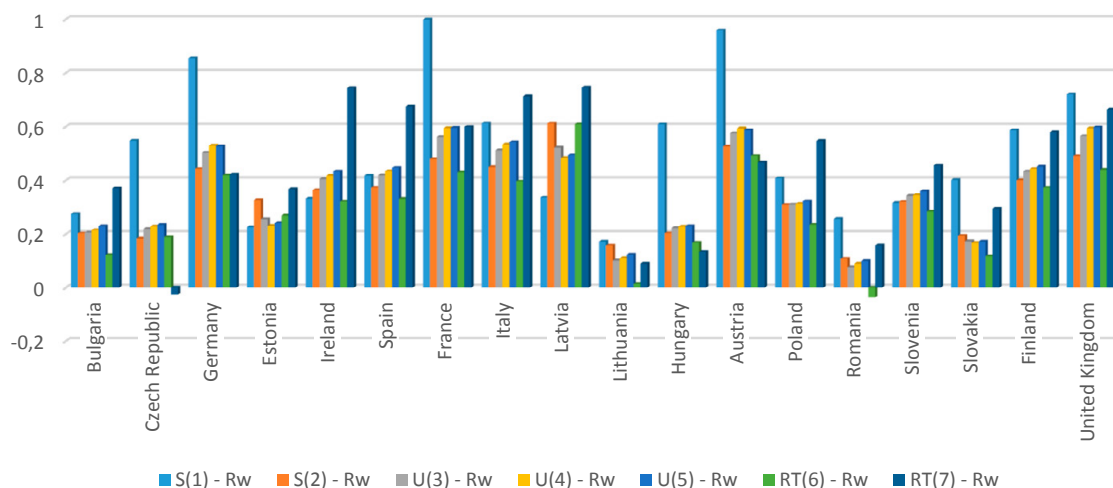


Fig. 1. Values of order synthetic measures constructed with different normalization methods in the area of railway transport

Notation: S(1) – standardization I, S(2) – standardization II, U(3) – unitarization I, U(4) – unitarization II, U(5) – unitarization III, RT(6) – ratio transformation I, RT(7) – ratio transformation II.

The analysis of graphical presentation proved that in most cases of normalization methods, the values of railway transport synthetic measures achieve similar values for particular member states.

Further, the values of synthetic measures in three different areas of transportation system were treated as the basis for the construction of the total European Union transport development measure. The maximum values of synthetic measures for modes of transport were treated as stimulants in the further analysis. This approach has already been introduced into poverty research because of the sophisticated character of analysed phenomenon as well as a very wide range of diagnostic variables (Młodak et al., 2016). The location of European Union member states in the scope of transport mode development as well as the total approach are presented in Table 2.

The analysis of presented rankings of the European Union transport development according to different normalization methods proved that some of the constructed measures resulted in similar positions of particular member states. On the other hand, in few cases, constructed measures give quite different orders. It is to be noticed that rankings constructed

with two forms of ratio transformations locate Austria the sixth or twelfth in the case of total development of transportation system. This proves that this kind of normalization is not applicable in linear ordering, however, Austria is considered as one of the most developed countries in Europe in the area of transportation.

Hence, to compare distributions of synthetic measures Pearson correlation coefficients were calculated and presented in Table 3.

The analysis of presented data indicates that the total synthetic measure of transportation development constructed with two forms of ratio transformation is very weakly correlated with other taxonomic measures. Furthermore, a similar phenomenon is noticed in the area of roads as well as air transport. Almost all synthetic measures are highly correlated, which proves the previous analysis in the transport development of chosen European Union member states. Evidence suggests that the suspicion regarding ratio transformation can bring results in the process of synthetic measure construction, which do not reflect the real state of transport development. Nevertheless, it is very important to be aware of the linear

Tab. 3. Matrixes of Pearson's correlation coefficients of synthetic measures constructed according to different normalization methods

	S(1)	S(2)	U(3)	U(4)	U(5)	RT(6)	RT(7)	S(1)	S(2)	U(3)	U(4)	U(5)	RT(6)	RT(7)
	ROADS							RAILWAYS						
S(1)	1.00	0.78	0.77	0.78	0.78	0.64	0.55	1.00	0.55	0.71	0.75	0.73	0.57	0.22
S(2)	0.78	1.00	1.00	0.99	0.99	0.95	0.91	0.55	1.00	0.96	0.93	0.93	0.98	0.80
U(3)	0.77	1.00	1.00	1.00	1.00	0.95	0.90	0.71	0.96	1.00	1.00	1.00	0.95	0.79
U(4)	0.78	0.99	1.00	1.00	1.00	0.94	0.89	0.75	0.93	1.00	1.00	1.00	0.92	0.76
U(5)	0.78	0.99	1.00	1.00	1.00	0.93	0.88	0.73	0.93	1.00	1.00	1.00	0.92	0.78
RT(6)	0.64	0.95	0.95	0.94	0.93	1.00	0.96	0.57	0.98	0.95	0.92	0.92	1.00	0.76
RT(7)	0.55	0.91	0.90	0.89	0.88	0.96	1.00	0.22	0.80	0.79	0.76	0.78	0.76	1.00
	AIR							TOTAL						
S(1)	1.00	0.81	0.60	0.82	0.80	0.43	0.24	1.00	0.86	0.89	0.90	0.83	0.28	-0.01
S(2)	0.81	1.00	0.86	1.00	1.00	0.66	0.46	0.86	1.00	0.95	0.94	0.84	0.12	-0.25
U(3)	0.60	0.86	1.00	0.82	0.82	0.94	0.84	0.89	0.95	1.00	1.00	0.94	0.37	0.00
U(4)	0.82	1.00	0.82	1.00	1.00	0.60	0.39	0.90	0.94	1.00	1.00	0.95	0.39	0.02
U(5)	0.80	1.00	0.82	1.00	1.00	0.60	0.39	0.83	0.84	0.94	0.95	1.00	0.58	0.19
RT(6)	0.43	0.66	0.94	0.60	0.60	1.00	0.97	0.28	0.12	0.37	0.39	0.58	1.00	0.87
RT(7)	0.24	0.46	0.84	0.39	0.39	0.97	1.00	-0.01	-0.25	0.00	0.02	0.19	0.87	1.00

Notation: S(1) – standardization I, S(2) – standardization II, U(3) – unitarization I, U(4) – unitarization II, U(5) – unitarization III, RT(6) – ratio transformation I, RT(7) – ratio transformation II.

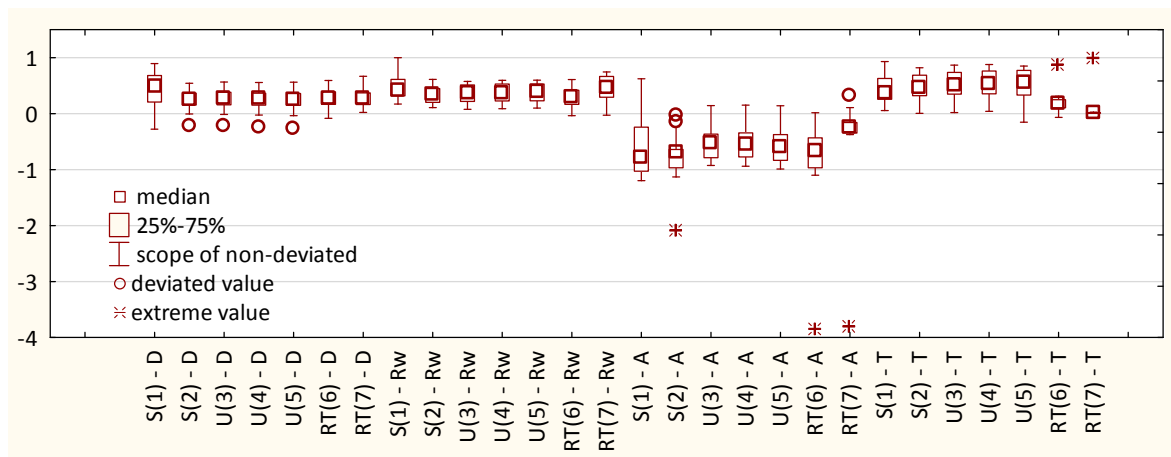


Fig 2. Distributions of order synthetic measures constructed according to different normalization methods

Notation: S(1) – standardization I, S(2) – standardization II, U(3) – unitarization I, U(4) – unitarization II, U(5) – unitarization III, RT(6) – ratio transformation I, RT(7) – ratio transformation II, D – roads, Rw – railways, A – air, T – total.

The analysis of presented graphical distributions of particular synthetic measures in three transport branches as well as the total one indicates the skewness in their distributions. Furthermore, the existence of non-typical (deviated and extreme) values of synthetic measures as well as the asymmetrical location of the median and a different length of whiskers in plots indicate that the implementation of the Pearson's correlation coefficients may not be proper.

Hence, the Spearman correlation coefficient was introduced to compare the results of the taxonomic research. The exchange of values of synthetic measures on ranks eliminates the negative impact of non-typical observations (Stanisz, 2006). The results of carried out correlation analysis confirmed the results obtained with the Pearson's coefficient about synthetic measure construction with ratio transformation for the whole transportation system.

4. DISCUSSION OF THE RESULTS

The task of the synthetic measure construction with different normalization methods was to confirm the previous research of the European Union transport development. The paper presents the results obtained in the process of taxonomic research with the Weber median to take into account interactions in a sophisticated transportation system.

The analysis of the data presented in Table 2 allows indicating some trends connected with the ranking of the selected European Union countries in the scope of the road, railway, and air transport development. There are large spans of the development of certain branches of the transportation system in European Union member states. In addition, there is a noticeable correlation between the socio-economic development of particular European Union member states and technical infrastructure, including the logistics one.

The largest European economies, such as Germany, the United Kingdom or France, are considered leading countries in the development of road and railway networks. The carried out analysis proved that the situation connected with the condition of road network and railway transport is more favourable to smaller countries, such as Latvia and Ireland, compared to large ones, such as Finland.

Hence, the observed situation arose due to the influence of the socio-economic policy of European Union member states. It should be noted that the sustainable development policy is considered a priority in some member states. Unfortunately, this kind of policy conflicts with the needs of transport infrastructure development, which creates conditions for the balanced development of regions in those countries. The constant saturation level of roads and railway tracks is observed in Germany, Italy, and the United Kingdom. However, the new investments in those fields are occasionally introduced. The burden of investment concerns modernization and upgrading the existing railway tracks and roads in Germany and France. In addition, the most dynamic growth is observed in air transport of those countries. The carried out analysis proved that both member states took leading positions. Furthermore, the leader of the ranking in the area of air transport is Germany. Apart from Germany, high positions are occupied by Ireland and Finland, which take the second and third place.

The research analysis, which took into account indirectly observed relationships, brought some unforeseen results. On the one hand, the ranking connected with the development level of traditional modes of transport that is roads and railways indicate the leading position of Germany, Slovenia, Spain, and France. Furthermore, Germany, Ireland, Finland, and the United Kingdom are placed highly in the area of air transport. On the other hand, the distant location in that ranking is taken by Romania, Poland, and Slovenia, which occupy positions sixteen to eighteen among the eighteen countries included in the analysis.

The research of the total synthetic measure of transport development led to several conclusions. The high positions of Slovenia, Poland or Latvia, can be considered unexpected. However, the leading positions according to the total ranking are occupied by the most developed and so-called old member states, such as Spain, Germany, Finland, and Italy. Nevertheless, the ninth, tenth and twelfth positions of Great Britain, France, and Austria according to the synthetic measure constructed with the ratio transformation is unexpected. In addition, the choice of the improper normalization method can deliver the ranking, which does not reflect the socio-economic reality.

CONCLUSIONS

The conducted research according to some normalization methods allowed stating that in most cases, different normalization methods lead to similar results.

On the one hand, most of the so-called old member states have a well-developed logistics infrastructure, which is highly correlated with the whole socio-economic space. Going further, the well-developed railways, roads, motorways, and airports are the elements of this infrastructure. It is strictly connected with such countries as Germany, Spain or Finland.

On the other hand, the group of countries that take a distant place in the rankings of all three examined modes of transport was named. In general, the conclusion relates to the following countries: Romania, Czech Republic, and Lithuania. The underdevelopment of technical infrastructure of these countries is caused by historical conditions and the pace of construction of the so-called new market reality. This

proposal is adjusted to most states and regions that have been under the influence of the Soviet Union.

In addition, there is a group of states with one better-developed branch of transport in comparison to two others. Slovenia is a member state that takes the first place in the summary ranking. Nevertheless, this country has the eighteen position in the scope of air transport development. Hence, the mountainous terrain and relatively small surface of this country have a significant impact on its state.

To sum up, the synthetic measure construction with most of the normalization methods relates to selected European Union countries and confirms the previous scientific research of the European Union transport development. The researcher feels that the study findings will facilitate such analysis and create more efficient transportation policy for the whole European Union. Moreover, the presented statistical research methods can be used by economic practices; however, the strict cooperation between science and business is a crucial factor.

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RANKING OF OFFICE LEASE OPTIONS BY MULTI-CRITERIA METHODS

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ABSTRACT

Due to the growing scales of business and internationalisation, the issue of the office lease is becoming more and more relevant for companies. They are becoming an inherent part of business, on which the results of the commercial activity depend. Currently existing methodologies for the assessment of the office lease options are imperfect as they lack complexity; they are not associated with the objective of the lease – the improvement of the business results; the methods of the quantitative assessment of lease options are far from perfect. The paper aims at formulating the hierarchical indicator system of commercial real estate facilities (offices) adjusted for the multi-criteria assessment and at calculating the lease options based on this indicator system. To achieve this goal, the following methods have been used: scientific literature analysis and multi-criteria assessment methods.

KEY WORDS

lease of commercial facilities (offices), forming the indicator system, multi-criteria assessment methods

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INTRODUCTION

The business trend analysis shows that the gradually increasing demand for offices derives from both internal and external needs. The former appear where the companies establish their affiliates and subsidiaries, expand their business in new areas, want to improve the office environment and focus their activities on one space. The external demand is the

need for offices among foreign companies that invest in the country. The global investors currently optimising their business are increasingly interested in the Middle Europe and the Baltic States, and they are gradually turning away from India and Asian countries. Consequently, the demand for offices will continue to grow.

Recently, an office has been considered an important factor affecting the business results. Therefore, the premises for rent are subject to more stringent requirements regarding technical characteristics, quality and variety of offered services, working environment, etc. (French & Wisemann, 2003; Nase et al., 2013; Pagourtzi et al., 2003; Ginevičius et al., 2004; Zhang, 2015). Consequently, the potential tenant, when selecting the premises, considers the aggregate of criteria covering various aspects. It depends on a place (Alonso, 1964; Muth, 1969; Mills, 1972; DiPasaquale & Wheaton, 1992; Dunse & Jones, 1998; French & Wiseman, 2003; Pagourtzi et al., 2003; Čeh et al., 2012; Nase et al., 2013), year of built and architectural solutions (Wagner et al., 2014; French & Wiseman, 2003; Pagourtzi et al., 2003; Nase et al., 2013), engineering infrastructure (Dunse & Jones, 1998; Ncube & Riffat, 2012), car parking facilities (Nase et al., 2013; Wagner et al., 2014), additional services provided (Peng et al., 2014; Wagner et al., 2014), level of fit out at the premises (Nase et al., 2013; Khamkanya et al., 2012; French & Wiseman, 2003; Pagourtzi et al., 2003), external environment (Nase et al., 2013; Čeh et al., 2012).

In this case, the office lease options are defined by multiple various indicators. Phenomena manifesting through various aspects of reality are attributed to complicated and complex ones. Such phenomena may only be recognised when assessing all criteria reflecting such a phenomenon as a whole. This is where the criteria-based approach of the office lease comes from as a phenomenon. The multi-criteria methods are most eligible for the assessment.

1. FORMATION OF THE INDICATOR SYSTEM OF OFFICE LEASE OPTIONS

The essential stage of the multi-criteria assessment is the formation of the indicator system of the phenomenon in question. This is because the adequacy of reflecting the phenomenon in question largely depends on its completeness and structure. When forming such a system, the following statements are usually referred to (Ginevičius et al., 2004; Ginevičius & Podvezko, 2005): first, the more indica-

tors are included in the system, the more thoroughly the phenomenon in question is reflected, and vice versa, the fewer indicators are included in the system, the greater is a threat that the significant indicators will not be assessed and the assessment of the status of the phenomenon in question will seem inadequate; second, the more indicators are included in the system, the more indicators will be difficult to formalise; moreover, the system will become complicated, and it will be hard to accurately determine weights of the indicators, which will result in higher calculation costs and lower accuracy.

The formation of the indicator system starts with the list compilation. The objective of formation of the system itself is an adequate reflection of the phenomenon in question and its adjustment for the multi-criteria assessment. The content and result of this process depend on how many indicators are included in the system. Where there are a few indicators, the single-level indicator system is formed (Fig. 1).

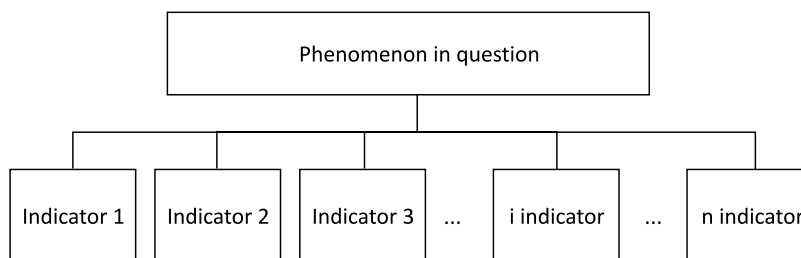


Fig. 1. Single-level indicator system

The use of such an indicator system for the multi-criteria assessment of complicated complex phenomena is rather limited as in this case, it is subject to an intractable issue related to the indicator significance determination. This means that the experts may somewhat accurately assess the weights of a limited number of indicators only. The proposed complicated approaches to determine the significance of indicators do not fully resolve this problem as well (Saaty, 1980). According to the references, without greater evidence, however, this number equals 10–12 (Ginevičius, 2009). When looking for a solution, it is necessary to find a method enabling to reduce the number of simultaneously assessed indicators. This problem may be resolved by means of hierarchical structuring of the indicator system, which enables the reduction in the number of simultaneously assessed indicators to the preferred number (Ginevičius, 2007a, 2007b, 2009).

Based on this methodology, the following hierarchically structured system of indicators of the office

lease options was formed (Fig. 1). It consists of 51 indicators; all of them are divided into three blocks by affinity, i.e. economic, environmental, and premises. The number of indicators in some of the main blocks (environmental and buildings) appeared to be too high in terms of the weight assessment; therefore, based on the principles of affinity again, they were divided into several parts: the block of environmental indicators – into infrastructure and location, and buildings – into the level of technical layout, atmosphere and options (Fig. 2).

2. MULTI-CRITERIA ASSESSMENT OF THE OFFICE LEASE INDICATOR SYSTEM

First of all, the method of carrying out the multi-criteria assessment of the hierarchically structured indicator system needs to be discussed. To carry out such an assessment, the weights and values of all indicators of the hierarchical level must be known.

The determination of the indicator weights starts from the lowest level of the hierarchical structure. This is done in two stages. Firstly, the experts set the indicator ranks for each group of the indicators of this level (in our case, there are six groups). This helps the experts to express a more uniform opinion when it comes to the assessment of the indicator weights. As the number of indicators in each group does not exceed 12, their weights may be determined directly, i.e. by distributing 1 among the indicators subject to assessment.

$$\text{It is presumed that } \sum_{i=1}^n w_i = 1$$

where:

- w_i – i -th indicator weight, n – a number of indicators, $i = \overline{1, n}$).

When the weights of the indicators of the lowest level of the hierarchical indicator system are determined, the weights of the higher-level indicators must be determined. As shown in Fig. 1, this level contains two environmental blocks and three premise indicator blocks. Their weights are determined in the same way as in the previous case.

Similarly, the weights of three main indicator blocks (economic, environmental, and premises) are determined. In all cases, the indicator weights were determined directly, i.e. the experts had to distribute parts of 1 among the indicators subject to assessment, where weights were equal to one.

When the weights of the hierarchical structure indicators are determined, their values must be set. A further complication is that a part of them is expressed in measurable dimensions, i.e. per cent, units, euro, metres, etc., and others belong to the hardly formalised ones, i.e. the ones that cannot be measured, for instance, prestige of the location, view through the office windows, the administration procedure, etc. In such cases, the only way to attribute values to such indicators is per expert assessment.

Lease options differ not only in economic (price, contract terms and conditions, etc.), environmental (prestige of the location, geographical location, communications, etc.) and premise (technical layout, arrangement, lighting, etc.) indicators, but also in their nature as some of them are maximising (the situation improves with the increasing indicator value) and other indicators are minimising (the increasing value leads to the worsening of the situation). The multi-criteria assessment method SAW, which was applied when determining the priorities of the lease options, requires the uniformity of changes in the indicators, i.e. all of them must be either maximising or minimising. The maximisation of minimising indicators is carried out as follows (Hwang & Yoon, 1981):

$$q_{\bar{j} \max} = \frac{q_{j \min}}{q_j} \quad (1)$$

where:

- $q_{\bar{j} \max}$ – the maximised value of the i -th indicator of the j -th variant,
- q_j – the value of the i -th indicator of the j -th variant,
- $q_{j \min}$ – the lowest possible value of the i -th indicator of the j -th variant.

The minimisation of indicator values is carried out as follows (Hwang & Yoon, 1981):

$$q_{\bar{j} \min} = \frac{q_j}{q_{j \max}} \quad (2)$$

where:

- $q_{\bar{j} \min}$ – the minimised value of the i -th indicator of the j -th variant,
- $q_{j \max}$ – the highest possible value of the i -th indicator of the j -th variant.

The lease options are expressed in different dimensions; therefore, they cannot be combined in one generalised unit. They are converted into non-dimensional ones through the value standardisation (Podvezko 2008):

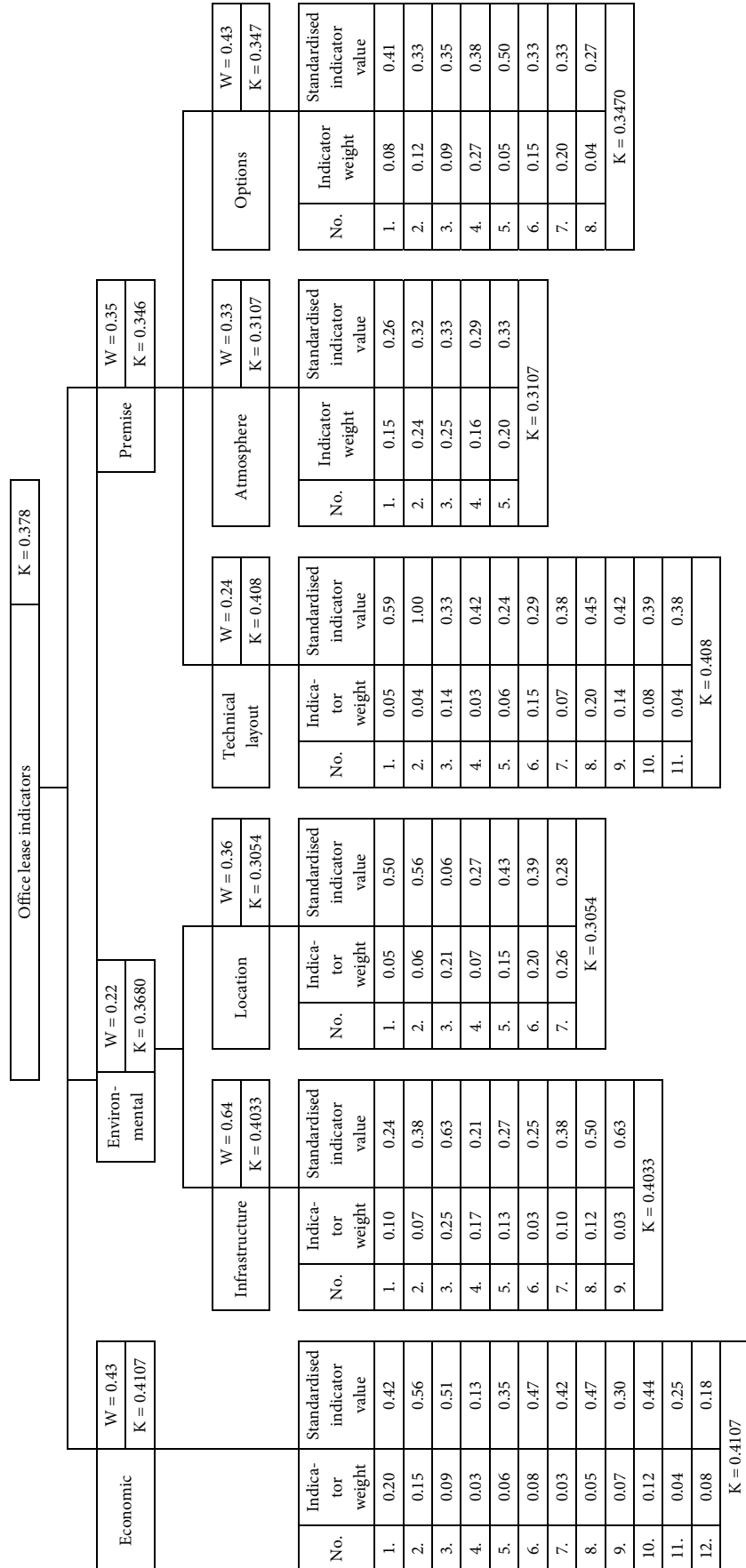


Fig. 2. Hierarchical indicator system of commercial real estate facilities (offices) lease

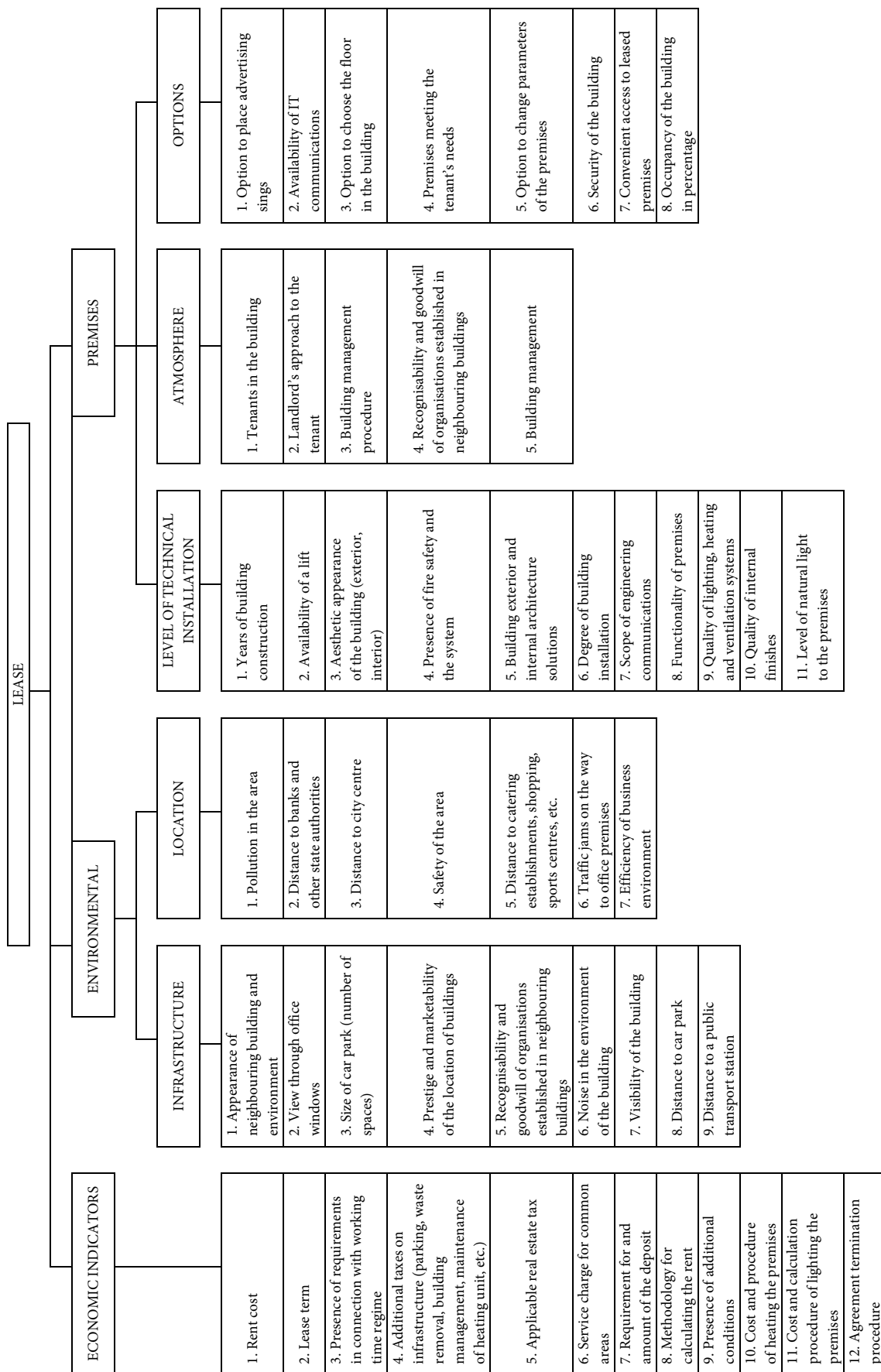


Fig. 3. Hierarchically structured system of commercial real estate (office) lease indicator

$$\tilde{q}_j = \frac{q_j}{\sum_{i=1}^n q_j} \tag{3}$$

where:

- \tilde{q}_j – the standardised value of the i-th indicator of the j-th lease option,
- n – a number of indicators ($i = \overline{1, n}$).

The multi-criteria assessment of the hierarchical indicator system of the lease options was carried out by means of the method SAW (Hwang & Yoon, 1981):

$$K_j = \sum_{i=1}^n w_{jik} \tilde{q}_{jik} \tag{4}$$

where:

- K_j – the value of indicator system of multi-criteria assessment through SAW of the k-th indicator group of the j-th hierarchical level,
- w_{jik} – the weight of the i-th indicator of the k-th indicator group of the j-th hierarchical level,
- \tilde{q}_{jik} – the standardised value of the i-th indicator of the k-th indicator group of the j-th hierarchical level.

3. RANKING OF OFFICE LEASE OPTIONS BASED ON THE HIERARCHICAL SYSTEM OF INDICATORS

The multicriteria assessment of hierarchically structured system of indicators is bottom-up, i.e. it starts at the bottom level in the hierarchy. Following formulas (1–3), the weights and normalised values of all six groups of related indicators are determined (Fig. 3).

Based on Table 1, the following values of the third-level multicriteria assessment of the lease of a

commercial real estate object (office) have been obtained.

These values immediately become the same of the units combining the above groups of indicators and positioned on a higher level of the hierarchical structure (infrastructure, location, level of technical installations, ambience, and options).

To perform a second-level multicriteria assessment of the hierarchical structure, one needs to know the weights of the environmental and premises groups of indicators. Following the expert survey, it has been obtained that the weights of groups of environmental indicators (infrastructure and location) equal 0.64 and 0.36, respectively; whereas the same of groups of premises indicators (level of technical installations, ambience, and options) are 0.24; 0.33 and 0.43, accordingly. Based on Table 1 and the weights determined, the following results of the multicriteria assessment for the second-level indicators have been obtained for the lease of a commercial real estate object (office), (Table 2).

The values of the multicriteria assessment of the first-level economic indicators (Table 1) and the second-level environmental and premises indicators (Table 2) of the hierarchical system of indicators are the values of the key units (economic, environmental, and premises) of the system of indicators. To carry out the final multicriteria assessment of lease options, one needs to know the weights of the above units. Following an expert evaluation performed, it has been obtained that the above weights equal 0.43, 0.22, and 0.35, respectively.

Following the multicriteria assessment, the following results have been obtained (Table 3).

It is evident in the multicriteria assessment of three lease options carried out based on the hierarchically structured system of indicators that such assessment calls for many calculations. The scope will significantly increase if there are many options to be

Tab. 1. Results of multicriteria assessment of the third-level indicators of the lease of a commercial real estate object (office) using the SAW method

NAME OF INDICATOR GROUP	ECONOMIC			ENVIRONMENTAL						PREMISES								
				INFRASTRUCTURE			LOCATION			LEVEL OF TECHNICAL INSTALLATIONS			AMBIENCE			OPTIONS		
	ALTERNATIVES			ALTERNATIVES			ALTERNATIVES			ALTERNATIVES			ALTERNATIVES					
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3			
SAW value	0.4107	0.3136	0.4183	0.4033	0.3172	0.2778	0.3054	0.263	0.4316	0.408	0.3281	0.2829	0.3107	0.3206	0.3687	0.347	0.3567	0.2855

Tab. 2. Results of multicriteria assessment of the second-level indicators of commercial real estate object (office) lease using the SAW method

NAME OF INDICATOR UNITS	ENVIRONMENT			PREMISES		
	ALTERNATIVES			ALTERNATIVES		
	1	2	3	1	2	3
SAW value	0.3680	0.2977	0.3332	0.3496	0.3379	0.3124

Tab. 3. Results of the multicriteria assessment for the first-level indicators of the lease of a commercial real estate object (office) using the SAW method

OPTIONS	FIRST	SECOND	THIRD
SAW value	0.3780	0.3186	0.261
Rank	first	second	third

assessed (there can be dozens of them). Hence, the assessment of lease options provided will only be worthwhile if the calculations are automated. They can be performed by a computerised decision-support system.

CONCLUSIONS

Today, the company offices are becoming an inherent part of the business that significantly affects the results of the commercial activity. The increasing demand for offices derives from both the internal and external needs. The former arise where the companies establish their affiliates and subsidiaries, expand their business in new areas, improve the office environment, focus their activities on one space, and improve their image; the latter mean the foreign capital. The global investors optimising their business are increasingly interested in the Middle Europe and the Baltic States, and they are gradually turning away from India and Asian countries.

Today, when selecting the premises, a potential tenant considers the aggregate of criteria covering various aspects rather than several basic criteria. In this case, the office lease options are defined by multiple various indicators. To rank such options, the indicators need to be combined in one generalised unit. The multi-criteria methods may be used to resolve such tasks.

The adequacy of the lease option assessment largely depends on the system reflecting their indicators. In the case of a small number of indicators, a single-level system may be used. And in the case of many indicators, the experts cannot accurately assess their weights. The formation of the hierarchical system is a proven method to reduce the number of

simultaneously assessed indicators. The hierarchical structure of the lease option indicators was formed on their basis. It consists of three main blocks, i.e. economic, environmental, and premise indicators. The first was assigned 11 indicators, environmental – 16 indicators, and premises – 24 indicators. The number of indicators in environmental

and premise blocks appeared to be too high in terms of the weight assessment; therefore, they were divided into several parts: the block of environmental indicators – infrastructure and location, and buildings – the technical layout, atmosphere, and options.

The multi-criteria assessment of one of the lease options, based on the hierarchical indicator system, was carried out as follows: first, the multi-criteria assessment values of all six allied indicator groups were determined through the method SAW. They became the values of the blocks combining such groups (infrastructure, location, technical layout, atmosphere, and options). On this basis and the weights of such blocks, the values of the blocks of the previous level (environmental and premises) were determined. During the last stage, based on the weights and values of three main blocks, the generalised multi-criteria assessment of the determined lease option was carried out.

The multicriteria assessment of lease options for commercial real estate objects (offices) requires large-scale calculations. They significantly increase if we take dozens of options for consideration. Hence, to make use of the proposed methodology efficiently, a computerised decision-support system needs to be developed.

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MEMETIC POOL AS A NEW APPROACH IN SERVICE QUALITY ANALYSIS

KRZYSZTOF STEPANIUK

ABSTRACT

This paper attempts to decompose, as well as perform a quantitative and qualitative analysis of the way to externalize the perception of the accommodation service. The research material consisted of the opinions of users of accommodation facilities, located in the vicinity of the twelve selected national parks in Poland. It was assumed that the reflection of the perception of the quality of the service process is the transfer of intangible content related to the service itself, which can be externalized, among other things, through entries in social networks.

The study was conducted based on the theory of memes as cultural information carriers. According to this theory, in such a transmission, it is possible to distinguish certain components, which can be defined as memes. Therefore, it is possible to analyse and track their presence, transfer, as well as incidence. A memetic pool was constructed using the assumptions of the perceptual-cognitive model of the formation of the tourism image. It was a direct expression of the mental changes of the recipient, resulting from the use of the service.

Studies of this type are intended to optimize the design of services in terms of building positive relationships on the line service provider-customer. At the same time, they allow for a slightly different, evolutionary approach to analyses, concerning the formation of the image of the service provider, as well as forming the expectations of service recipients.

KEY WORDS

accommodation service, service quality perception, meme theory, meme transfer, User Generated Content, memetic pool formation

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INTRODUCTION

The systemic approach to service quality refers to three basic components, i.e. the quality of input (the competence of employees providing a service, the circumstances of the service), process quality (interactions between the staff providing a service and the recipient), and the quality of output (changes in the physical and mental state of a recipient, resulting

from the consumption of a service), (Urban, 2007; Juran, 1992 based on: Johnson et al. (1995) as well as Lehtinen & Lehtinen (1991).

The customer perception of the quality of service summarizes his/her expectations with the actual effects of the consumption of the service. From this perspective, the decomposition of the perception of

the quality of service, in terms of the quality process, provides a chance to extract quantitative and qualitative parameters (attributes) that make up the image of the service. These parameters are reflected in the mental image (and its externalization) of the quality of the service by the customer. This externalization, on a wider scale, can accumulate in the form of a set of defined and structured attributes. The thus obtained package of quantitative and qualitative characteristics can be used in a variety of ways. Firstly, during the design or modification of the service, it is possible to emphasize the elements most frequently perceived by the recipients, and also introduce new elements. Secondly, by emphasizing the service and its promotion during the planning stage, it is possible to build and manage certain expectations for the service. Extensive possibilities of conducting research from this perspective are provided by the application of the theory of memes (Dawkins, 1976, 1982).

The main scientific objective of the study was to demonstrate the possibility of building a memetic pool relating to the method of decoding the perception of service quality, using the example of the quality of the accommodation service.

1. LITERATURE REVIEW

1.1. MEME THEORY

Memes are the carriers of cultural information (Dawkins, 1976). They are the cultural analogue of genes. They shape attitudes, styles, behaviour, ways of dressing, and the manner of self-expression. Memes spread in the community through imitation or copying (Blackmoore, 2000). Because of this feature, it is possible to refer to them as replicators (Ball, 1984). Replicators exist and reproduce themselves through social interactions, passing from person to person, from brain to brain (Gabora, 2013). A slightly different viewpoint, associated with the viral approach to the transfer of replicators has been presented by Wang & Wood (2011). The subsequent properties of replicators are (Dawkins, 1982; Gabora, 2013):

- Longevity – it survives long enough to replicate, or make copies of itself;
- Fecundity – at least one version of it can replicate;
- Fidelity – even after several generations of replication, it is still almost identical to the original.

Knobel & Lankshear (2007) divide memes into less and more “expansive”. The incidence of the effects

of more expansive memes will be significantly higher in the analysed group than that of the less expansive ones. Memes compete for the “existence” in the population. The most popular ones, i.e. the ones most commonly used by an individual or social group are visible in the form of specific behaviours or styles decidedly more often than the less popular ones. Depending on the nature of the social environment, a specific set of adapted (assimilated) memes can contribute to an increase or decrease in the level adjustment of an individual. Thus, the “success” of a single meme or a set of memes is determined not only by the content but also by the environment, in which this content is externalized. The increase in the level of adaptation would then be synonymous with the increase in the level of acceptance of certain behaviours and their frequent imitation by the other members of the community. This is a situation analogous to biological evolution, where one phenotype can be beneficial in a variety of environmental conditions, while not in others.

1.2. MEMES AND SERVICE QUALITY

Parasuraman et al. (1988) define the concept of service quality as the difference between customer expectations and the experience resulting from the consumption of such a service. The potentially memetic nature of the quality of services is evidenced by its features, identical to the properties of memes (Shifman, 2013):

- object/content of services – understood as a comprehensive set of goods, obtained by the recipient of the service;
- a form of communication, which may be identical to the method of service realization;
- relationship/correlation between the provider and the recipient, i.e. the source and the recipient of the message (i.e. stance).

The subject, form, and relationship are the basic features of memes. At the same time, these elements, combined with the characteristic of the quality of services, which causes changes in the mental and the physical state of clients (Johnson, 1995), justify the memetic approach. Difficulties may also be caused by isolating a single meme, which, being a carrier of a particular meaning, affects the mental state change of the consumer. For further consideration, it is assumed that the quality of the service process is a conglomeration of memes, i.e. a memetic pool, by analogy with the genetic pool, as a set of genes in the population. Constructing a memetic pool can facilitate the

analysis of the manner of the perception of service quality, the image of the reception area, etc.

The memetic content, emphasized with a varying intensity during the consumption of a service, can be reflected in the manner of perception of the quality of service. This feature is conditioned by the possibility of the transfer of memes between the members of the community. The transfer of the memetic content is carried out, among other ways, through the method of building a subjective perception of reality, and manifests itself in the method of conveying this content to the environment (Lisch, 2014). The content shared on the social networks is, in this case, the direct expression of the perception of reality by network users, and, therefore, also reflects their perception of the quality of a service.

1.3. SOCIAL MEDIA AND THEIR CONNECTIONS WITH THE MEME THEORY

The possibility of a direct and individual expression of the perception of reality is provided by the social media. Kaplan & Haenlein (2010) define social media as online platforms enabling the creation of individual accounts, building a network of friends, as well as the creation and sharing of a variety of pieces of content (graphics, text, and multimedia). The content elements, to a large extent, consist of the so-called User Generated Content (UGC), i.e. the content created and shared by the users with other people. This content is used to obtain information on tourist attractions, services, the experiences of others, etc. (Sparks et al., 2013). Each of these elements contains some semantic meaning, which is read and absorbed by the recipient. Sometimes, certain content seems to exist in a veiled, hidden form. Kim & Stepchenkova (2015) showed a significant influence of the so-called latent content, the elements not constituting the main plan of a photograph on the affective and cognitive activity of customers. Moreover, based on the obtained results, the authors confirm that the photos represent a set of attributes captured by the author, sent in the form of a photograph, and interpreted by the recipient. The emotional factor is also important with regard to the method of interpretation. Xu et al. (2015) argue that social media provide a platform for the presentation and transfer of emotions, which can have a positive, negative or neutral character (Li & Xu, 2014). Choi & Tom (2014) indicate the importance of the emotional component in the transfer of content via social networks. A similar approach is demonstrated by Highhouse et al. (2009), suggesting

that through the proper formulation of the communication content, it is possible to control the impressions of the recipients of specific content. Using the desired pool of traits, this enables the formation of a particular perception of places, events, etc. At the same time, Kim & Stepchenkova (2015) show that the recipients of the content “decode” their meaning in a way very similar to the organic image of a destination (Gartner, 1994), i.e. the one formed on the basis of the non-commercial sources of information. These sources are most likely related to the activities of local DMOs (Destination Management Organisations). They build a positive impression of a particular area, and at the same time create a mental, so-called “iconic” impression of the destination in the head of the customer.

2. RESEARCH QUESTIONS AND THE DEVELOPMENT OF A HYPOTHESIS

Su et al. (2015) suggest that customer-company identification, created by building mutual relationships, is one of the variables mediating between the perception of the quality of the product/service and the loyalty to a product/service as well as own well-being. Therefore, building high-quality services is one of the elements of relationship marketing, on the way to building customer confidence (Kim & Cha, 2002). Relationship marketing deals with the establishment of partner relationships between the provider and the recipient to achieve individual goals through the exchange of certain values and the meeting of commitments (Grönroos, 1984). Replacing certain values, meanings, ideas, combined with the property of the quality of services, changing the physical and mental state of the recipients (Johnson et al., 1995) are the factors driving the use of the memetic approach in the analysis of perception and externalization of the quality of services. It is problematic, however, to transform the memetic content into measurable variables. With this in mind, the main research questions have been formulated:

- RQ1: Is it possible to construct a hypothetical memetic pool concerning the perception of the quality of certain services by a group of consumers?
- RQ2: Is it possible to divide the thus created memetic pool into the groups of attributes

(memes) allowing for the examination of their incidence?

The aim of the study was to use the netnographic method (Jemielniak, 2013) to demonstrate the practical possibilities of using the model for the creation of the tourism image (Baloglu & McCleary, 1999) to form, describe, and decompose the memetic pool related to the perception of the quality of certain services. Such a pool, as an effect of mental changes created due to the accommodation service consumption, has been developed based on the semantic analysis of the comments left on business cards of agrotourism farms located in the vicinity of the selected national parks in Poland, and the ones listed on the sites that compare offers for tourists.

The contents of the comments were referred to the cognitive-perceptual attributes of the model of the tourism image, grouped into three main factors (Baloglu & McCleary, 1999):

- Factor I Experience: Cleanliness and hygiene of accommodation and catering; Quality of the available infrastructure; High quality of entertainment; Tasty cuisine; Good conditions for practicing recreation; Cosy accommodation; Interesting, Friendly People; Personal safety;
- Factor II Attractions: Historical monuments; Local handcraft; Cultural attractions; Mass events;
- Factor III: Environment: Clean, unpolluted environment; Beautiful, natural landscape; Attractive wild fauna and flora; Health-friendly climate

These are the indicators enabling the decomposition of the hotel service and its perception from the perspective of the quality of the process (Grönroos, 1984). From this perspective, the quality of the service is simultaneously reflected, among other things, in the mental state of the service recipient (Johnson et al., 1995), which can be externalized and transmitted, for example in the form of short entries on the sites comparing tourist offers. This latter feature allows for the examination of the quality of services from the perspective of the memetic approach (Dawkins, 1976).

The problematic issue, however, is the task of defining a meme itself. In the case of this study, it was assumed that a meme is a semantic reflection of the mental state of the recipient of the specific content. This condition, in turn, is externalized, among other ways, through the manner of expression of the opinion about a specific subject, product or service. The direct expression of the transfer and decomposition

of fragments the memetic pool were the authorial entries of social network users, defined as UGC.

Another problem was to generate a point of reference and a tool, through the use of which it would be possible to decode and read the specific memetic content. In this paper, it is assumed that the use of the perceptual-cognitive component of the model of creating the tourist image (Baloglu & McCleary, 1999) provides a basis for the creation of a memetic pool, as a set of memes relating to a particular service. At the same time, a collection created in that manner, can be easily decomposed. This distribution, in turn, allows for the analysis of the incidence of specific memes.

To gather as many comments as possible, the contents of five randomly selected comparison sites for tourist offers were analysed i.e. e-holiday.pl, nocowanie.pl, spanie.pl, emeteor.pl, and e-turysta.net. Due to the pilot nature of the research, the work included 12 of the 23 Polish national parks. In each of the comparison sites, with the use of the search engine integrated into the site, business cards have been identified relating to the agrotourism farms associated with each of the analysed national parks. The comments were archived with the use of Google spreadsheets. The contents of each comment were referred to the attributes grouped according to the three main factors mentioned above: experience, attractions, environment (based on Baloglu & McCleary, 1999). A single comment can contain one or more semantic references to the attributes mentioned above. At the same time, each of them was seen by the author as a single meme. The study was conducted between January and March 2016.

3. RESEARCH RESULTS

During the conducted pilot research, 497 comments were identified. Out of these, 104 were related to the tourist lodging, located in the vicinity of Białowiecki National Park (104), Biebrzanski National Park (45), Bieszczadzki National Park (31), Kampinoski National Park (21), Karkonoski National Park (19), Narwiański National Park (84), Ojcowski National Park (24), Roztoczański National Park (66), Słowiński National Park (19), Tatrzański National Park (8), Wigierski National Park (21), and Woliński National Park (55).

Using the three classification factors presented above, it was found that among the analysed comments, 1341 semantic and direct references were

made to the attributes identified with the quality of service. This pool (Fig. 1) was dominated by the indications associated with Factor I, i.e. concerning the overall experience (1127, i.e. 83.9%). The second most frequently noted group of indications (193, i.e. 14.54%) was related to the third factor, referring to

the perception of the natural attributes in the immediate vicinity of the accommodation services (environment). The least numerous (21, i.e. 1.56%) were the indications relating to Factor II, describing the attributes associated with the local cultural heritage (attractions).

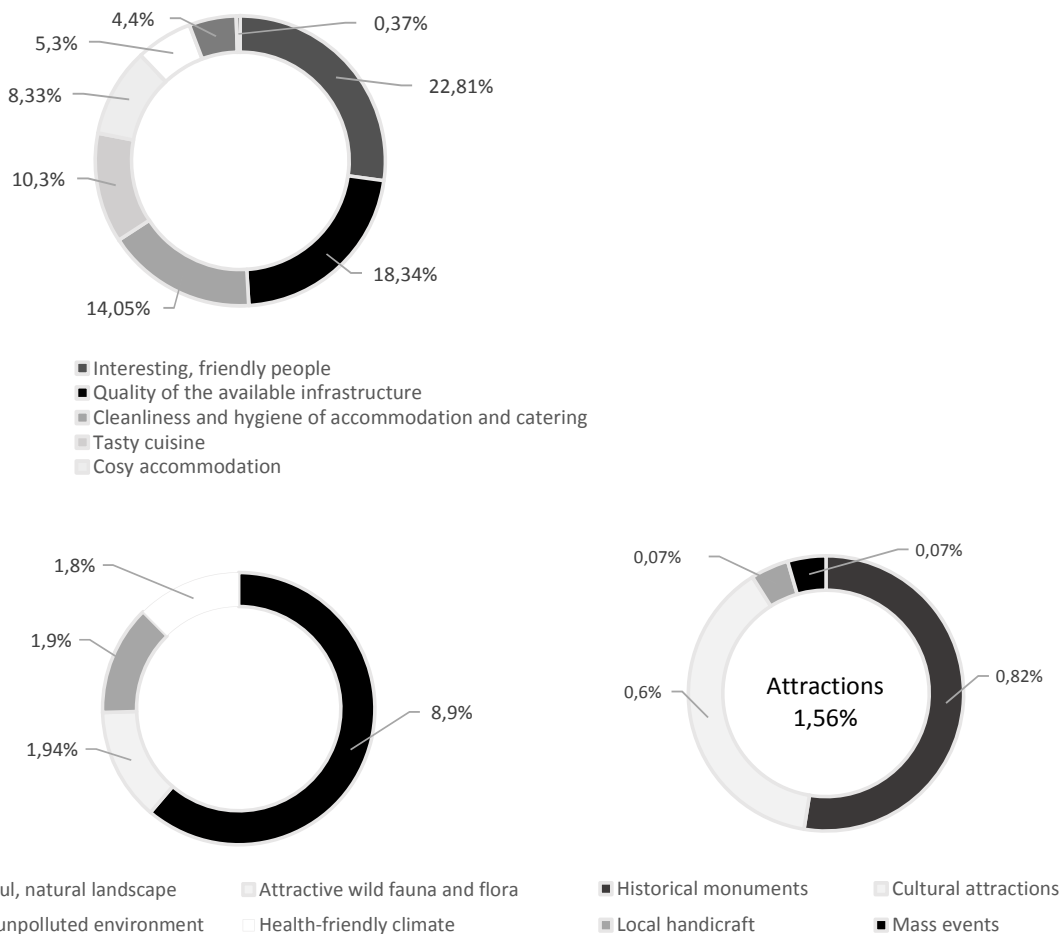


Fig. 1. Content of the memetic pool, reflecting the manner of perception of the quality of the accommodation service by its recipients from the perspective of the quality of the process

From the perspective of the first factor (experience), the dominant roles belong to the memes relating meaningfully to the friendly and welcoming service (22.81%) and the quality of the available infrastructure (18.34%). The least frequently represented factor is personal safety (0.37%). The third factor (environment) was represented mainly by the references to the landscape (8.9%). The semantic references to the second factor (attractions), was the least represented category of memes across the analysed memetic pool. Its share, not exceeding 2% of the total, relates mainly to historical monuments (0.82%).

4. DISCUSSION OF THE RESULTS

The conducted studies have shown the ability to identify and analyse the memetic bank, relating to a particular phenomenon (quality of accommodation service). Therefore, it is possible to create a set of memes being the result of changes in the mental and emotional state of the consumer. In this case, the factor attributes of the formation model of tourist image by Baloglu & McCleary (1999) were the tools of decomposition. A similar approach but without any

indication of the memetic context was showed by Tiago et al. (2015). The authors analysed the contents of commentaries regarding the semantic links to the senses of sight, hearing, taste, and touch, demonstrating that the meaning of the comments refers not so much to taste and smell, but also to a number of other attributes e.g. visual effect, freshness of the ingredients, and healthiness of the meal. At the same time, these are the factors based on the direct experience of consumers, and, thus, positively affecting the scope of the spread of the content within the social network. Undoubtedly, the factor deciding about the increased coverage in this case is a positive emotional tone. The potential and positive impact of the transfer of experience through UGC in building the trust and making consumer decisions is also indicated by Bahtar & Muda (2016).

The need to systematise and organise the data available within the social network is shown, among others, by Injadat et al. (2016). The authors particularly emphasize the unstructured nature of social media data, connected with different data types, such as text, images, and videos. Application of the theory of memes and the memetic bank as a collection of memes, allows for a simple systematisation of photographs, films and text elements, using common criteria. Assigning particular content to a single or several memes may be problematic, however, because of the subjective approach to categorizing.

Zhang et al. (2016) had an interesting debate, related in meaning to the theory of memes, although not referring directly to it, on the example of the financial markets. The authors argue that "... market can be partially predicted since people tend to accept messages which are confirmed by social environment and then invest according to what they have learned".

In this case, one may try to explain the transfer of the memetic content using the IPI (influence of Presumed Influence) theory. In the situation when a recipient of chosen content assumes that certain attitudes and behaviours presented in the transmission constitute a norm in a social (peer) group, there is a greater probability that they will be implemented by him/her (Gunther et al., 2006). From this perspective, building a high quality service is the transfer of information related to the "exceptional" nature of the specific service. The acquisition of such content by the recipient results in its further sharing. At the same time, the so-called "iconic" image of the provider is being built, setting out the way the provider is perceived by potential consumers. And, in turn, this implies a certain organic image of the provider, whose

expression can be transferred. At the same time, certain expectations of the recipient in relation to the offered service are created. However, the analysis of the relationship between the perception of service quality and its impact on the formation of expectations regarding the quality of the service among future consumers requires a further detailed study.

D'Agostino et al. (2015) show that social networks are collections of hidden knowledge, relating to many fields of human activity. These authors distinguish general networks (Facebook), where the content on various aspects is collected, and specific networks (e.g. LinkedIn), associated with profiled areas of user activity. Therefore, it can be assumed that these networks are holistic or specific memetic banks, where takeover and replacement of certain memes take place. To some extent, this approach enforces the way of defining the memetic bank as a set of memes (present in the content elements) and transmitted across the network or beyond it. In turn, the nature of the network depends on the number of users, motives of their activities, interests, primary and secondary social bonds (Podgórecki & Łoś, 1979). Also, the phenomenon of homophile, i.e., the integration of people with similar interests, is not without significance (Lazarsfeld, 1954). On the other hand, the occurrence of certain memes depends on the type of network and subject area, for which it exists.

At the same time, D'Agostino et al. (2015) compare the transfer of content within the SN to the physical process of diffusion. The memetic approach, in turn, transfers the level of the considerations similar to biological sciences and evolutionary phenomena. Such studies enable attempts to build scenarios for the development of the perception of the quality of services in the future, and the prediction of the potential distribution of the incidence of memes in a memetic pool concerning e.g. the quality of products or services.

Lymperopoulos & Ioannou (2015) indicate that the impact (positive or negative) on the determination of the affective and behavioural activities of social network users is mainly exerted by self-generated bias, the online interactions, and the external environment. This approach is identical to the processes of exchange of genetic information in bacteria. Similar to these organisms, the users in the process of transformation, download information (memes) from the environment (other users, groups, associations of users, communities). This acquired piece of information is in the next type of information/meme

flow process, i.e. conjugation is transmitted between the individuals and entities creating a social network.

Assuming that the quality of the process can be regarded as the so-called memetic pool (i.e. the total set of quantitative and qualitative attributes for describing the whole service process), it is possible to distinguish more expansive and less expansive memes (attributes) within it. The first category will dominate in the transmission to the recipient, while the other will constitute a subordinate element. The dominant memes will be identical to customer expectations, completed in the course of the consumption of the service. They will be transferred and/or processed (in the form of UGC). This transformation, from the perspective of a single recipient, may vary substantially in terms of quantity and quality. However, in the case analysis of a sample from the population (i.e. the analysis of the content of UGC and the memes externalized within them), it will create a ranking of the elements of the cultural transmission, which dominate the manner of perception of a service by the recipients. This, in turn, will provide a theoretical basis for the creation of strategies for building the quality of services while simultaneously building certain tourist expectations (Smoleński, 2011), as well as the tourist image (Tosun et al., 2015; Smoleński, 2010).

In summary, it has been shown that based on the semantic analysis of User Generated Content, is possible to construct a memetic bank, illustrating the manner of perceiving the accommodation service quality. To understand this phenomenon more thoroughly, we should carry out further research regarding the manner of creating the service quality by the service provider. Confronting the base bank, created by the service provider, with a bank, which was assimilated and externalized by recipients, would provide interesting results in the analysis of the effectiveness of the memetic content transfer.

CONCLUSIONS

The aim of the study was to demonstrate the potentially memetic nature of the quality of accommodation services. The quality of service, as perceived from the perspective of the quality of the process, was adopted as the theoretical basis. In this perspective, the manifestation of memetic transmission is the way of describing the quality of services by the recipients.

In this approach, the quality attributes of services form the memetic transmission, constituting a kind

of a memetic pool. During service realization, but also indirectly during the image building of service providers in social networks, this transmission is transmitted in the direction of the recipients (current and potential). The result of the transmission is the perception of services and their quality through confrontation with the expectations of a service recipient (after using the service) or building the expectations themselves (before using the service). Subsequently, thanks to the properties of memes, an individual way of communication regarding the services and their quality is formed and expressed. This stage may be identified with the adoption of a specific subset – part of the meme pool, and the process of their transformation, i.e. individual transformations done by a single customer. The final stage will be the further transfer, i.e. to subsequent users through sharing, of a packet of memes in the UGC form.

The presented considerations, although supported by the results of partial studies, are theoretical in nature. They direct the research on the phenomenon of the quality of services to the population-evolutionary approach. The meme pools, described by the frequency of occurrence of individual memes, are dynamic, i.e. changing over time, depending on the external factors influencing the demand for certain products and services. At the same time, the chances for evolutionary success, defined as the stable presence on the market, pertain only to those services and related service providers, in the case of which the marketing activities and the process of service realization itself, are building the proper relationship with service recipients.

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IDENTIFICATION OF PRODUCTION BOTTLENECKS WITH THE USE OF PLANT SIMULATION SOFTWARE

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ABSTRACT

The problem of bottlenecks is a key issue in optimising and increasing the efficiency of manufacturing processes. Detecting and analysing bottlenecks is one of the basic constraints to the contemporary production enterprises. The enterprises should not ignore problems that significantly influence the efficiency of the processes. People responsible for the proper course of production try to devise methods to eliminate bottlenecks and the waiting time at the production line. The possibilities of production lines are limited by the throughput of bottlenecks that disturb the smoothness of the processes. The presented results of the experimental research show the possibilities of a computer simulation as a method for analysing problems connected with limiting the production capacity. A computer-assisted simulation allows for studying issues of various complexities that could be too work-consuming or impossible while using classic analytical methods. The article presents the results of the computer model analysis that involved the functioning of machinery within a chosen technological line of an enterprise from a sanitary sector. The major objective of the paper is to identify the possibility of applying selected simulation tool while analysing production bottlenecks. An additional purpose is to illustrate the subjects of production bottlenecks and creating simulation models. The problem analysis involved the application of the software Tecnomatix Plant Simulation by Siemens. The basic methods of research used in the study were literature studies and computer simulation.

KEY WORDS

computer simulation, production process, bottleneck, simulation model, Tecnomatix Plant Simulation

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INTRODUCTION

Contemporary production is characterised by a wide selection of products, reduction of the product's life cycle, production costs and the time span between designing and launching products (Weiss, 1998). A constantly shortened cycle of the product's life caused by strong competition and changing requirements of customers, force producers to identify weak

points of production processes and implement changes aimed at improving their operation. It can be stated with high probability that every production process allows for some limitations to the manufacturing capacity of the enterprise since the existence of a bottleneck is the main factor affecting the efficiency of the production line and management (Liu & Lin,

1994; Chiang et al., 2001). Every enterprise can face constraints limiting the obtained revenue. The Theory of Constraints (TOC) assumes that every system has one basic limitation that influences the efficiency of the system in a given period (Chlebus, 2000; Goldratt et al., 2004). Localising bottlenecks is a key issue of production systems. Studying production bottlenecks is also a regular subject matter of scientific research. Production bottlenecks lead to various consequences. They can cause two major problems in a production process. Firstly, if the capacity of the assembly line does not suffice to meet the demand, an enterprise may lose its customers. Secondly, if the surplus of stocks is accumulated before the workstations of the bottleneck, this breeds additional costs connected with storing.

The development of computer science and the enormous computing power boost the increasing popularity of simulations that use appropriate software to project changes on real objects and situations before making any changes. The advancing computer simulation technology is gaining importance and becoming one of the most significant elements of production management. The reason behind this development is the necessity for companies to solve increasingly complex production problems as soon as possible. The development of programs for the simulation of processes makes it possible to use them in any enterprise, regardless of the profile. This software is used e.g. in the cells of the design, management and storage (Zdanowicz, 2007). The construction of a simulation model is a difficult task and requires a lot of information about the real process.

Simulation models allow evaluating different variants of production and their effectiveness. In addition, the simulation allows to use new strategies and procedures, verification of the production in the revised system, locate bottlenecks in the flow of materials, increase productivity while reducing inventory and reduce the cost of the implemented changes (Hromada & Plinta, 2000).

1. LITERATURE REVIEW

Literature provides many definitions of bottlenecks, though most of them cannot be applied in general (Wang et al., 2005). According to one of the definitions referring to production, a bottleneck is an element of a production process, where every resource that must be used to maximise production, is used in 100% (Durlik, 1995). A one-hundred-percent use of the production capacity of a given workstation breeds a considerable threat to the effectiveness of production processes. A workstation, being a bottleneck, is characterised by the highest level of exploitation, which also means a high risk of failure. At the same time, it is also the main factor affecting the completion date concerning the entire production process (Koliński, 2010).

A bottleneck is defined as a workstation limiting the production efficiency of the entire process (Betterson, 2012; Hsiao et al., 2010). It is the enterprise's workstation or a production cell that is characterised by the lowest level of a specific production parameter among all co-participating parameters in the manufacturing process. This can lead to a situation, in which a workstation before the bottleneck completes processing, but it cannot forward materials, as the workstation that follows it, being the bottleneck of the process, is still engaged in processing earlier orders. Bottlenecks can also extend the time of the standstill in the processes occurring at subsequent stages (Li, 2009), prolonging the waiting time for further orders. Bottlenecks mark the pace of the entire process. All definitions are consistent in one sense – bottlenecks have an adverse effect on the efficiency of production systems, the flow of materials in the process as well as even burdening of workstations (Kuo et al., 1996). Figure 1 presents the idea of bottlenecks.

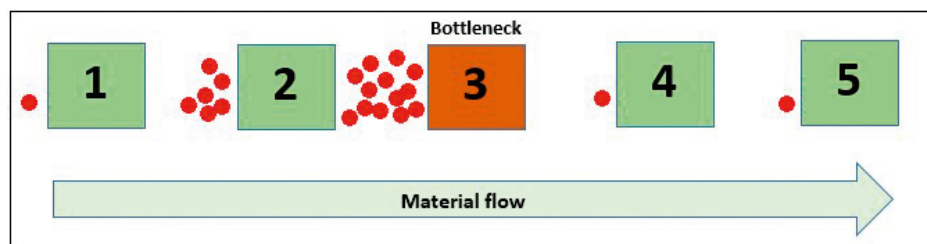


Fig. 1. Idea of bottlenecks

Source: Elaborated by the author based on (Betterson, 2012; Hsiao, Lin, & Huang, 2010).

Improving the functioning of workstations that delay the production is a crucial issue. However, it should be noted that before taking action aimed at improving the operation of workstations defined as bottlenecks, it becomes crucial to identify their precise location.

Identifying a bottleneck in the system is the first stage of managing constraints according to the Theory of Constraints (Goldratt et al., 2004). It involves localising the system's limitations. The following are other stages of managing constraints that can also be used in the analysis of computer-assisted simulation models:

- Making a decision on the manner of using a bottleneck;
- Subordinating all other operations to the decisions made in stage two;
- Eliminating the system's bottleneck;
- Returning to stage one (if it was possible to eliminate the bottleneck) and preventing the limiting effect of inertia.

As every system has its constraints, the identification and elimination of some of them results in the occurrence of the new constraints that replace the old ones. The procedure of a five-stage system management is sequential and continuous.

The literature identifies many methods of detecting production bottlenecks. However, there are still no expanded elaborations and case studies that use digital simulation models in that respect (Kliment et al., 2014; Leporis & Králová, 2010; Pawlewski & Fertsch, 2010; Siderska, 2016). Therefore, the raised issue requires further studies involving diverse software. The developing computer simulation tools with increasing capabilities are an ongoing research challenge.

2. RESEARCH METHODS

Studying phenomena and processes is the aim of many research programmes. This involves the application of various methods, beginning with practical activities in the form of observations, and ending with theoretical analyses. Such procedures require a mathematical apparatus. In the contemporary world dominated by ICT tools, a computer simulation becomes an exceptionally significant and effective research method. It reflects the studied phenomenon or a process in the form of a computer program, also called a computer model, which is cre-

ated with the use of a mathematical model (Gierulski et al., 2015).

Simulation is an approximate imitation of a studied phenomenon or behaviour of a given system in the virtual space with the use of its so-called simulation model. A simulation model is based on a mathematical model frequently recorded in the form of a computer program. At present, many tools are available for conducting computer simulations that allow creating simulation models (Ciszak, 2007a). Simulation models are used to reduce the risk of failure while implementing significant changes into the existing manufacturing systems. Upon generating the model, a simulation analysis is performed to determine particular elements of the process. The model of a studied system presents its properties, features and limitations as well as the manner in which the process in specific conditions takes place. Simulation, by means of adequate tools, allows for a respectively simple and cheap way of verifying different variants connected with the functioning of the processes (Glinka, 2012).

With a view to the objective of the simulation, it can be divided into three types (Ignasiak, 1997):

- a simulation aimed at understanding the principles of the functioning of the system and its properties that are difficult to distinguish based on a formal analysis;
- a simulation aimed at facilitating decision-making within the functioning of the system;
- a simulation, whose aim is to train decision makers concerning the functioning of the system.

The simulation of production processes is a technique used for solving problems occurring during the manufacturing process. It is based on virtual models (Kłos & Patalas-Maliszewska, 2016). As a method, a computer simulation is a system of research activities, i.e. a structure of stage activities aimed at achieving a research objective. The creation of a simulation model of a process is a multi-stage task (Gordon, 1974; Naylor, 1975; Law, 2008). Figure 2 presents the seven-step approach to conducting a successful simulation study.

Modelling the production process involves the creation of a virtual manufacturing process that allows conducting a simulation and collecting statistics. Statistics facilitate conducting reports and comparing selected settings of the parameters that characterise workstations. Computer models can be freely improved, and further simulations can be applied to various variants and settings anticipated by the user.

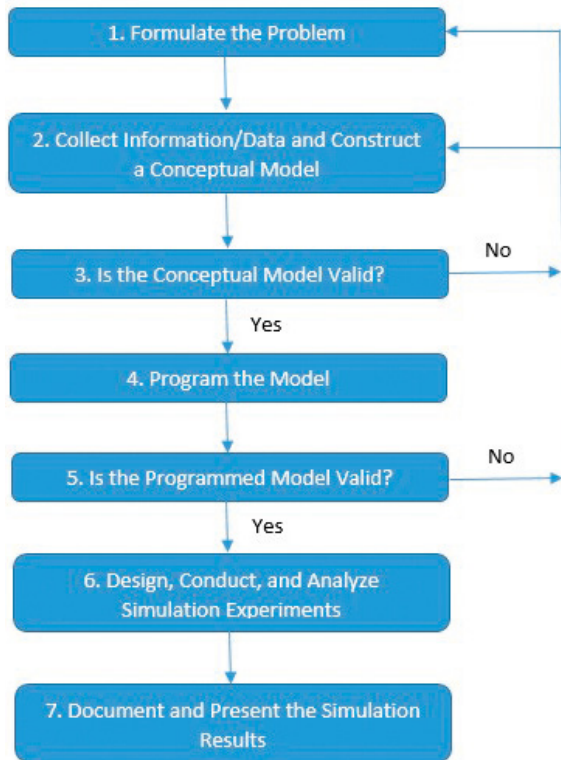


Fig. 2. Seven-step approach to conducting a successful simulation study

Source: (Law, 2008).

Simulation studies are applied to and are used in many scientific fields (Nazarko, 2013; Halicka, 2016). The application of a simulation in production processes constitutes a form of experimenting with a computer model. Its objective is to provide an answer to the question on how the production system will react to various situations, according to arranged scenarios. The application of simulation models allows for a more effective selection of manufacturing strategies by enterprises. Simulation models are typically used when it is impossible or very difficult to devise an analytical solution of a studied problem. This takes place in the case of analysing a dynamic behaviour of production systems and processes. An adequate selection of strategies and skilful management of chosen tools, including methods of computer simulation, allow and facilitate solving of problems that occur in the activity of an enterprise (Karkula, 2012). Digital manufacturing fosters modelling and simulation any product. Thanks to the application of computer assistance, production enterprises can optimise manufacturing processes in terms of time, costs and the quality level. The inclusion of ICT into manufacturing processes is a common phenomenon. The creation of computer models allows

analysing manufacturing processes, helps to localise their weak points, and creates possibilities for their improvement (Kikolski, 2016).

Computer simulations are identified as the most popular tools for the analysis of the possibilities that optimise processes in production engineering. Conducting of computer simulations allows assessing whether the undertaking was properly designed and is conducted in an adequate manner. A simulation ensures a total, complex view of the studied process or product, facilitates a multi-criterion analysis and testing various scenarios (Siderska, 2016). Modelling and digital simulations are used when it is too complicated or impossible to obtain a solution with analytical methods and experimenting with the real process within a production hall is too labour- or cost-intensive due to the enforced standstills in operation. Thanks to the application of the Plant Simulation tool, the analysis of chosen production processes is also possible at the stage of production design (Kikolski, 2016). Modelling and simulation are also used in situations where it is impossible to achieve the required level of confidence while applying other methods. The level of confidence means a condition in which the manufacturing process proves assumptions that were ascribed to the virtual model. The simulation of production processes allows familiarising with the functioning of the studied object and its analysis. Among other things, the studied objects are procedures, operations, transportation, stations, distortions, and stocks. A simulation facilitates tracking the system's operation from several minutes to several years. Moreover, it makes it possible to control the established assumptions before their practical application. It also allows for an earlier detection of irregularities that may disturb production in the future (Ćwikala & Gołda, 2005).

3. CASE STUDY

To verify theoretical assumptions, the analysis involved a case study, which incorporates modelling and computer simulation into the identification of a production bottleneck. It should be noted that the creation of a simulation model requires adequate knowledge of the modelled object. The success in applying a computer simulation for solving research problems resets in the proper creation of the model and the adequate execution of a simulation experiment. Creating a model of a production system and

conducting a proper simulation experiment determine a successful application of a computer-assisted simulation into solving research problems. To create a production system, it is necessary to gather and map out the necessary information as well as input data. They identify the level of the quality, quantity and form. It is an initial stage, thanks to which it is possible to gain knowledge of the problem as well as acquire information on methods that can be used to solve it (Ciszak, 2007b). It is also necessary to properly study the tools of the program that are to be used.

and design, through simulation and verification of processes (Danilczuk et al., 2014; Plinta 2013).

The aim is to achieve the simplest possible model; however, the prerogative is to devise a model that describes the activity of the modelled process with the highest precision (Małopolski, 2012). Nevertheless, it should be noted that oversimplifications used in the creation of the model can lead to false results of the simulation, i.e. results that vary from the real state of the system in given conditions. To properly define the parameters of specific operations, it appeared

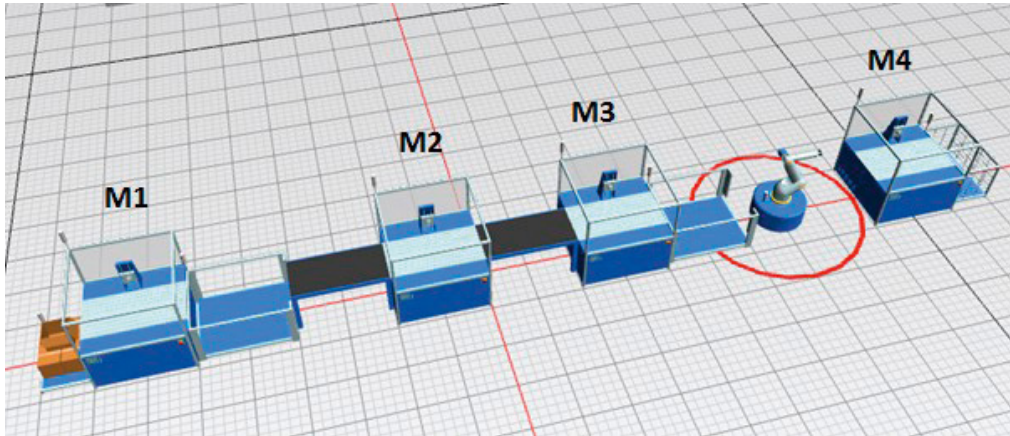


Fig. 3. Virtual 3D model of the analysed process

The research involved the use of the Siemens product Tecnomatix Plant Simulation, one of the tools available on the market for creating simulation models. The choice of the system is not the most important thing. The possibility of applying the system to selected problems should be noted. In addition, studies have used other systems for the simulation of production processes, which include (Ciszak, 2007a; Danilczuk et al., 2014):

- Arena,
- Enterprise Dynamics,
- Flexim,
- Matlab Simulink,
- ShowFlow,
- SIMUL8.

Plant Simulation choice is dictated by the availability of research version. The selected tool enables conducting simulations and product analysis throughout the entire manufacturing process. This ensures planning a sustainable production process prior to its implementation as well as conducting the analysis and optimising already existing processes. It combines the fields of technology, production engineering and logistics. It also includes issues related to planning

necessary to conduct studies that involved gathering information during the active production hours within the production hall.

The model of a production system (Fig. 3) is based on an example of a real production department, with the use of Tecnomatix Plant Simulation software. The input data are determined based on the known technological data of the process and the data concerning material flow during production. It is particularly essential to reflect activities connected with the processing of individual components.

The project does not use energy and cost data, neither does it consider work performed by the employees. To achieve the objectives of the research paper, it is crucial to incorporate the elements of the production process that directly affect the time of performing tasks within the machine park.

Proper identification of basic properties of the system is crucial for achieving proper results of the analysis. The gathered information was used in creating virtual processes of manufacturing and defining their basic tasks. The creation of simulation models relied on approved assumptions concerning simula-

tion times. Table 1 presents unit timing of processing at specific stations.

Tab. 1. Components time of processing on workplaces (in seconds)

WORKPLACE	TIME OF PROCESSING (IN SECONDS)
M1	24.32
M2	20.16
M3	49.68
M4	32.55

The studied process involves four workstations and auxiliary infrastructure that is used for transporting semi-finished products. The analysis was conducted during one work shift (6:00–14:00), which was broken into two intervals of 30 minutes.

4. RESEARCH RESULTS

The simulation involved one product; therefore, the model did not require resetting machines at specific stations. All machines have a high (M1 and M3) or medium (M2 and M4) work coefficient. During an eight-hour-long simulation, the virtual model produced 541 units of products prepared for further production and assembly (not covered by the simulation). The Chart in Fig. 4 presents the results gathered during the simulation. It shows the percentage-based burdening of all stations that take part in a process.

An initial analysis of the chart leads to the conclusion that the station M3 is the bottleneck of the analysed process. Table 2 provides detailed results of burdening specific stations.

Tab. 2. Detailed statistics in the basic model

WORKPLACE	WORKING TIME [%]	WAITING TIME [%]	BLOCKED TIME [%]	PAUSED TIME [%]
M1	88.75	–	5.00	6.25
M2	38.29	0.18	55.28	6.25
M3	93.58	0.17	–	6.25
M4	61.22	32.53	–	6.25

The analysis of detailed data confirms that the bottleneck in the studied example is the station M3, which is used with 93.58% intensity, whereas the remaining time is devoted to breaks in the production that are planned in advance. It can be observed that the station M3 causes considerable standstills at the station M2, reaching 55.28% of the simulation time. Moreover, the identified bottleneck causes increased mid-operation stocks as well as gradual blocking of the station M2. It also enforces the waiting time for semi-finished products at the station M4.

5. DISCUSSION OF THE RESULTS

The analyses required applying adequate software. They involved one of already available systems for designing and optimising virtual models of pro-

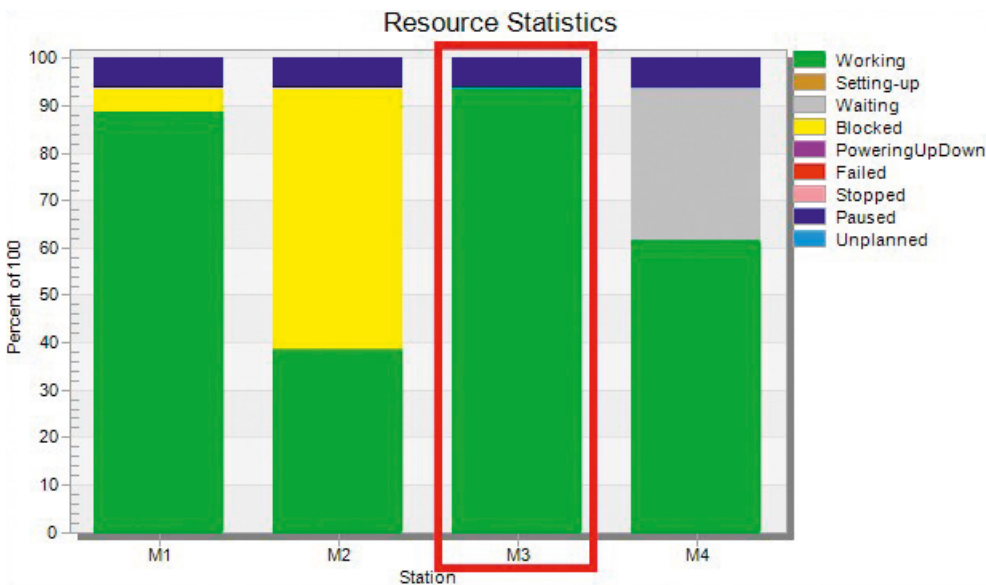


Fig. 4. Chart of efficiency for the basic model

duction processes, identifying possibilities of its use in analysing production processes.

It should be emphasised that the operation of the lowest efficiency limits the efficiency of the entire production process, but also identifies its efficiency. A bottleneck is a resource that prevents from compensating for lagging behind or delayed production orders. It also determines the level of the integration of other workstation in the production process.

Some of the ways to solve problems of a production bottleneck are: introducing shift-based production, increasing the number of overtime, intensifying quality control before the bottleneck to eliminate the production rejected in the bottleneck, expanding the machine park or, ultimately, purchasing from the

market the missing semi-finished products manufactured by the bottleneck. All of the above-enumerated solutions can be implemented in a basic model, extending its functionalities in terms of the selected auxiliary assumptions. Tests in the virtual environment facilitate a free configuration of the technological line, without interfering with the real process within the production hall, until the optimum solution that an enterprise can afford is chosen.

As the simulation in the presented case involves the course of one shift, it is not possible to increase the working time of specific stations to compare the basic to the extended model.

One of the solutions that can be implemented in the analysed model is expanding the production line

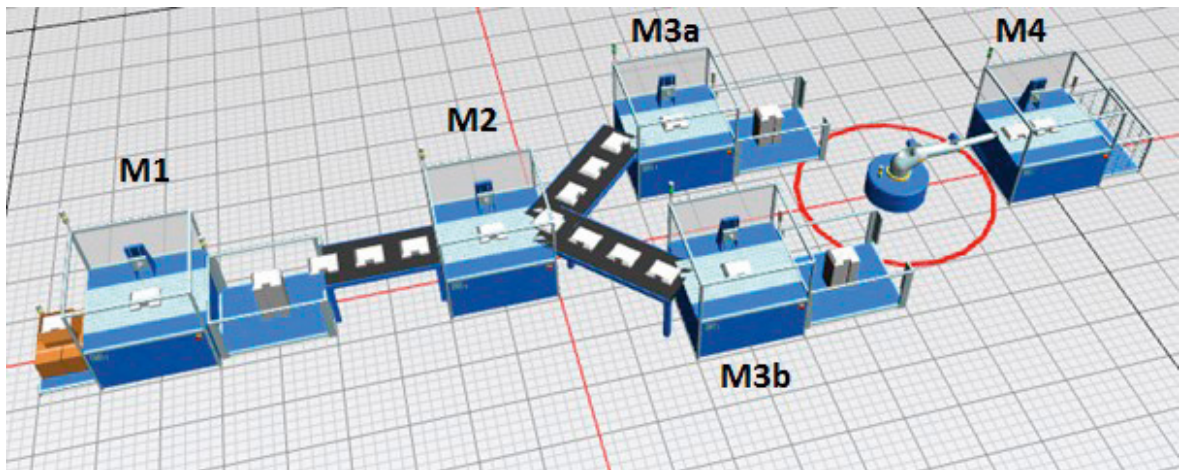


Fig. 5. Extended model of the analysed process

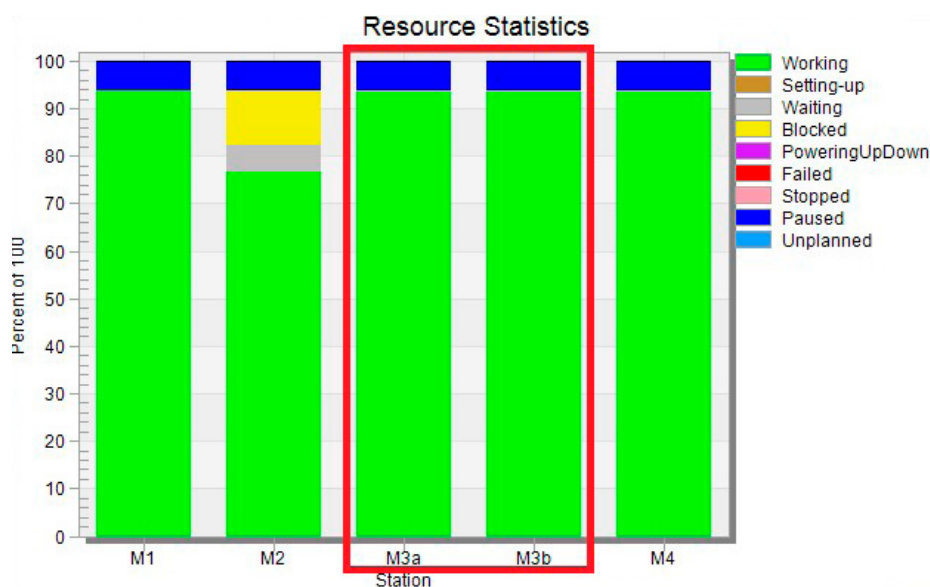


Fig. 6. Chart of efficiency for extended model

by a parallel station of the work node M3, which is the bottleneck of the output process. The extended model is presented in Figure 5. The parameters of workstations remained unchanged. The efficiency of the process, as compared to the basic model, increased from 541 to 826 units of the manufactured semi-finished product during an eight-hour-long shift.

Figure 5 presents the chart that shows the efficiency of the analysed process upon changes made according to the alternative scenario that involves expanding the machine park. Detailed results are presented in Table 3.

Tab. 3. Detailed statistics in extended model

WORKPLACE	WORKING TIME (PERCENTAGE)	WAITING TIME (PERCENTAGE)	BLOCKED TIME (PERCENTAGE)	PAUSED TIME (PERCENTAGE)
M1	93.75%	–	–	6.25%
M2	76.58%	5.59%	11.58%	6.25%
M3a	93.58%	0.17%	–	6.25%
M3b	93.49%	0.26%	–	6.25%
M4	61.22%	32.53%	–	6.25%

The introduced changes did not fully solve the problem of the bottleneck at the station M3, but they considerably improved the smooth operation of the entire production line. Firstly, the blocking of the machine M2 was considerably reduced, and the idleness of the machine M4 was eliminated. Machine M4 could prove to be the new production bottleneck in extended studies, though it does not affect the other objects of the process as much as the station M3 in case of the first scenario.

It should be noted that the described scenarios did not consider the costs of expanding and maintaining the machine park. The current model cannot identify if the obtained growth in production efficiency could balance the cost of expanding the production line. This fact necessitates further studies focused not only on the growth in the production efficiency, but also accounting for the costs of implementing changes and their cost-effectiveness.

CONCLUSIONS

The problem of a bottleneck is one of the core issues faced by production enterprises while, e.g., planning or optimising their production. The main problem in the case study was to find a production bottleneck with the use of a simulation model.

The article presents the analysis and assessment of the chosen production line in two versions. The studies facilitated an initial evaluation of the efficiency of specific elements in the process and the indication of its bottleneck.

The subject of the reported research was to develop a simulation model of the actual production line and examine the load of individual workstations. Developed simulation model allows the bottleneck location of the production process. The results of simulation studies have shown that one bottleneck exists in the reporting process at the station M3.

It interferes with the operation of the entire process, resulting in blocking of the work at the station M2 and forced to idle at the station M4. It has been proposed to improve the process, involving the extension of the parallel position at the point of detection of the bottleneck. The result of the expansion was mainly to increase the production capacity of the process and the vast reduction of the time of locking at the station M2 and expectations for components at the station M4. The analysed production line began to work smoothly.

The performed study confirms the possibility of applying Plant Simulation software in the analysis of simple production processes. The use of computer simulation tool allows to predict the work of the production line and provide some of the behaviour of systems. A wider scope research can provide an answer to the questions concerning the suitability of such solutions in the analysis of complex processes.

Using simulation tools does not exclude a traditional form of design. However, it may become a source of confirming the adequacy of a designed object. The application of a computer simulation for solving research problems relies on the proper creation of the model and adequate execution of a simulation experiment. The choice of the relevant tool for conducting a simulation is extremely essential. It is important that a given program has an adequate functionality in the sense of the simulation's objective.

It should be noted that the conducted analysis is only an example of using simulation models for the identification of bottlenecks and that it was focused on the part of the production process. Expanding research to encompass other elements of the process can affect the statistics of the efficiency of specific stations.

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