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Logistics management of the rail connections using graph theory: the case of a public transportation company on the example of Koleje Dolnośląskie S.A.

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A B S T R A C T
The main purpose of the paper was the structural analysis of the connections network used by a railway carrier Koleje Dolnośląskie S.A. operating in southern Poland. The analysis used simulation methods. The analysis and simulation were based on graph theory, which is successfully used in analysing a wide variety of networks (social, biological, computer, virtual and transportation networks). The paper presents indicators which allow judging the analysed connections network according to an appropriate level of transport services. Simulation results allowed proposing some modifications for the improvement of the analysed connections network. The paper also demonstrates that graph theory and network simulations should be used as tools by transportation companies during the stage of planning a connections network.

K E Y W O R D S
Koleje Dolnośląskie, railway transport, structural analysis of networks, transport company management, transport networks

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Introduction

According to the information provided in the literature (Sołtysik, 2000), logistics management is a sequence of activities constituting a component within the process for the creation of a company's logistics concept and the implementation of logistics activities using appropriate control and control systems. Logistics management should use a number of tools (Bukowski, 2014) to ensure the effectiveness of actions taken in the supply chain (including the provision of transport services), considering both efficiency and resilience to possible threats. Among other things, logistics management consists of appropriate transport or, specifically, transport services implemented following the principles of logistics (Kerap et al., 2017).

Transport is an important branch of the economy that affects urban and rural residents and businesses (Mesjasz-Lech, 2014). Consequently, it is important to create efficient and effective transport systems in cities and regions. Such systems should enable the acquisition and maintenance of their users (customers).

Customer acquisition and service require an appropriate level of performance (transport services included) to ensure customer maintenance, which is one of the main tasks in the management of a company for the managerial staff and employees (Witkowski, 1995). Transport companies must meet several requirements to acquire and retain customers. These requirements are mainly related to the level of services, which mainly concerns the quality encompassing:

- travel comfort,
- operating frequency,
- number of connections,
- travel time,
- the cost of travel,
- intermodality.

It is important to note that nowadays, transport companies operate according to free-market principles. Consequently, on the one hand, they have to compete in the services market and, on the other hand, they must cooperate with other service providers operating at the same scope (including the same branch and substitute branches in the industry of the company's operation). The above conditions and difficulties apply to the area of transport services in general and the area of public transport in particular.

As an element of the modern economy, public transport has commercial and social importance. Congestion is a major challenge for urban and metropolitan areas (Badura, 2017). Not only does congestion raise air pollution concerns but also gives rise to social pressure to improve the quality of life. Consequently, efficient transport systems currently play an even more significant role than in previous decades. Also, congestion generates enormous costs and wastes travel time as well as fuel. The United States, for instance, lose 11 billion hours and incur the increase of 11 billion litres in fuel consumption (Szołtysek, 2014).

Since the beginning of the 1990s, private transport has played an increasingly important role in Poland. However, pursuant to some studies of and situations in Western European cities, such as London or Kraków and Katowice in Poland, this type of transport will no longer guarantee efficiency and, most importantly, will not be considered environmentally friendly. The aggravating factor is an especially unfavourable vehicle occupancy rate of a passenger car, averaging at 1.3 people per vehicle. The solution has been proposed in the EU's sustainable transport policy: to improve transport in urban and agglomeration areas by means of efficient and effective public transport.

Poland as well as Europe, take measures to increase the share of public transport at the expense of private transport. These measures include legislative and organisational solutions as well as social actions.

Attractiveness to passengers is a crucial factor in increasing the share of public transport. In this respect, several factors are important, including travel comfort, availability, travel time, and cost. The total effort related to these factors must result in the attractiveness of the public transport superseding the appeal of personal cars. It must be underlined that changing habits is not an easy task to achieve. Thus, public transport services should ensure maximum benefits with minimum costs and time losses (Krykawskyy et al., 2015).

The above problem is not only particular to cities but also agglomerations, such as Wrocław, and some regions, such as the province of Lower Silesia. Additionally, the movement of people from urban to suburban or rural areas has become a growing phenomenon. More and more people choose life or leisure outside cities, especially city centres. However, greater occupational or educational opportunities make the people take trips to large urban centres.

This situation requires an efficient and effective transport system to and from the city as well as inside it. Also, an efficient transport system has a significant impact on the development of a region in economic terms. If a transport system encourages residents to live in a certain area, including a suburb, by facilitating efficient and quick access to the workplace, the attractiveness of such an area significantly increases and brings investments.

Currently, a bus is the most popular mode of public transport in Poland. It has several advantages, including high flexibility and availability, but also many disadvantages, such as the environmental unfriendliness and operating on the same roads as cars. These issues are mitigated using appropriate legislative measures, e.g. the prohibition for personal cars to enter a city, and organisational solutions, such as purchasing buses powered by hydrogen or electricity and introducing bus lanes. However, these actions are inadequate to ensure efficient traffic management, especially in city centres and suburban and rural areas.

Rail transport is considered an effective and frequent solution used for linking a city with suburban/rural areas. Some of the advantages of this mode of transport are high transport capacity, punctuality and safety. Nowadays, regional rail carriers offer high travel comfort using modern rolling stock, which, as mentioned before, is also very important. Besides, it is an important element of the logistics strategy as part of business management.

Several decades after the collapse, the rail system of Poland, including agglomeration and urban areas, is undergoing a revival. Agglomeration or urban networks are being built or rebuilt in every major Polish agglomeration or metropolis.

One network is available in Lower Silesian Voivodeship. One of its main goals is to ensure efficient transport between cities and suburban or rural areas. This network is operated by the railway carrier Koleje Dolnośląskie S.A. Appropriate modelling, optimisation and assessment of connections in the carrier network have a significant impact on ensuring the required level and quality of transport services. Consequently, it is an important element of business management. Furthermore, it is significant in terms of ensuring an adequate level of security and responsiveness to disturbances and risks, many of which are currently very difficult to detect, such as black swan events (Bukowski, 2015). Graph theory, among other things, can be used to evaluate the connection network.

1. Characteristics of the carrier Koleje Dolnośląskie

According to available information (Koleje Dolnośląskie, 2016), Koleje Dolnośląskie was established by the Authorities of Lower Silesian Voivodeship on 28 December 2007. The company is owned by the Regional Government of Lower Silesian Voivodeship. The company is tasked to provide passenger rail services with the objective to ensure an efficient regional rail system. The current carrier's rolling stock consists of two groups of vehicles, namely, diesel traction units and electric multiple units. Detailed information is presented in Tab. 1.

Tab. 1. List of railway vehicles owned by Koleje Dolnośląskie

Diesel traction units	
Vehicle type	No. of items
SA106	1
SA109	2
SA132	1
SA134	8
SA135	9
SA139	4
Sum:	25
Electric multiple units	
Vehicle type	No. of items
31WE	10
36WEa	6
EN57	4
Sum:	20

Source: (Koleje Dolnośląskie, 2016).

In addition to information about the current state of the rolling stock, the dynamics of the carrier's development is also very important. Tab. 2 presents the number of passengers transported by the carrier and transport work performed in 2011–2017. The data presented in Tab. 2 is shown graphically in Fig. 1 and 2.

As shown in Fig. 1, the number of passengers in the period from 2011 grew almost exponentially, while transport performance increased linearly. This indicates an intensive development of the carrier and high popularity of transport services. Significantly, according to the data of the Central Statistical Office, the population of Dolnośląskie Voivodeship was 2 903 710, which ranks it 5th in Poland in terms of the population and 3th in terms of population density.

In addition to modern rolling stock, an adequate level of service requires a well-organised structure of services provided, with the network of connections as one of its main elements. The structure of connections

Tab. 2. Number of transported passengers and transport work performed by the Koleje Dolnosląskie in 2011–2017

	Year						
	2011	2012	2013	2014	2015	2016	2017
The number of transported passengers [mln]	0.900559	1.840128	2.421163	3.603254	5.222432	7.312884	9.380451
Transport work [mln paskm]	30.128947	87.057838	115.158880	204.665963	316.994350	391.213509	508.047568

Source: (UTK statistical data).

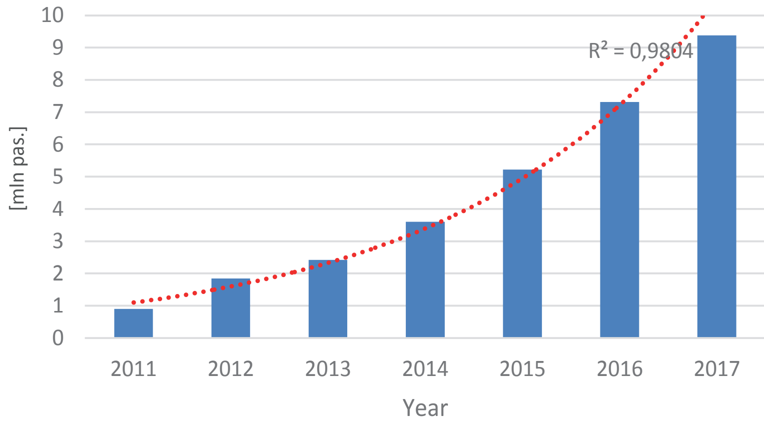

Fig. 1. Number of transported passengers in 2011–2017

Source: own study based on (UTK statistical data).

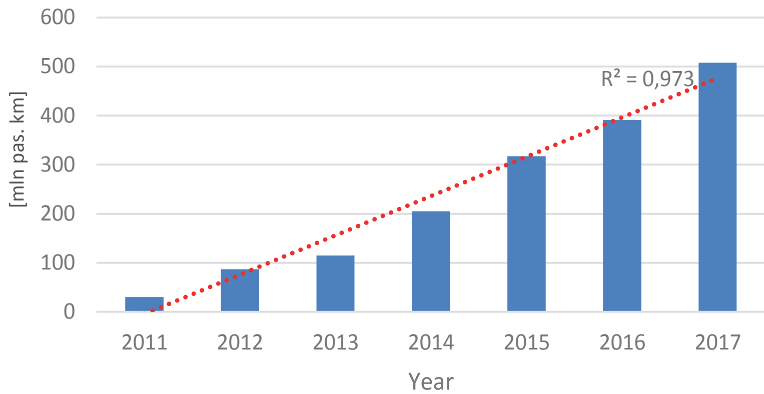

Fig. 2. Transport work in 2011–2017

Source: own study based on (UTK statistical data).

(communication network) of the Koleje Dolnosląskie is shown in Fig. 3.

According to the information provided in Fig. 3, the connections network of Koleje Dolnośląskie is divided into 17 lines that allow connections between the capital of the voivodeship and virtually all larger towns located in the Lower Silesia. Naturally, the service is also available in many smaller towns. It should be stressed that the carrier also offers connections to neighbouring countries (Germany and the Czech Republic) sharing a border with the voivodeship.

In contrast, Fig. 4 shows the existing railway network in the Lower Silesian Voivodeship. Comparison of Fig. 3 and 4 reveals that the carrier's connections network does not utilise all possible existing railway connections in the analysed area. The existing railway network allows making some changes and modifications to the currently used connections network, which may contribute to the further development of the company through increased accessibility of the carrier services. Thanks to the existing network, this availability can be increased without costly infrastructure investments. Certainly, the choice of new connections or the modification of the connections network is not an easy task. Decision taking can be made easier by using graph theory.

2. Graph theory in network analysis including transport networks

Transport networks are one of the most important elements of the national and regional economy. Their main task is to ensure a smooth movement from point A to point B. Therefore, they must be resistant to any interference and ensure an adequate level of security (Dunn & Wilkinson, 2017).

Current transport systems (just as electric, telecommunications or IT systems) constitute a network of complex connections and links (Eusgeld et al.,

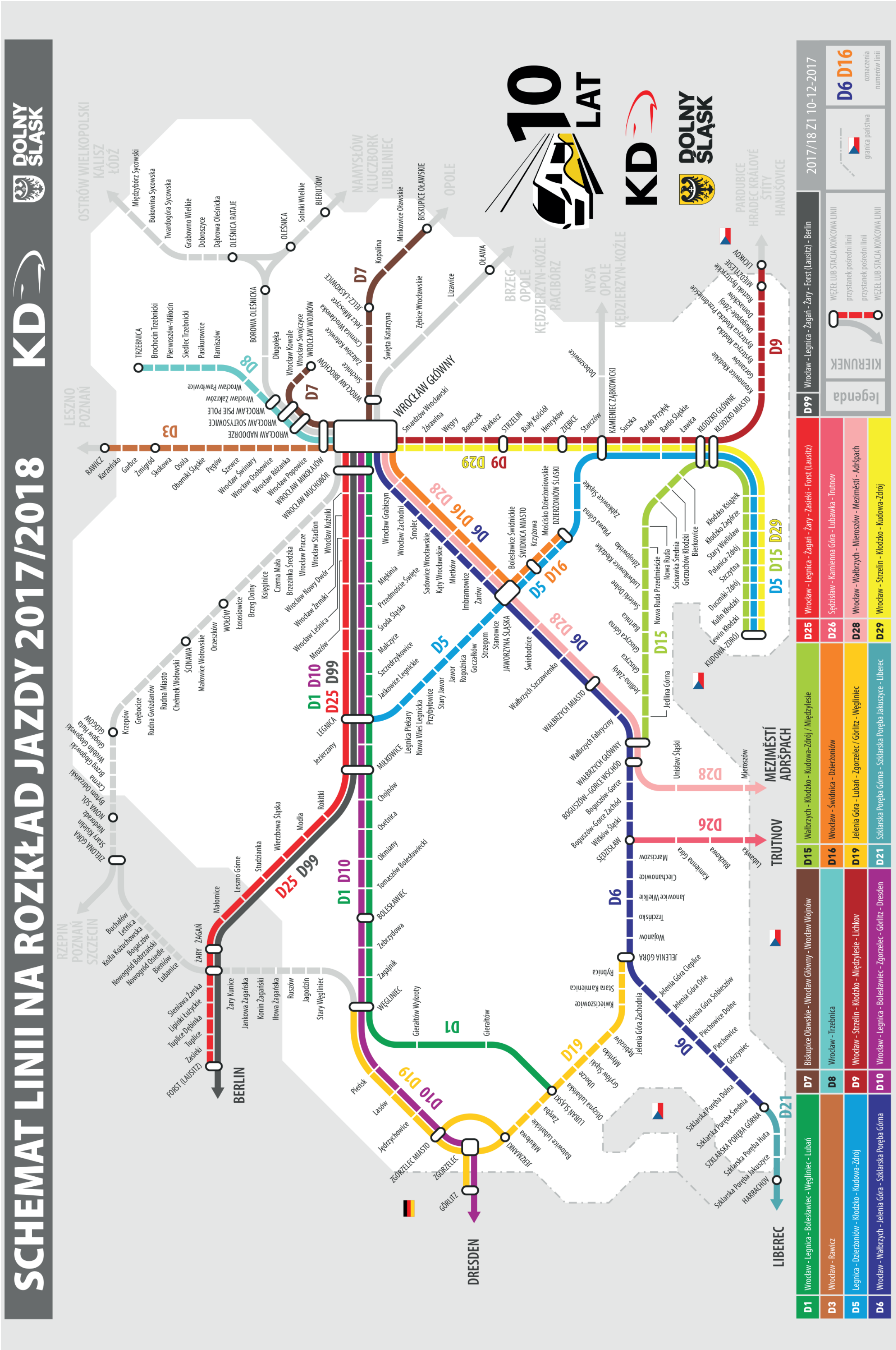

Fig. 3. Diagram of the connections network of Koleje Dolnośląskie

Source: (https://www.kolejedolnoslaskie.eu).

Fig. 4. Railway network in the Lower Silesia Voivodeship

Source: (http://www.bazakolejowa.pl).

2009; La Rovere & Vestrucci, 2012). This important feature hinders the analysis both from the organisational viewpoint as well as in terms of the resistance to possible disruptions (Infrastructure engineering…, 2011).

Network analysis methods are widely used for the analysis of social networks (Amaral et al., 2000; Arenas et al., 2003; Butts, 2008; Newman et al., 2002; Otte & Rousseau, 2002; Popp et al., 2018), but also biological networks (Rual et al., 2005), neural networks (Bullmore & Sporns, 2009; Sporns, 2002; Stam & Reijneveld, 2007) and computer networks (Valverde & Solé, 2003).

According to some authors (Dunn & Wilkinson, 2017; Li et al., 2014; Newman, 2002; Ouyang et al., 2015; Tarapata, 2015; Wilkinso et al., 2012), the methods and coefficients used to analyse social networks can also be effectively applied in the analysis of transport networks.

With the help of graph theory, the article analyses the structural transport network of connections used by the regional rail carrier Koleje Dolnośląskie. According to the information provided in the literature (Amara et al., 2000; Bullmore & Sporns, 2009; Dunn & Wilkinson, 2017; Li et al., 2014; Newman, 2010; Ouyang et al., 2015; Rual et al., 2005; Sporns, 2002; Stam & Reijneveld, 2007; Tarapata, 2015; Valverde & Solé, 2003; Wilkinson et al., 2012) transport networks can be analysed using a group of meters that allow obtaining information regarding the characteristics of the analysed network. The meters used to calculate the parameters of individual network nodes and the entire network are also described in publications by other authors (Stawiarska & Sobczak, 2018; Newman, 2010; Sobczak, 2017; Tarapata, 2015).

The factor allows obtaining information about the role of individual nodes in the network and determining its parameters.

Each network can be described as a collection of nodes and their links:

$$G = \langle V, E \rangle \tag{1}$$

where:

V – collection of nodes,

E – collection of their interrelations.

Of course, the following relationship applies to every analysed network:

$$|V| = N, |E| = M \tag{2}$$

The most popular measures are described below.

Normalised degree (dc_i) for an i-th node:

$$dc_i = \frac{k_i}{N-1} \tag{3}$$

where:
k_i – degree of this i-th node in the network (the number of node connections with other nodes),
N – number of nodes in the network.

The higher is the dc_i coefficient value for this i-th node, the more important role this node has in the network, or the closer the node is situated to the centre.

Eccentricity (ec_i) of an i-th node in the network:

$$ec_i = \max_{j \in V} d_{ij} \tag{4}$$

where:
d_{ij} – number of links among the nodes, wherein a link is understood as the shortest distance between node i and node j.

Eccentricity is defined as a maximum distance between two nodes (http://www.geeksforgeeks.org). The lower is the ec_i coefficient value for this i-th node, the more important role this node has in the network, or the closer the node is situated to the centre.

Radius (rc_i) of this i-th node in the network:

$$rc_i = \frac{1}{\max_{j \in V} d_{ij}} = \frac{1}{ec_i} \tag{5}$$

where:
d_{ij} – number of links among the nodes, where a link is understood as the shortest distance between node i and node j,
ec_i – eccentricity of this i-th node in the network.

The higher is the rc_i coefficient value for this i-th node, the more important role this node has in the network, or the closer the node is situated to the centre.

Closeness (cc_i) for an i-th node in the network:

$$cc_i = \frac{N-1}{\sum_{j \in V} d_{ij}} \tag{6}$$

where:
N – number of nodes in the network,
d_{ij} – number of links among the nodes, wherein a link is understood as the shortest distance between node i and node j.

Closeness measures the average distance from a given node to all other nodes in the network (https://github.com).

Betweenness (bc_i) for an i-th node in the network:

$$bc_i = \sum_{l \in V} \sum_{k \neq l \in V} \frac{p_{l,i,k}}{p_{l,k}} \tag{7}$$

where:
$p_{l,i,k}$ – number of connections with the lowest number of nodes between nodes l and k (containing node i),
$p_{l,k}$ – number of connections with the lowest number of nodes between nodes l and k (which do not contain node i).

Betweenness measures how often a node appears on shortest paths between nodes in the network (https://github.com). The higher is the bc_i coefficient value for this i-th node, the more important role this node has in the network, or the closer the node is situated to the centre.

Clusterisation (gc_i) of this i-th node in the network:

$$gc_i = \frac{2E_i}{k_i(k_i-1)}, k_i > 1 \tag{8}$$

where:
E_i – number of links among nodes which are situated closest (neighbours) to the i-th node,
k_i – degree of this i-th node in the network (number of node connections to other nodes).

The higher is the gci coefficient value for this i-th node, the more important role this node has in the network, or the closer the node is situated to the centre.

Formulas (2)–(8) describe the parameters of particular nodes in a network. However, coefficients used to determine the parameters of an entire network are also applied. These are (Newman, 2010; Tarapata, 2015).

Average shortest paths length (L):

$$L = \frac{1}{N(N-1)} \sum_{i \neq j \in V} d_{ij} \tag{9}$$

where:
N – number of nodes in the network,
d_{ij} – number of links among the nodes, where a link is understood as the shortest distance between node i and node j.

The lower is the value of the average shortest path length, the better is the analysed network.

Clusterisation coefficient (C):

$$C = \frac{1}{N} \sum_{i \in V} gc_i \tag{10}$$

where:
N – number of nodes in the network,
gc_i – clusterisation coefficient.

The higher is the value of the clusterisation coefficient, the better is the analysed network.

Diameter (D):

$$D = \max_{i \in V} ec_i \tag{11}$$

where:

ec_i – eccentricity of the i-th node in the network.

The smaller is the diameter, the better is the network.

Radius of a network (R):

$$R = \min_{i \in V} ec_i \tag{12}$$

where:

ec_i – eccentricity of the i-th node in the network.

The smaller is the radius of the network, the better is the network.

Average nodes degree ($\bar{k}$):

$$\bar{k} = \frac{1}{N} \sum_{i \in V} k_i \tag{13}$$

where:

N – number of nodes in the network,

k_i – degree of this i-th node in the network (number of node connections to other nodes).

The higher is the average node degree in the network, the better is the network.

The analysis of coefficients relating to individual network nodes as well as to the network as a whole allows assessing its current status, optimising, and proposing changes and modifications that may contribute to the improvement of network parameters.

The analyses presented below were made using freeware Gephi, which allows analysing the network and its parameters. Gephi is used by researchers for analyses related to networks (Popp et al., 2018; Zirkelbach et al., 2015), which confirms the effectiveness and, most importantly, the reliability of analysis results obtained with the use of the software (parameters of nodes and networks). The advantage of using the software, in addition to its availability, is also the opportunity to learn about the algorithms used and suggestions for their improvement on websites and the software forum (https://github.com; forum-gephi.org).

3. Research results

As part of the research, the connections network used by Koleje Dolnośląskie was simulated using Gephi. The simulated network is shown in Fig. 5. It presents the analysed network considering the network node degree (a train stop).

Fig. 5 shows the current connections network of the carrier between particular nodes (train stations) that are operated by the carrier. However, the lines between nodes mean the existing connection between the given stations. The size of individual nodes means the size of a given parameter (in Fig. 5, it is the degree of nodes) calculated for each node (train station), i.e. the larger is the size of a given parameter, the greater is the value.

Next, basic network parameters were calculated using Gephi in accordance with formulas described by other authors (Newman, 2010; Sobczak, 2017;

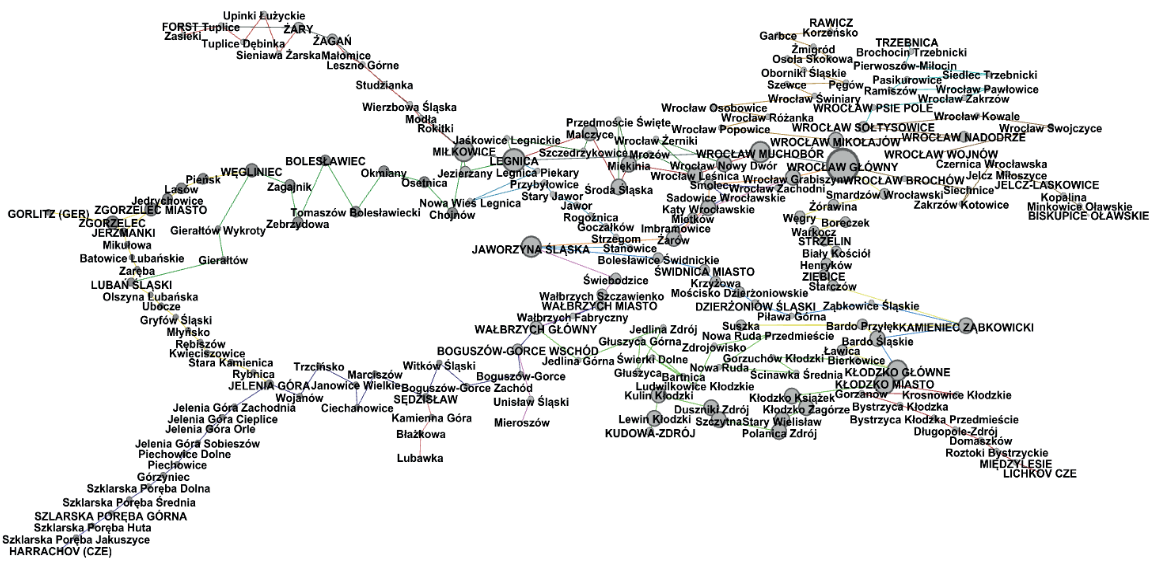

Fig. 5. Connections network used by Koleje Dolnośląskie on the degree of nodes

Source: own elaboration based on (https://www.kolejedolnoslaskie.eu) made using Gephi software.

Stawiarska & Sobczak, 2018; Tarapata, 2015). Due to a large volume of calculated data (202 nodes/stops) in Tab. 3, indicators are presented only for selected stops, regarded as main by the carrier (these are mainly node and terminal stations).

The calculated ratios are presented in Tab. 3. For illustrative indicators, their values are presented in a graphical form in Figures 6–8.

As shown in Table 3 and Figures 6–8, the key nodes of the analysed network are the main stops (stations) located in the main cities of the voivodeship. The stations Wrocław, Wrocław Muchobór, Miłkowice, Legnica, Wałbrzych, Kłodzko (Main and the City) and Jaworzyna Śląska deserve particular attention. It is clearly visible that the centre of the network is concentrated around the main city of the province – Wrocław.

Then, the coefficients determining the state of the network as a whole were calculated. The obtained values of coefficients are presented in Tab. 4.

The resulting network indicators show that it has a rather good performance, but that can be improved by making some modifications to the connections network.

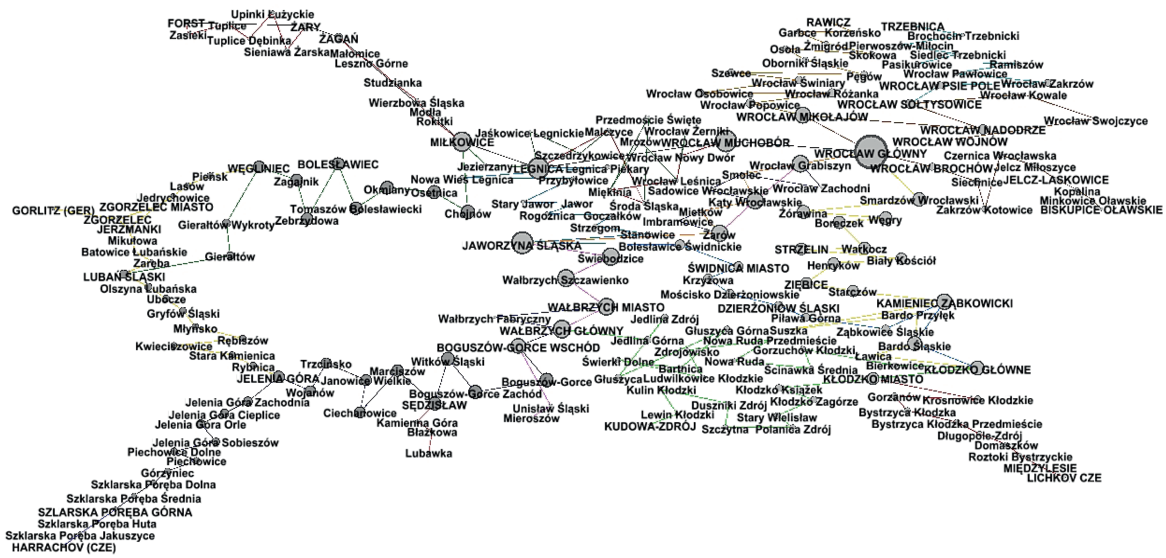

Fig. 6. Betweenness coefficient for the analysed network

Source: own study using Gephi software.

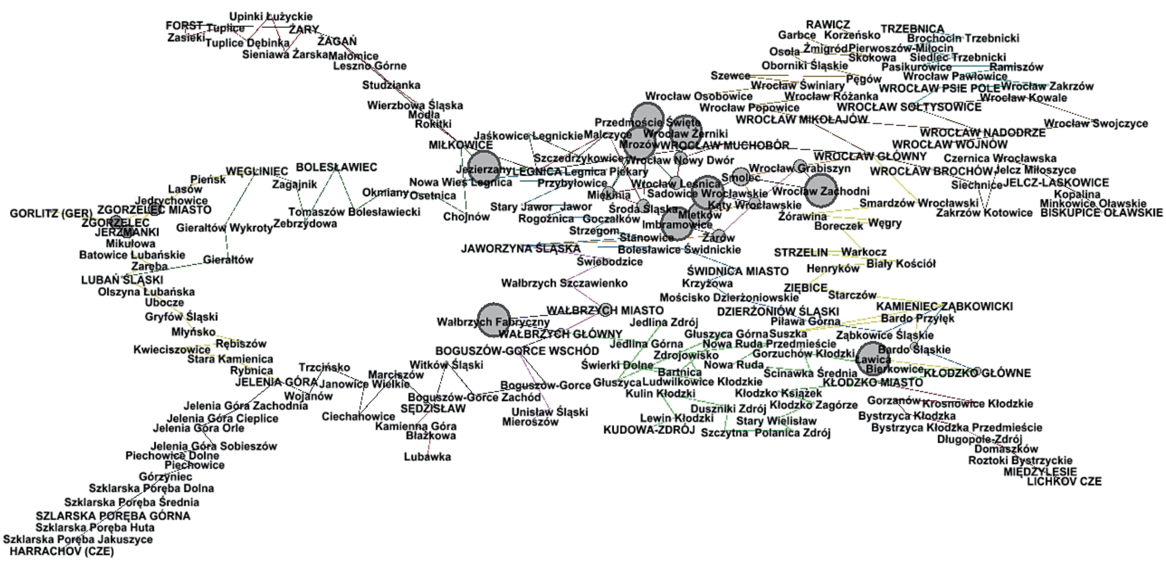

Fig. 7. Clusterisation coefficient for the analysed network

Source: own study using Gephi software.

Tab. 3. Indicators calculated for selected stops (nodes) of the Koleje Dolnośląskie network

City (Node)	Normalised degree	Eccen-tricity	Radius	Closeness centrality	Betweenness centrality	Clustering	Eigencent-rality
Wrocław Główny	0.064676617	32	0.03125	0.093358105	0.559471814	0	1
Wrocław Brochów	0.009950249	33	0.03030303	0.086007702	0.07681592	0	0.147281398
Jelcz-Laskowice	0.009950249	38	0.02631579	0.061149985	0.029552239	0	0.009281612
Biskupice Oławskie	0.004975124	41	0.02439024	0.051790776	0	0	0.004272244
Wrocław Mikołajów	0.029850746	33	0.03030303	0.087429317	0.24278607	0	0.490023117
Rawicz	0.004975124	46	0.02173913	0.042378242	0	0	0.004272244
Wrocław Nadodrze	0.019900498	34	0.02941176	0.0812778	0.12159204	0	0.16955391
Wrocław Sołtysowice	0.019900498	35	0.02857143	0.07587769	0.114179104	0	0.067583692
Wrocław Psie Pole	0.009950249	36	0.02777778	0.070949523	0.07681592	0	0.019328113
Trzebnica	0.004975124	44	0.02272727	0.045921864	0	0	0.004272244
Wrocław Wojnów	0.004975124	38	0.02631579	0.061979648	0	0	0.004483397
Smardzów Wrocławski	0.019900498	33	0.03030303	0.088351648	0.193225376	0	0.325712893
Strzelin	0.019900498	38	0.02631579	0.070402802	0.164369655	0	0.059340589
Kamieniec Ząbkowicki	0.029850746	36	0.02777778	0.065387118	0.233827914	0	0.11909069
Kłodzko Główne	0.039800995	38	0.02631579	0.060161628	0.202862693	0.166666667	0.386658822
Kłodzko Miasto	0.039800995	39	0.02564103	0.057346648	0.167910448	0	0.429333981
Międzylesie	0.009950249	47	0.0212766	0.03993642	0.009950249	0	0.007580234
Lichkov (CZE)	0.004975124	48	0.02083333	0.03841009	0	0	0.004272244
Kudowa-Zdrój	0.014925373	48	0.02083333	0.03841009	0	0	0.097813175
Jaworzyna Śląska	0.039800995	28	0.03571429	0.089852481	0.346612407	0	0.208516098
Świdnica Miasto	0.019900498	30	0.03333333	0.081015719	0.119181586	0	0.075408434
Dzierżoniów Śląski	0.014925373	33	0.03030303	0.070974576	0.101587174	0	0.031920644
Wałbrzych Główny	0.024875622	25	0.04	0.076484018	0.271342836	0.166666667	0.052877195
Wałbrzych Miasto	0.019900498	25	0.04	0.079227434	0.254739462	0.333333333	0.0561526
Boguszów-Gorce Wschód	0.019900498	25	0.04	0.073304158	0.217688124	0	0.041094005
Legnica	0.044776119	34	0.02941176	0.086787565	0.334128359	0.066666667	0.402312847
Wrocław Muchobór	0.039800995	33	0.03030303	0.090094128	0.342473322	0	0.816298021
Miłkowice	0.039800995	33	0.03030303	0.083715119	0.302567076	0.1	0.284505544
Żagań	0.019900498	34	0.02941176	0.077876792	0.091044776	0	0.080547097
Żary	0.019900498	35	0.02857143	0.072589382	0.058358209	0	0.046911533
Bolesławiec	0.019900498	31	0.03225806	0.067653989	0.172709835	0	0.060080128
Lubań Śląski	0.014925373	37	0.02702703	0.055509528	0.09962796	0	0.015623384
Zgorzelec Miasto	0.024875622	38	0.02631579	0.050616973	0.030537606	0.333333333	0.077011692
Zgorzelec	0.024875622	39	0.02564103	0.048715463	0.009950249	0.333333333	0.066127548
Jerzmanki	0.014925373	39	0.02564103	0.049204406	0.013329529	0.333333333	0.041069654
Gorlitz (GER)	0.009950249	40	0.025	0.046463245	0	0	0.033285248
Sędzisław	0.014925373	29	0.03448276	0.063207547	0.186295141	0	0.015236981
Jelenia Góra	0.014925373	35	0.02857143	0.052411995	0.161410508	0	0.015282294
Szlarska Poręba Górna	0.009950249	45	0.02222222	0.035356201	0.029552239	0	0.009280346
Szklarska Poręba Huta	0.009950249	46	0.02173913	0.034177861	0.019800995	0	0.008938041
Szklarska Poręba Jakuszyce	0.009950249	47	0.0212766	0.033064649	0.009950249	0	0.007580231
Harrachov (CZE)	0.004975124	48	0.02083333	0.032011467	0	0	0.004272244

Source: own study using Gephi software.

Tab. 4. Values of factors determining network parameters

Average Clustering Coefficient	Average path length	Diameter	Radius of a network	Average nodes degree
0.071617162	16.704694350032018	48	25	3.03960396

Source: own study using Gephi software and on the basis of (Tab. 3).

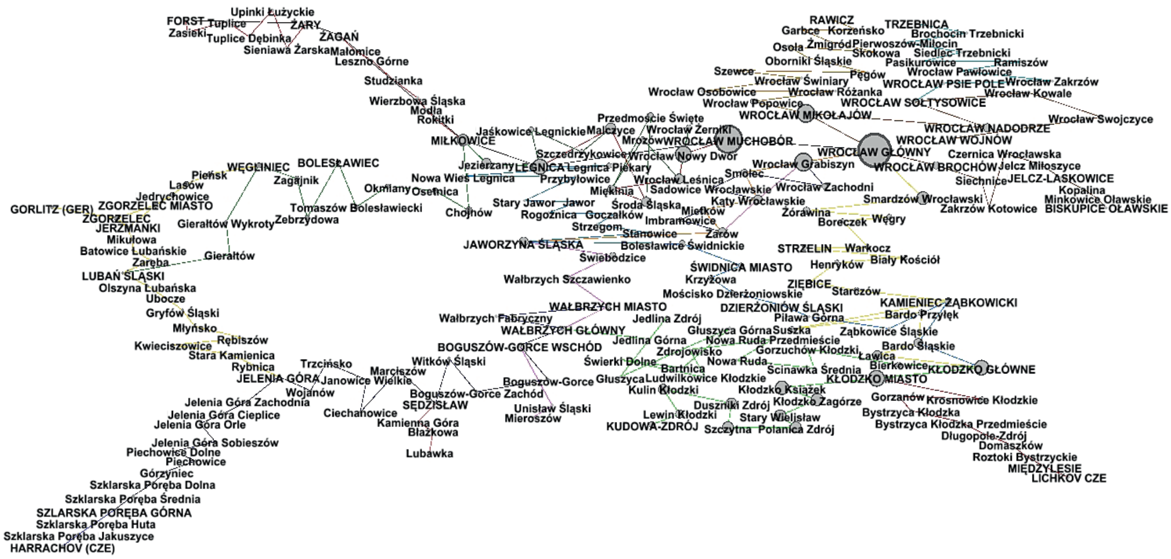

Fig. 8. Eigenvector coefficient for the analysed network

Source: own study using Gephi software.

4. Discussion of the results: analysis of the network structure – proposed modification

As part of the analysis of the structure of the connections network used by Koleje Dolnośląskie, it was proposed to introduce modifications that improved the network by increasing its cross-linking. As already mentioned, network modification, and quality analysis and evaluation are important elements of business management. As part of the research, it was proposed to add connections to the existing network. The implementation of the proposal is enabled by the railway network in the Lower Silesian Voivodship. The following connections were added to the analysed structure:

1. Wrocław Wojnów – Dobrzykowice Wr. – Nadolice Wielkie – Chrząstawa Wlk. – Jelcz Miłoszyce;
2. Wrocław Różanka –Wrocław Sołtysowice;
3. Wrocław Nowy Dwór – Wrocław Zachodni;
4. Jelenia Góra – Pilchowice Nielestno – Wleń – Lwówek Śląski – Niwnice – Nowogrodziec – Zebrzydowa;
5. Legnica – Jerzmanice – Wojcieszów – Marciszów;
6. Węgliniec – Ruszów – Jankowa Żagańska – Żagań and Żary;
7. Lwówek Śląski – Jerzmanice;
8. Marciszów – Strzegom;
9. Strzegom – Malczyce.

The network with added connections is shown in Fig. 9.

Indicators were also calculated for individual network nodes for networks after the modification. The obtained calculation results are presented in Tab. 5 (for selected stations).

As shown in Tab. 5 and Fig. 10–12, the main stations have not changed, but there has been an increase in network cross-linking.

Then, coefficients determining the state of the network as a whole were calculated. The obtained values of coefficients are presented in Tab. 6.

Then, the comparison was made of values of coefficients determining the network parameters before and after the proposed modification. The compared data is presented in Tab. 7.

As shown in Tab. 7, the introduction of new stations and connections to the carrier network contributed to the improvement of their parameters. Only Average Clustering Coefficient deteriorated, which means the deterioration of the ability to form groups (clusters) of stations directly related to one another. According to the authors, it is an apparent deterioration as it is the result of increasing the availability of transport networks through the addition of new nodes (stations) and connections. This statement is supported by improved network parameters. It is clearly visible that the average length of the path has been reduced, i.e. a journey from node A to node B is faster at least theoretically (through a smaller number of nodes). The situation looks similar to the radius of the network and its diameter, which diminishes in

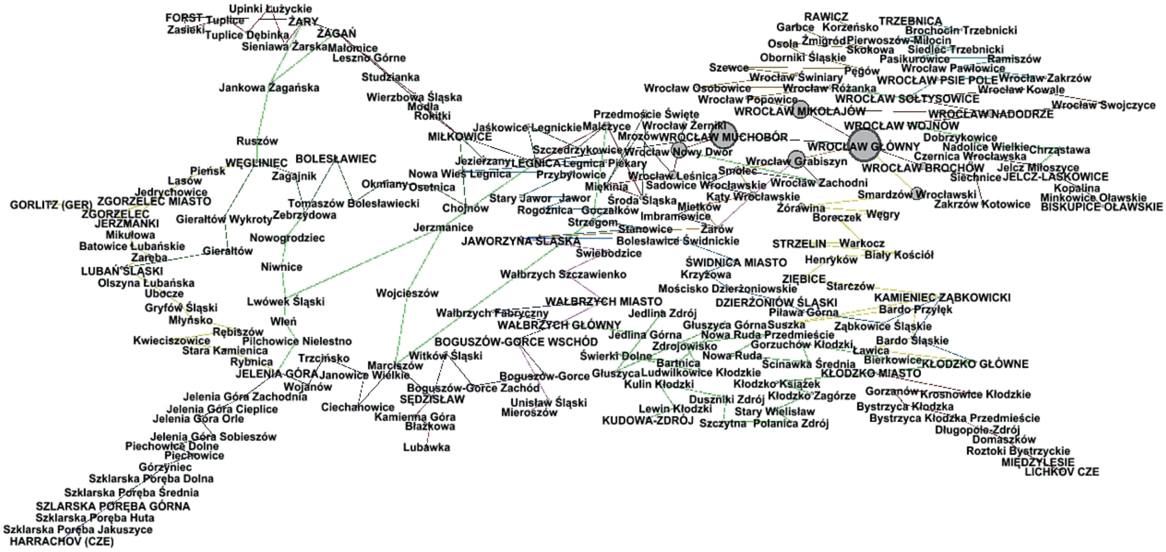

Fig. 9. Connections network used by Koleje Dolnośląskie with additional proposed connections

Source: own elaboration based on (Fig. 3 and 4).

Tab. 5. Indicators calculated for particular stops (nodes) of the Koleje Dolnośląskie network with the modification

City (Node)	Normalized degree	Eccentric-ity	Radius	Closeness centrality	Betweenness centrality	Clustering	Eigencen-trality
Wrocław Główny	0.061032864	23	0.04347826	0.11576087	0.391290999	0	1
Wrocław Brochów	0.009389671	24	0.04166667	0.104874446	0.083255824	0	0.145903823
Jelcz Miłoszyce	0.014084507	28	0.03571429	0.076453697	0.053315174	0	0.015025101
Jelcz-Laskowice	0.009389671	29	0.03448276	0.07118984	0.027903269	0	0.010996589
Biskupice Oławskie	0.004694836	32	0.03125	0.058807289	0	0	0.004213444
Wrocław Mikołajów	0.028169014	24	0.04166667	0.106766917	0.222816458	0	0.487666755
Wrocław Różanka	0.014084507	26	0.03846154	0.091612903	0.099089822	0	0.035827756
Rawicz	0.004694836	37	0.02702703	0.046844073	0	0	0.004205025
Wrocław Nadodrze	0.018779343	25	0.04	0.098428835	0.110594384	0	0.172788688
Wrocław Sołtysowice	0.023474178	26	0.03846154	0.091968912	0.117514837	0	0.078817379
Wrocław Psie Pole	0.009389671	27	0.03703704	0.084792994	0.07263708	0	0.021852225
Trzebnica	0.004694836	35	0.02857143	0.051300578	0	0	0.004205025
Wrocław Wojnów	0.009389671	29	0.03448276	0.073727934	0.014671362	0	0.009491183
Strzelin	0.018779343	26	0.03846154	0.081484315	0.091327451	0	0.057918505
Ziębice	0.018779343	29	0.03448276	0.072745902	0.077433962	0	0.064799391
Kamieniec Ząbkowicki	0.028169014	29	0.03448276	0.072572402	0.22369535	0	0.115888142
Kłodzko Główne	0.037558685	31	0.03225806	0.066026038	0.196072395	0.166666667	0.374518125
Kłodzko Miasto	0.037558685	32	0.03125	0.062610229	0.159048631	0	0.415725032
Międzylesie	0.009389671	40	0.025	0.042379626	0.009389671	0	0.00746195
Lichkov (CZE)	0.004694836	41	0.02439024	0.040664376	0	0	0.004205025
Kudowa-Zdrój	0.014084507	41	0.02439024	0.040664376	0	0	0.094983554
Jaworzyna Śląska	0.037558685	21	0.04761905	0.109118852	0.290992003	0	0.205175045
Wrocław Zachodni	0.014084507	24	0.04166667	0.103700097	0.005569894	0.333333333	0.162088441
Świdnica Miasto	0.018779343	23	0.04347826	0.095945946	0.184653459	0	0.073568432
Dzierżoniów Śląski	0.014084507	26	0.03846154	0.081703107	0.167395611	0	0.03120762

Tab. 5. Continued: Indicators calculated for particular stops (nodes) of the Koleje Dolnośląskie network with the modification

City (Node)	Normalized degree	Eccentricity	Radius	Closeness centrality	Betweenness centrality	Clustering	Eigencentrality
Wałbrzych Główny	0.023474178	24	0.04166667	0.081986143	0.086967146	0.166666667	0.05170528
Wałbrzych Miasto	0.018779343	24	0.04166667	0.0863047	0.078660525	0.333333333	0.054814794
Boguszów-Gorce Wschód	0.018779343	25	0.04	0.079924953	0.042734651	0	0.040209956
Malczyce	0.03286385	23	0.04347826	0.115384615	0.197801665	0	0.287913585
Wrocław Nowy Dwór	0.03286385	25	0.04	0.105654762	0.029781542	0.166666667	0.464967642
Wrocław Muchobór	0.037558685	24	0.04166667	0.11525974	0.263636556	0	0.830075071
Strzegom	0.018779343	22	0.04545455	0.113297872	0.261755671	0	0.07783938
Żagań	0.023474178	26	0.03846154	0.102749638	0.20248157	0.166666667	0.103484379
Żary	0.023474178	27	0.03703704	0.09475089	0.055142174	0.166666667	0.068336354
Forst	0.009389671	28	0.03571429	0.086761711	0.018469306	0	0.021419112
Bolesławiec	0.018779343	30	0.03333333	0.079477612	0.004637393	0	0.065067299
Zebrzydowa	0.023474178	29	0.03448276	0.085714286	0.028441881	0	0.073554421
Węgliniec	0.028169014	29	0.03448276	0.08489438	0.135313643	0	0.084645059
Lubań Śląski	0.014084507	32	0.03125	0.07029703	0.042896173	0	0.015429683
Zgorzelec Miasto	0.023474178	33	0.03030303	0.06480073	0.033885909	0.333333333	0.075333652
Zgorzelec	0.023474178	34	0.02941176	0.061154177	0.009389671	0.333333333	0.064591327
Jerzmanki	0.014084507	34	0.02941176	0.061365601	0.009365544	0.333333333	0.040125841
Gorlitz (GER)	0.009389671	35	0.02857143	0.057645467	0	0	0.032498012
Sędzisław	0.014084507	24	0.04166667	0.098611111	0.080241258	0	0.021015194
Marciszów	0.018779343	23	0.04347826	0.106927711	0.157245796	0	0.037049332
Jelenia Góra	0.018779343	28	0.03571429	0.087474333	0.164932364	0	0.021818036
Szlarska Poręba Górna	0.009389671	38	0.02631579	0.048354143	0.027903269	0	0.009127539
Harrachov (CZE)	0.004694836	41	0.02439024	0.042303873	0	0	0.004205025
Dobrzykowice	0.009389671	30	0.03333333	0.069155844	0.006211799	0	0.009294607
Nadolice Wielkie	0.009389671	30	0.03333333	0.068754035	0.005414563	0	0.009614059
Chrząstawa	0.009389671	29	0.03448276	0.072375127	0.012312871	0	0.011062289
Pilchowice Nielestno	0.009389671	28	0.03571429	0.090638298	0.098845473	0	0.013683839
Wleń	0.009389671	27	0.03703704	0.097304705	0.105984525	0	0.013572447
Lwówek Śląski	0.014084507	26	0.03846154	0.105133268	0.14252879	0	0.027273728
Niwnice	0.009389671	27	0.03703704	0.097171533	0.037159916	0	0.014993587
Nowogrodziec	0.009389671	28	0.03571429	0.090754154	0.030441971	0	0.023155518
Jerzmanice	0.014084507	25	0.04	0.111811024	0.152985494	0	0.08618425
Wojcieszów	0.009389671	24	0.04166667	0.108121827	0.033682055	0	0.027143182
Ruszów	0.009389671	28	0.03571429	0.089121339	0.120640242	0	0.031666199
Jankowa Żagańska	0.014084507	27	0.03703704	0.095515695	0.127165136	0.333333333	0.04663749

Source: own study using Gephi software.

Tab. 6. Values of coefficients defining network parameters after modification

Average Clustering Coefficient	Average path length	Diameter	Radius of a network	Average nodes degree
0.066733422	13.63279365	41	21	3.074766355

Source: own study using Gephi software and based on (Tab. 5).

Tab. 7. Values of coefficients determining network parameters before and after the modification

	Average Clustering Coefficient	Average path length	Diameter	Radius of a network	Average nodes degree
Original network	0.071617162	16.704694350032018	48	25	3.03960396
Network after modification	0.066733422	13.63279365	41	21	3.074766355
The effect of modification	Deterioration of the parameter	Improvement of the parameter	Improvement of the parameter	Improvement of the parameter	Improvement of the parameter

Source: own study using Gephi software and based on (Tab. 3 and 5).

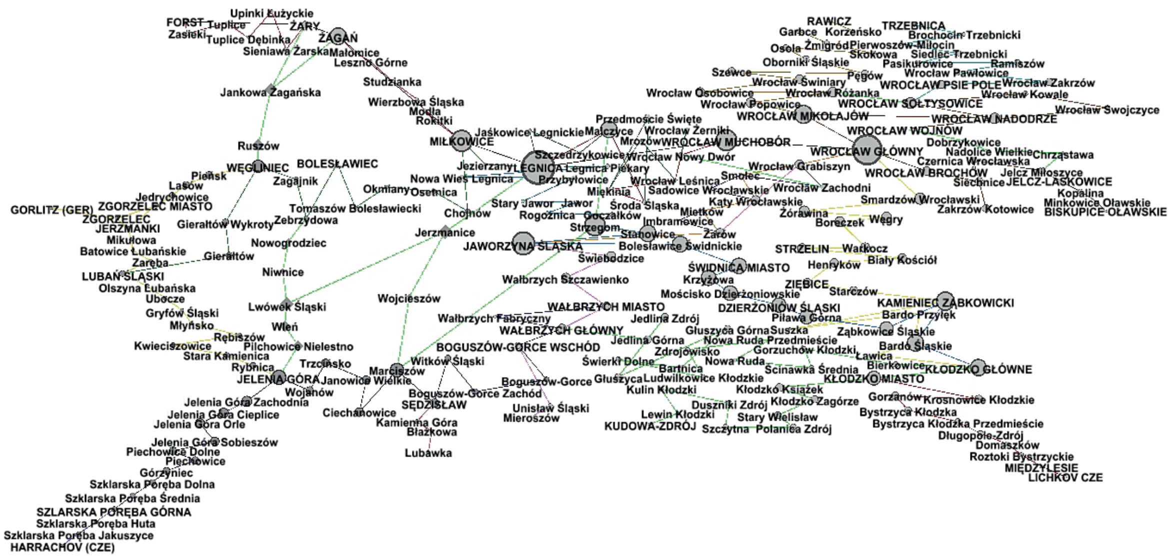

Fig. 10. Connections network used by Koleje Dolnośląskie with additional proposed connections

Source: own study using Gephi software.

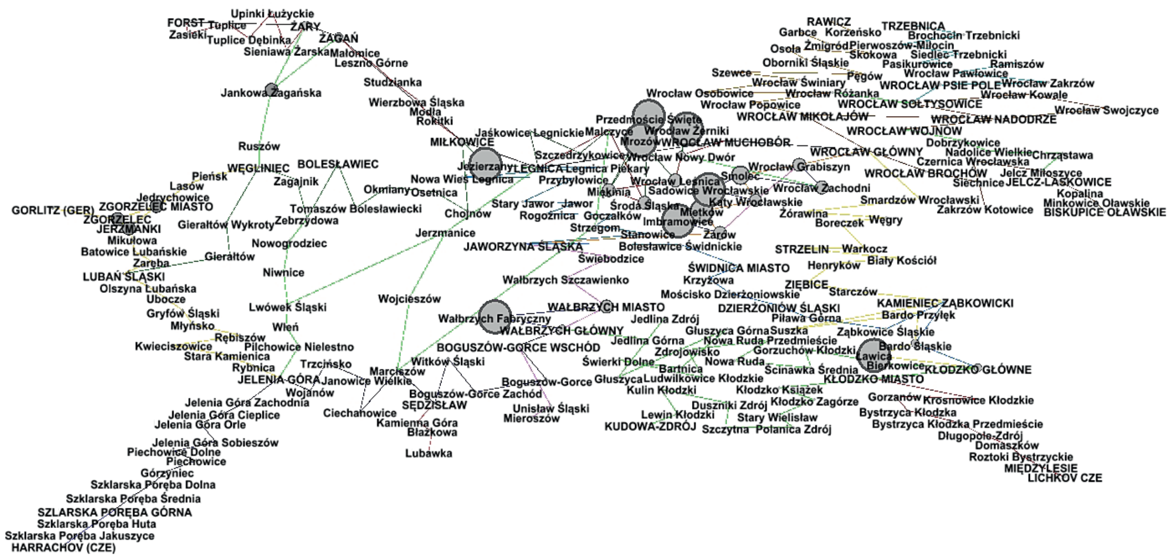

Fig. 11. Clusterisation coefficient for the analysed network after the modification

Source: own study using Gephi software.

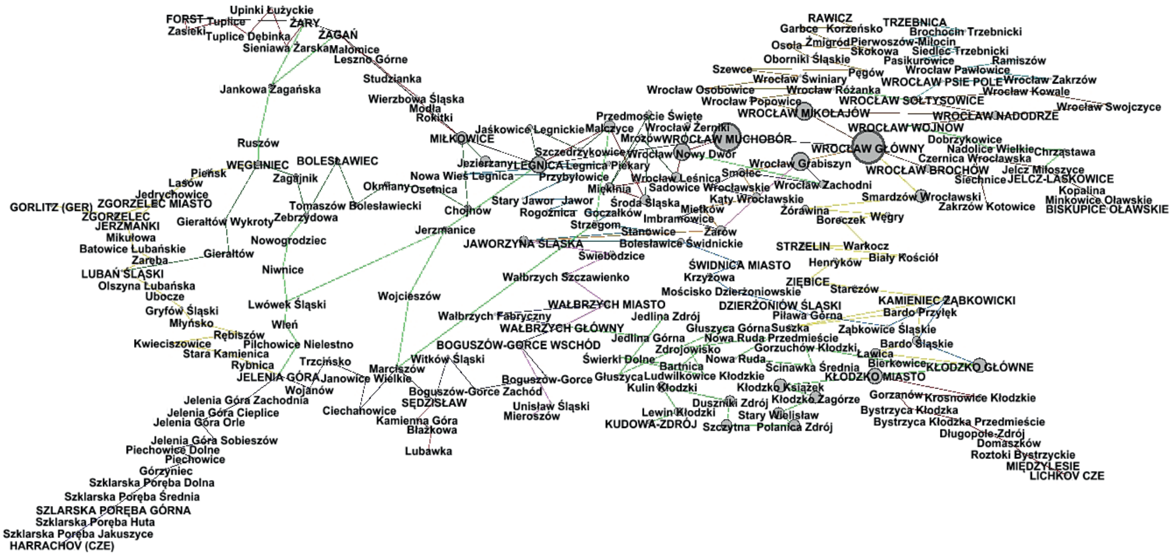

Fig. 12. Eigenvector coefficient for the analysed network after the modification

Source: own study using Gephi software.

value as a smaller number of stations need to be passed on the way from point A to point B. The obtained average nodes degree also indicates the improvement of the network parameters, showing an increase in the average number of nodes to which the node is connected, which means the network of connections has grown and accessibility of the network has increased.

Conclusions

Transport networks are essential elements of the modern economy. Competition in the field of transport services in connection with traveller preferences of transport branches means that maintaining existing customers and acquiring new ones requires carriers to continuously improve their services. One of the elements of competitive advantage may be to improve the structure of the connections network to increase service availability. The analysed carrier Koleje Dolnośląskie has considerably increased the number of passengers carried in recent years; however, efforts should still be made to attract new customers (passengers).

The article proposed to introduce additional connections based on calculation results. They would contribute to the increase in the cross-linking of the connections structure, and this could, in turn, contribute to an increase in the number of travellers. Naturally, before making changes to the connections structure, it is required to analyse and forecasts the real interest of travellers in using the proposed new connections. The analysis can be made using Gephi software, which was used for analyses presented in this article.

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Supply chain management in SMEs: evidence from Poland and Kazakhstan

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ABSTRACT

The research aimed to assess Supply Chain Management (SCM) in small and medium enterprises in Kazakhstan and Poland, and, more specifically, identify similarities and differences in the approach to the SCM concept in selected countries. The research methodology was based on ANOVA analysis comparing samples of contemporary SMEs operating in Poland and Kazakhstan. Primary data was collected using the CAWI quantitative method and then studied using the ANOVA statistical data analysis method. The research results demonstrated similar involvement in the implementation of the concept with significant differences in some areas, such as cost reduction and focus on end customers. The concept of Supply Chain Management is a very common subject of theoretical and practical analysis. Even though research efforts in this area indicate the positive effects of the implemented concept, most of them concern large organisations. The research results showed similar involvement in the implementation of the concept, although significant differences were found in selected areas, such as cost reduction and focus on end customers.

KEY WORDS
ANOVA analysis, small and medium enterprises, supply chain management

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Introduction

Small and medium companies are key to the process of shaping economic growth at the domestic and international levels (OECD, 2009). In today's complex and competitive business environment, adoption of appropriate strategies is particularly important in the SME efforts to survive (Kozubikova et al., 2017; Kljucnikov et al., 2016; Pietrasieński et al., 2015; Bohušová et al., 2017). In this context, the adoption of the concept of Supply Chain Management (SCM) in SME strategies seems to be crucial as supply chain operations cover all actions and activities associated with various processes required for the flow and transformation of raw materials into finished products delivered to the end customer. Naturally, the flow of goods in the supply chain is accompanied by required information. Competition is rapidly moving from the level of enterprises to that of supply chains. Nowadays, customers not only expect companies to supply better and cheaper products using faster and more flexible shipments but also higher-level services (Kovács et al., 2016; Liberko et al., 2015). An initial analysis allowed to elaborate the research aim, namely, to assess Supply Chain Management in small and medium enterprises operating in Kazakhstan and Poland, and, more specifically, identify similarities and differences in the approach to the SCM concept in selected countries.

1. Literature review

A literature review in the context of Supply Chain Management indicated a significant disparity in the number of studies dedicated to small and medium enterprises. Among the existing studies in this area, no comprehensive and cross-sectional contributions were available, while research was fragmented and focused on small research samples.

A greater part of research on Supply Chain Management was dedicated to a relationship between SMEs and their performance in analysed countries. It has been shown that the lack of effective SCM implementation through the use of technology and systems results in a loss of SME competitiveness. The focus on strategic supply chain performance can improve the operational efficiency of the SME sector leading to a competitive advantage. Some authors maintain that Supply Chain Management is unsuitable for the SME sector (Arend et al., 2005) as in practice, it leads to poorer business performance and less return on investment. Foreign investments are driving the local economy through the influence of the local SME sector and the application of an appropriate policy for their development (Thompson & Zang, 2015). Improving the growth of SME innovations in the market requires simultaneously effective implementation of information and communication technologies (ICT) (Jones, 2011). The Polish SME sector generally includes family enterprises (Koładkiewicz, 2013).

Several authors of studies connected with this subject (Thakkar et al., 2008; Thakkar et al., 2011; Tvaronavičienė, 2015) note that some SMEs see SCM benefits, such as collaboration leading to a focus on value-generating activities or a more transparent strategy development and cooperation of supply chain members in the area of competitiveness improvement. Still, a part of the SME sector perceives SCM as a tool to achieve customer satisfaction through significant investments in information technologies.

Issues related to the SME sector are also a subject of interest among researchers in Poland. The growing number of scientific publications on SCM is indicative of the rising popularity of the topic. However, the combination of these two issues, i.e. the role of SMEs in supply chains and supply chain management from the perspective of such entities, is the area yet to be more extensively explored by Polish researchers.

Although some authors use terms "supply chain" and "small and medium businesses" in article titles, the topic fails to be appropriately reflected due to the lack of actual references to SME activities in supply chains.

The role of small and medium enterprises as supply chain links is also recognised by Zowada (2011), who emphasises that every entity can be a link in a chain. He believes that due to certain features (flexibility, ability to adapt to customer requirements, adaptability to changes in the environment, and lower plant costs) they can achieve strong positions within chains, though in most cases, it will not be the role of the chain leader.

The most comprehensive position on Supply Chain Management from the point of view of SMEs seems to be provided in the publication entitled *Functioning of small and medium manufacturing companies in a supply chain* (Kisperska-Moron et al., 2010). It provides reflections on various aspects of SMEs functioning as members of a supply chain.

Wright (2013) conducted a study on SCM strategies showing a link between a supply chain strategy and a product type and an inconclusive alignment's effect on performance. The assessment of a supply chain strategy and a product type, as well as a role in the supply chain, is challenging. Even though a systematic approach is used, it is difficult to evaluate these aspects based on secondary data. Factors determining a supply chain strategy indicate that manufacturing companies in Romania align their strategy based on the type of a product.

For Kazakhstan, as the leading economy in Central Asia, the SCM issue is significant and rather unexplored especially in connection to SMEs. Historically, Kazakh people were nomads. So, logistics and transportation issues have been urgent since the beginning of the state formation. However, the development of SCM started with Kazakhstan becoming a part of the USSR. This economic period was characteristic of the establishment of big economic clusters, including production enterprises and developed centralised management. Several local researchers of the post-Soviet period studied and made significant contributions to the field of logistics and supply chain management, including Anikin (2010), Dybskaya (2013), Sergeyev (2001) and Sterligova (2014).

Romanko and Musabekova classify the development of logistics and supply change management into five main periods (Romanko & Musabekova, 2014). In the Period of Fragmentation (1920-1950), the key concept and principles of logistics formed. Theoretical and practical aspects of logistics developed during the Period of Formation (1950-1970). The Period of Development (1970-1980) explored new ways of cost reduction and distribution. Finally, all logistic elements were organised into one supply management chain system during the Period of Integration (1980-1990). In the 2000s, Kazakhstan experienced a big jump in the development of SCM in the context of SME development. Moreover, some contemporary Russian researches underline a clear relationship between the SCM development and the country's competitiveness (Kurganov, 2013).

Meanwhile, a more detailed consideration of SCM from the point of view of SMEs has been made since creating the Eurasian Union between Kazakhstan, the Russian Federation and Belarus. The contemporary Kazakhstani authors also support the idea and consider that an efficient system of logistics is an important factor for stable economic growth in a state, specifically focusing on the development factors under the conditions of economic instability (Zhussupova et al., 2018).

Rational use of national transport and logistics capabilities stimulates a rapid development of related industries and economic sectors. Under conditions of the globalising world and economy, and expanding integration processes, including the introduction of the Eurasian Economic Union, Kazakhstan is implementing an ambitious strategic goal of building a competitive economy. In this context, an efficient transport and logistics system has a key role in achieving the goal as it must provide high and efficient transport connectivity in the country as well as the necessary level of integration of Kazakhstan into the global transport and logistics network (Yergaliyeva & Raimbekova, 2016).

Finally, initiated by China and including more than 70 countries of Asia and Europe, the New Silk Road logistics project of the "One Belt, One Road" (OBOR) initiative is an additional important factor that proves the urgency and significance of the detailed consideration of various SCM approaches used in different countries, including Kazakhstan, Poland and Romania.

Despite many cited studies on SCM in the SME sector, there is a clear insufficiency in the knowledge regarding the relationship between SCM and the functioning of SMEs, which seems to be an important issue for research analysts and management practitioners. Equally important is the analysis of the factors supporting and hampering the implementation of SCM in large enterprises and, above all, SMEs. So far, there has been a lack of studies demonstrating SCM implementation by SMEs on the level of success achieved by large companies.

2. Research methods

The CAWI quantitative method was used for primary data collection required for the implementation of the designated research goal. The research was carried out in the first quarter of 2018 among randomly selected SMEs operating in Poland and Kazakhstan. Study participants were provided with a link to an online survey (CAWI), which was used for the collection of information.

The survey was divided into the part identifying the respondents and the substantive part concerning Supply Chain Management (SCM). A five-level Likert scale was used to evaluate the SCM concept, which measured the average level of the evaluation of factors in the following SCM areas. In Poland, the SME sector consists of 2 million companies. For this population, the size of the research sample was set at 211 entities. The maximum error for this sample was 6% for a confidence index of 95%. The obtained results, therefore, allowed for the dissemination of results on the entire population with an estimated error of 6%.

The purpose of the research was to assess supply chain management in small and medium enterprises operating in Kazakhstan and Poland, and, more specifically, to identify similarities and differences in the approach to the SCM concept in the named countries. The sample size was identical for each surveyed country (211 SMEs), and the sample structure was chosen randomly.

The majority of the surveyed Polish companies were small, but in the case of Kazakhstan, they were medium. As previous studies demonstrated no correlation between the size of a research participant and the evaluation given to elements of the SCM concept, it was assumed that the difference between the structures of the two countries would not influence the results of further analyses. Next, a distinction was made between the duration that companies had been operating on the market.

The survey was dominated by Kazakhstani companies with 3 to 15 years of presence in the market and Polish companies with more than 15 years of operation. These groups accounted for more than 50% of the surveyed entities. Sectors of services, retail and wholesale (16% in total) were predominant in the case of Polish companies, while the Kazakhstani companies mainly operated in fields of logistics and transport, services, and construction and construction materials (60% in total).

The evaluation focused on the application of the SCM concept in SMEs operating in Poland and Kazakhstan. The main part of the research was dedicated to the assessment of the approach to supply chain management in small and medium enterprises of Poland and Romania. The research aimed to evaluate differences in individual SCM areas depending on an SME country of operation.

The main hypothesis (H0) was formulated as follows: no essential differences in evaluation levels were found depending on the country of SME operation in neither of the areas (i.e., the area of SCM determinants, factors supporting the area, barriers in the Supply Chain Management area, business elements in the Supply Chain Management area, operation of the company within the supply chain area, environmental sustainability elements in the Supply Chain Management area, social aspects of sustainability in the Supply Chain Management area).

Aiming to verify the main hypothesis, statistical testing in each SCM area with the application of single-agent ANOVA analysis was conducted, which identified important differences between averages of evaluations given by respondents.

3. Research results

Preceding ANOVA analysis, Cronbach's alpha was used to check the reliability of the five-point scale used for survey questions. The overall result for all questions is presented in Tab. 1.

The obtained report indicates that Cronbach's alpha is very high (α = 0.913), which means high

Tab. 1. Reliability statistics for the scale used in the survey

Cronbach's α	Cronbach's α based on the standardised items	Items average	Items number
0.913	0.911	3.866	60

consistency or reliability of the scale of grades proposed for each question (60 items). Therefore, it should be considered that the given scale is a reliable measurement tool.

The evaluation concerned seven SCM areas. Observations were presented in individual tables and graphs. Primarily, the analysis focused on seven elements particular to the area of SCM determinants (Tab. 2).

Based on the F test, which accepted the statistically significant value for four factors of SCM determinants with the value $p < 0.001$ (SCM D_1, SCM D_2, SCM D_3 and SCM D_7), the alternative hypothesis regarding the essential differences between averages in the evaluation of these factors had to be adopted. SMEs gave different assessment levels to SCM determinants, i.e. global competitiveness against our supply chain, end customer needs, integration of processes within the supply chain, and internal cross-functional cooperation in the country of operation. Average evaluations of crucial factors were used to check the level of these differences in every table within the ANOVA analysis for individual SCM areas.

It was observed that on the average, Polish companies gave higher scores to end customer needs (SCM D_2 – 2.5% more positive compared to Kazakhstani companies) and internal cross-functional cooperation (SCM D_7 – 8% more). On the other hand, Kazakhstani companies gave better assessments to global competitiveness against our supply chain (SCM D_1 – 5% more compared to Polish companies) and integration of processes within the supply chain (SCM D_3 – 9.3% more). End customer needs received the highest assessment on average from both Polish and Kazakhstani companies.

The F test accepted the statistically significant value for four factors supporting the area (SCM) for $p < 0.001$ (FS_2 and FS_5) and $p < 0.05$ (FS_4 and FS_6). Therefore, an alternative hypothesis had to be adopted regarding important differences between evaluation averages of factors supporting the SCM area. In conclusion, SMEs from different countries gave different assessments to the integration of processes amongst members of the supply chain, an organisational structure designed to promote the cooperation and the coordination of activities, understanding of

Tab. 2. ANOVA analysis results for the area of SCM determinants

SCM determinants	Symbol	Results for groups	DF	Mean square	F	Significance
Global competitiveness against our supply chain	SCM D_1	Among	1	13.322	15.03	0.000
		Within	398	0.886		
End customer needs	SCM D_2	Among	1	15.210	41.91	0.000
		Within	398	0.363		
Integration of processes within the supply chain	SCM D_3	Among	1	8.702	16.57	0.000
		Within	398	0.525		
Members of the supply chain cooperation	SCM D_4	Among	1	0.902	1.88	0.171
		Within	398	0.479		
Costs reduction	SCM D_5	Among	1	0.090	0.19	0.661
		Within	398	0.468		
Improving processes and productivity	SCM D_6	Among	1	1.563	3.43	0.064
		Within	398	0.454		
Internal cross-functional cooperation	SCM D_7	Among	1	9.302	14.83	0.000
		Within	398	0.627		

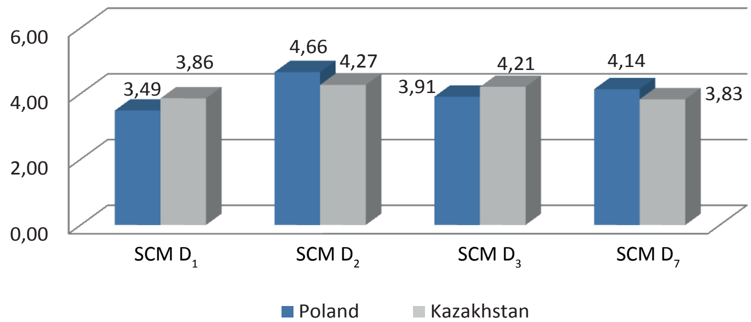

Fig. 1. Average assessment level given to significant factors in the area of SCM determinants in the studied groups

the SCM concept and support from the managers, and trust and openness amongst members of the supply chain.

It is apparent that on the average, Polish companies gave higher scores to an organisational structure designed to promote the cooperation and the coordination of activities (FS_5 – 12.3% more positive compared to Kazakhstani companies), and trust and openness amongst members of the supply chain (FS_6 – 3% more). On the other hand, Kazakhstani companies gave higher scores to the integration of processes amongst members of the supply chain (FS_2 – 6% more positive compared to Polish companies) and the understanding of the SCM concept and support from the managers (FS_4 – 5% more). On the average, Kazakhstani companies gave the highest assessments to the understanding of the SCM concept and support from the managers. In the case of Polish companies, the highest scores were given to trust and openness amongst members of the supply chain.

The F test accepted the statistically significant value for six factors of barriers to Supply Chain Management for $p < 0.001$ (B_3, B_6 and B_7) and $p < 0.05$ (B_1, B_4 and B_5). Therefore, an alternative hypothesis had to be adopted regarding important differences between evaluation averages received for factors relating to barriers in Supply Chain Management. This means that SMEs from different countries gave different assessments to organisational structure hampering the information exchange, laws and provisions hampering relations in SCM, some members of the supply chain not supporting the SCM concept, the lack of understanding of SCM goals and ideas amongst employees, problems with the quality of activities caused by members of the supply chain, communication problems and confidential data.

As observed, Polish companies gave higher average scores to one factor only, which is an organisational structure hampering the information exchange (B_3 – 10.2% more positive compared to Kazakhstani companies). On the other hand, Kazakhstani companies gave higher average scores to the majority of factors concerning SCM barriers, including the lack of understanding of SCM goals and ideas amongst employees (B_1 – 6% more positive compared to Polish companies), quality problems caused by members of

Tab. 3. ANOVA analysis results for factors supporting the area (SCM)

Factors supporting the area (SCM)	Symbol	Results for groups	df	Mean square	F	Significance
Information technology	FS_1	Among	1	0.090	0.20	0.652
		Within	398	0.443		
Integration of processes amongst members of the supply chain	FS_2	Among	1	6.760	14.64	0.000
		Within	398	0.462		
Concentration on end customers	FS_3	Among	1	0.022	0.05	0.809
		Within	398	0.383		
Understanding the SCM concept and support from the managers	FS_4	Among	1	3.240	5.73	0.017
		Within	398	0.565		
An organisational structure designed to promote the cooperation and the coordination of activities	FS_5	Among	1	16.000	27.36	0.000
		Within	398	0.585		
Trust and openness amongst members of the supply chain	FS_6	Among	1	2.890	5.87	0.016
		Within	398	0.492		
Readiness to share the knowledge	FS_7	Among	1	1.440	2.44	0.119
		Within	398	0.590		

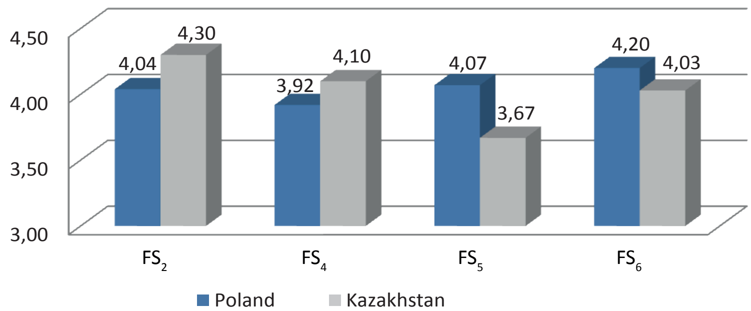

Fig. 2. Average evaluation level given to crucial factors of the factors supporting the area (SCM) in the examined groups

the supply chain (B_4 – 5% more), communication problems and confidential data (B_5 – 5% more), laws and provisions hampering relations in SCM (B_6 –12.2% more), and some members of the supply chain not supporting the SCM concept (B_7 – 15% more). On the average, Kazakhstani companies gave the highest score to laws and provisions hampering relations in SCM, while Polish companies underlined quality problems caused by members of the supply chain.

The F test accepted the statistically significant value for eight factors relating to the SME area of business elements for $p < 0.001$ (BE_1, BE_{10}) and $p < 0.05$ (BE_2, BE_4, BE_6, BE_9, BE_{12} and BE_{13}). Therefore, an alternative hypothesis had to be adopted regarding important differences between average evaluations of these elements. This means that SMEs from different countries gave different assessments to cooperation in inventory and logistics management, use of information technologies to increase the efficiency of communication, common clear vision of Supply Chain Management, exchange of production information on a regular basis, alignment of product strategies, supply, and distribution, and making a supply chain strategy, sharing information regarding customer requirements and design plans, common procedures to provide feedback from a customer involved in product development, and members of the supply chain using sustainability concepts in the supply chain strategy.

As observed, Polish companies gave higher average scores to the majority of crucial factors, including cooperation in inventory and logistics management (BE_1 – 20% more positive compared to Kazakhstani companies), use of information technologies to increase the efficiency of communication (BE_2 – 4.5% more), common clear vision of Supply Chain Management (BE_4 – 9.3% more), exchange of production information on a regular basis (BE_6 – 9.5% more), alignment of product strategies, supply, and distribution, and making a supply chain strategy (BE_9 – 10% more), sharing information about customer require-

Tab. 4. ANOVA analysis results for barriers in the SCM area

Barriers to Supply Chain Management	Symbol	Results for groups	DF	Mean square	F	Significance
Lack of understanding of SCM goals and ideas amongst employees	B_1	Among	1	5.063	9.02	0.003
		Within	398	0.561		
Resistance of employees before implementing changes connected with SCM	B_2	Among	1	0.250	0.30	0.582
		Within	398	0.823		
Organisational structure hampering the information exchange	B_3	Among	1	10.562	17.58	0.000
		Within	398	0.601		
Quality problems caused by members of the supply chain	B_4	Among	1	3.610	7.09	0.008
		Within	398	0.508		
Communication problems and confidential data	B_5	Among	1	3.423	6.25	0.013
		Within	398	0.547		
Laws and provisions hampering relations in SCM	B_6	Among	1	25.000	38.36	0.000
		Within	398	0.652		
Some members of the supply chain do not support the SCM concept	B_7	Among	1	42.903	65.16	0.000
		Within	398	0.658		

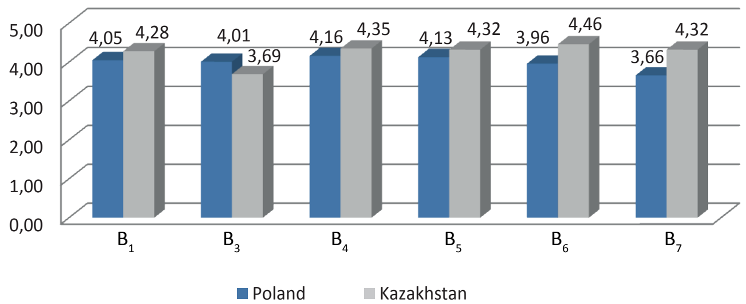

Fig. 3. Average level of the evaluation given to crucial factors related to carriers in the SCM area in the examined groups

ments and design plans (BE_{10} – 17.7% more), and members of the supply chain using sustainability concepts in the supply chain strategy (BE_{13} – 6.2% more). On the other hand, Kazakhstani companies gave higher average scores to common procedures to provide feedback from a customer involved in product development (BE_{12} – 6% more). On the average, the highest assessment by Polish companies was given to the use of information technologies to increase the efficiency of communication, while in the case of Kazakhstani companies, the emphasis was on common procedures to provide feedback from a customer involved in product development.

The value of the F test accepted the statistically significant value for five factors related to the operation of the company within the supply chain for $p < 0.001$ (OC_4) and $p < 0.05$ (OC_1, OC_3, OC_5 and OC_7). Therefore, an alternative hypothesis had to be adopted regarding important differences between evaluation averages given to factors in the SCM area in relation to the operation of the company within the supply chain. This means that SMEs from different countries gave different assessments to lower logistics costs: the ability to receive lower total logistics costs through effective collaboration in the supply chain and increased efficiency of activities; shortened lead time: the ability to reduce lead time from receipt of an order to delivery to a customer; shorter delivery time: the ability to adjust the delivery time to customer requirements; appropriate quantity on time: the ability to meet specified or scheduled delivery times and ordered quantities of products; and greater customer satisfaction: the extent to which the perceived performance of the business corresponds with customer expectations.

As observed, Polish companies gave higher average assessments to all crucial factors, including lower logistics costs: the ability to receive lower total logistics costs through effective collaboration in the supply chain and increased efficiency of activities (OC_1 – 2% more positive compared to Kazakhstani companies); shortened lead time: the ability to reduce lead time from receipt of an order to delivery to a customer (OC_3 – 3% more); shorter delivery time: the ability to

Tab. 5. ANOVA analysis results for business elements in the SCM area

Business elements in Supply Chain Management	Symbol	Results for groups	DF	Mean square	F	Significance
Cooperation in inventory and logistics management	BE_1	Among	1	52.563	60.06	0.000
		Within	398	0.875		
Use of information technologies to increase the efficiency of communication	BE_2	Among	1	7.290	10.13	0.002
		Within	398	0.719		
Building long-term relationships based on established guidelines	BE_3	Among	1	0.250	0.39	0.531
		Within	398	0.637		
Common clear vision of Supply Chain Management	BE_4	Among	1	6.503	8.77	0.003
		Within	398	0.741		
Use of Just-in-Time concept as a tool for enhancing competitiveness	BE_5	Among	1	1.823	1.90	0.168
		Within	398	0.955		
Exchange of production information on a regular basis, e.g. through sales and operational planning meetings	BE_6	Among	1	10.240	10.98	0.001
		Within	398	0.932		
Common introduction of benchmarking and performance metrics	BE_7	Among	1	0.422	0.38	0.535
		Within	398	1.095		
Standardisation of quality policy for both products and processes with established guidelines	BE_8	Among	1	2.103	2.43	0.120
		Within	398	0.865		
Alignment of product strategies, supply and distribution, and making a supply chain strategy	BE_9	Among	1	9.610	11.86	0.001
		Within	398	0.810		
Sharing information regarding customer requirements and design plans	BE_{10}	Among	1	46.923	59.25	0.000
		Within	398	0.792		
Use of the supply chain concept to design products, processes and packaging	BE_{11}	Among	1	0.002	0.01	0.960
		Within	398	1.018		
Common procedures to provide feedback from a customer involved in product development	BE_{12}	Among	1	5.760	7.77	0.006
		Within	398	0.741		
Members of our supply chain use sustainability concepts in the supply chain strategy	BE_{13}	Among	1	3.240	3.95	0.048
		Within	398	0.820		

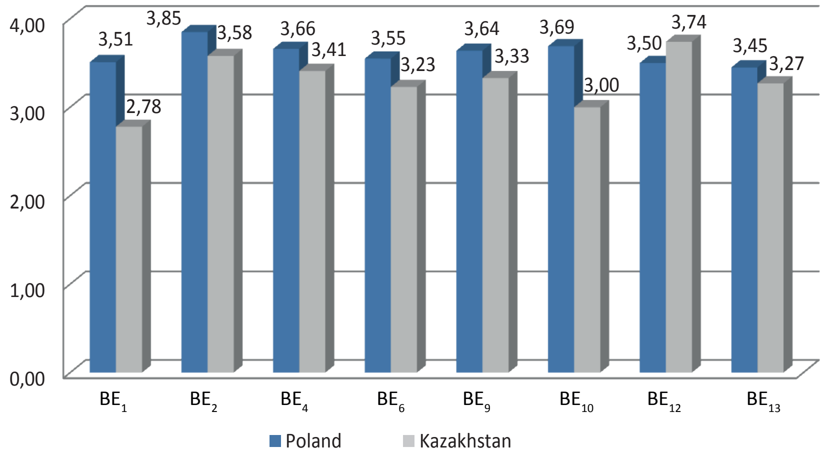

Fig. 4. Average evaluation level given to crucial factors related to business elements in the SCM area in the examined groups

Tab. 6. ANOVA analysis results for the operation of the company within the supply chain area

Operation of the company within the supply chain	Symbol	Results for groups	DF	Mean square	F	Significance
Lower logistics costs: the ability to receive lower total logistics costs through effective collaboration in the supply chain and increased efficiency of activities	OC_1	Among	1	3.240	6.90	0.009
		Within	398	0.469		
Lower total costs of products: product competitiveness due to a lower total cost of a unit	OC_2	Among	1	0.563	0.80	0.371
		Within	398	0.702		
Shortened lead time: the ability to reduce lead time from receipt of an order to delivery to a customer	OC_3	Among	1	4.623	6.84	0.009
		Within	398	0.676		
Shorter delivery time: the ability to adjust the delivery time to customer requirements	OC_4	Among	1	14.063	19.45	0.000
		Within	398	0.723		
Appropriate quantity on time: the ability to meet specified or scheduled delivery times and ordered quantities of products	OC_5	Among	1	7.840	11.05	0.001
		Within	398	0.709		
Higher inventory turnover ratio: value ratio of sold goods to the average value of inventory over a given period	OC_6	Among	1	0.123	0.22	0.635
		Within	398	0.543		
Greater customer satisfaction: the extent to which the perceived performance of the business corresponds with customer expectations	OC_7	Among	1	5.760	10.45	0.001
		Within	398	0.551		
Higher market share: the share of the company in the whole market on which it operates, environmental sustainability elements in Supply Chain Management	OC_8	Among	1	1.823	2.86	0.091
		Within	398	0.636		

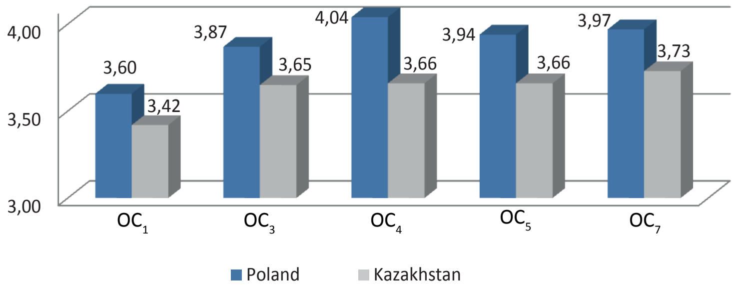

Fig. 5. Average evaluation level given to crucial factors related to the operation of the company within the supply chain area in the examined groups

adjust the delivery time to customer requirements (OC_4 – 6% more); appropriate quantity on time: the ability to meet specified or scheduled delivery times and ordered quantities of products (OC_5 – 5% more); and greater customer satisfaction: the extent to which the perceived performance of the business corresponds with customer expectations (OC_7 – 5.5% more). On the average, the highest scores were given by Polish companies to shorter delivery time: the ability to adjust the delivery time to customer requirements, while in the case of Kazakhstani companies, the focus was on the higher market share: the share of the company in the whole market on which it operates.

The value of the F test accepted the statistically significant value for six factors related to environmental sustainability elements in Supply Chain Management for $p < 0.001$ (ES_5 and ES_7) and $p < 0.05$ (ES_2, ES_4, ES_6, ES_8). Therefore, an alternative hypothesis had to be adopted regarding differences between evaluation averages given to factors in the SCM area in relation to environmental sustainability elements in Supply Chain Management. This means that SMEs from different countries gave different assessments to active involvement in the reduction of waste, the use of renewable sources in production, the reuse of materials, recycling of defective and waste products, choosing of partners in the supply chain on the basis

Tab. 7. ANOVA analysis results for environmental sustainability elements in the Supply Chain Management area

Environmental sustainability elements in Supply Chain Management	Symbol	Results for groups	DF	Mean square	F	Significance
Environmentally-friendly production processes	ES_1	Among	1	1.690	1.84	0.176
		Within	398	0.918		
Active involvement in the reduction of waste	ES_2	Among	1	7.562	10.68	0.001
		Within	398	0.708		
Engaging in production processes free from the emission of harmful substances	ES_3	Among	1	3.062	3.71	0.055
		Within	398	0.824		
Use of renewable sources in production	ES_4	Among	1	9.303	10.39	0.001
		Within	398	0.895		
Reuse of materials	ES_5	Among	1	31.360	29.41	0.000
		Within	398	1.066		
Recycling of defective and waste products	ES_6	Among	1	4.623	4.03	0.045
		Within	398	1.145		
Choosing partners in the supply chain on the basis of environmental guidelines	ES_7	Among	1	12.250	12.57	0.000
		Within	398	0.974		
Involving workers in environment protection schemes	ES_8	Among	1	5.063	4.93	0.027
		Within	398	1.025		

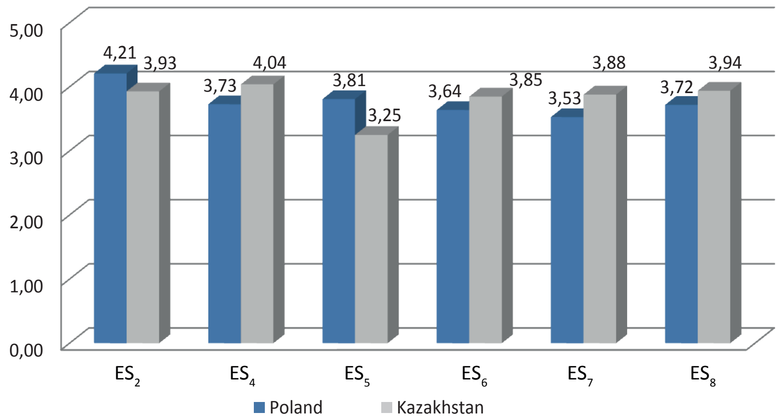

Fig. 6. Average evaluation level given to crucial factors related to environmental sustainability elements in the SCM area for the examined groups

of environmental guidelines and involving workers in environment protection schemes.

As observed, on the average, Polish companies gave higher assessments to two factors, namely, active involvement in the reduction of waste (ES_2 – 5% more positive compared to Kazakhstani companies) and the reuse of materials (ES_5 – 16.5% more). On the other hand, Kazakhstani companies gave the highest scores to the use of renewable sources in production (ES_4 – 7% more), recycling of defective and waste products (ES_6 – 3% more), choosing partners in the supply chain on the basis of environmental guidelines (ES_7 – 7.5% more), and involving workers in environment protection schemes (ES_8 – 5% more). On the average, Polish companies gave the highest scores to active involvement in the reduction of waste, while in the case of Kazakhstani companies, the focus was mainly on the use of renewable sources in production.

The value of the F test accepted the statistically significant value for nine factors related to social aspects of sustainability in Supply Chain Management for $p < 0.001$ (SA_1, SA_4, SA_5, SA_6, SA_7, SA_8, SA_9, SA_{10}) and $p < 0.05$ (SA_2). Therefore, an alternative hypothesis had to be adopted regarding essential differences between evaluation averages given to factors in the SCM area in relation to social aspects of sustainability in Supply Chain Management. This means that SMEs from different countries gave different assessments to applying the code of ethical conduct to employees and contractors, applying fair employment practices in the local community, investments

Tab. 8. ANOVA analysis results for social aspects of sustainability in the SCM area

Social aspects of sustainability in Supply Chain Management	Symbol	Results for groups	DF	Mean square	F	Significance
Applying the code of ethical conduct to employees and contractors	SA_1	Among	1	37.210	69.41	0.000
		Within	398	0.536		
Applying fair employment practices in the local community	SA_2	Among	1	5.760	10.66	0.001
		Within	398	0.540		
Providing health and safety equipment	SA_3	Among	1	0.063	0.16	0.686
		Within	398	0.381		
Investments in infrastructural facilities	SA_4	Among	1	9.000	14.49	0.000
		Within	398	0.621		
Timely and lawful payment of taxes and fees	SA_5	Among	1	6.502	14.92	0.000
		Within	398	0.436		
Clearance of taxable income	SA_6	Among	1	17.640	36.36	0.000
		Within	398	0.485		
Applying ethical business and trade standards	SA_7	Among	1	19.360	46.56	0.000
		Within	398	0.416		
Investments in poverty reduction programmes	SA_8	Among	1	42.903	53.93	0.000
		Within	398	0.795		
Contribution to local community charities	SA_9	Among	1	74.823	91.43	0.000
		Within	398	0.818		
Contribution to regional and supra-regional development initiatives	SA_{10}	Among	1	75.690	87.55	0.000
		Within	398	0.864		

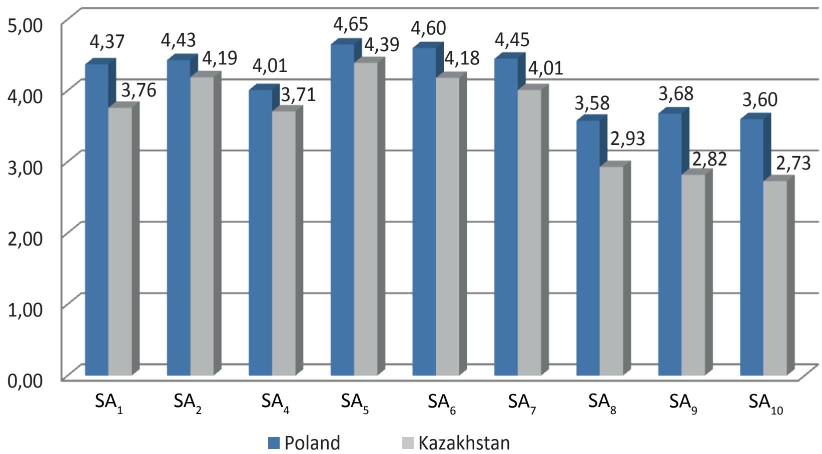

Fig. 7. Average evaluation level given to crucial factors in relation to social aspects of sustainability in SCM area for the examined groups

in infrastructural facilities, timely and lawful payment of taxes and fees, clearance of taxable income, applying ethical business and trade standards, investments in poverty reduction programs, contribution to local community charities, and contribution to regional and supra-regional development initiatives.

As observed, on the average, Polish companies gave higher scores to all crucial factors, including applying the code of ethical conduct to employees and contractors (SA_1 – 13% more positive compared to Kazakhstani companies), applying fair employment practices in the local community (SA_2 – 5% more), investments in infrastructural facilities (SA_4 – 8% more), timely and lawful payment of taxes and fees (SA_5 – 5% more), clearance of taxable income (SA_6 – 6% more), applying ethical business and trade standards (SA_7 – 8.5% more), investments in poverty reduction programs (SA_8 – 12% more), contribution to local community charities (SA_9 – 20.5% more), and contribution to regional and supra-regional development initiatives (SA_{10} – 22.5% more). Both Polish and Kazakhstani companies gave the highest scores to timely and lawful payment of taxes and fees.

4. Discussion of the results

Making a progress report from individual SCM areas, it is possible to observe important differences in the average evaluation of the vast majority of its individual elements, which attest results accumulated in Tab. 9.

At least a half of elements from every SCM area demonstrated important differences in the perception depending on the country of operation. Therefore, the main zero research hypothesis should be rejected. Polish SMEs have a different view of the SCM strategy in their country. The majority of country-dependent differences were observed in relation to barrier elements and social aspects of sustainability in SCM areas.

Amongst the identified elements, which differed depending on the country, the most important ones were chosen for the Polish and Kazakhstani SMEs. SMEs operating in Kazakhstan and Poland recognised end customer needs as the most important SCM determinant in terms of practice; however, Polish companies gave more weight to this factor. The most important factor facilitating the SCM implementation in Kazakhstani companies was the integration of processes amongst members of the supply chain, while in the case of Polish companies, it was trust and openness amongst members of the supply chain. The greatest concerns in relation to the SCM implementation in Kazakhstan were laws and provisions hampering relations in SCM; meanwhile, in Poland, the issues were mostly related to quality problems caused by members of the supply chain. Kazakhstani companies underlined common procedures to provide feedback from a customer involved in product development as the most important business element of the sustainable development in SCM. In this respect, Polish companies chose the use of information technologies to increase the efficiency of communication. Comparing companies to their chief competitors and with reference to the possibility of basing a supply chain on an end customer requirement, Kazakhstani companies were superior in evaluating customer satisfaction: the extent to which the perceived performance of the business corresponds with customer expectations. Polish companies believed that compared to their competitors, they had shorter delivery time: the ability to adjust the delivery time to customer requirements. The most important element of the sustainable development in SCM in Kazakhstan was the use of renewable sources in production, while Polish companies emphasised active involvement in the reduction of waste. The most important social element of sustainable development for companies operating in Kazakhstan as well as Poland was timely and lawful payment of taxes and fees.

While most assessed areas were considered important, the operation of a company within the supply chain generally received the lowest average scores from both countries. It was also the area that had the larger differences between average evaluations given from companies of the explored countries. The smallest differences between average evaluations of individual countries were received in the case of environmental sustainability elements in the SCM area.

The analysis of the main components for the seven SCM areas allowed a significant reduction in the number of variables to approximately a dozen factors that were supposed to explain the variance of the results for the whole studied phenomenon. Preliminary observations indicated that the main reasons for the SCM implementation were the desire to increase the efficiency of processes and meet the needs of end customers. The latter was also a key factor supporting the SCM implementation. At the same time,

Tab. 9. Number of significant differences in the assessment of SCM areas

SCM area	Total number of elements in the area	Number of elements for which $p < 0.05$	Alternative hypothesis
SCM determinants	7	4	support
Factors supporting the area (SCM)	7	4	support
Barriers to Supply Chain Management	7	6	support
Business elements in Supply Chain Management	13	8	support
Operation of the company within the supply chain	8	5	support
Environmental sustainability elements in Supply Chain Management	8	6	support
Social aspects of sustainability in Supply Chain Management	10	9	support

the biggest barriers were the formal and communicative constraints and the reluctance of employees to change. Practices implemented in the field of information exchange and the formalisation and standardisation of activities resulted in high-level customer service and, thus, increased sales compared to those of competitors. Waste recycling and the use of pro-environmental technologies plaid an important role in sustainable development. Ethical behaviour towards the local society was also very important.

Conclusions

Previous research on SCM in SMEs targeting Romanian and Kazakhstani companies primarily focused on the association between product diversity and topology of the supply chain. SCM is achieved through partnerships with 3PL suppliers/transportation companies and customers. According to some studies, this could be resolved through the expansion of upstream and downstream company activities. Data analysis and interpretation for the logistics services market in Kazakhstan indicated its growth over the last decade, considering the construction of logistics parks that provided multiple facilities and the increase in the quality of transport operations through the appropriate support of the industry. The survey used in this study evaluated the SCM concept in SMEs and measured averages of evaluations given to factors concerning different SCM areas.

The research aimed to assess the differences in the perception of individual SCM areas depending on the country of SME operation. Sample sizes were identical for each surveyed country, and the sample structure was chosen randomly. Although the statistical models used in this study appeared robust, there were limitations concerning the number and choice of industries (more industries may be needed to ensure a representative sample) and the size of companies (the sample represented a wide range of sizes). Even though a systematic approach was used, it was still difficult to evaluate all aspects based on tertiary data. Future research could benefit from a deeper investigation of the present research results.

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Management of changes in business processes: an empirical study in Slovak enterprises

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ABSTRACT
Constant change is typical of the current business environment. The ability to manage change is a highly appreciated managerial skill. Being adaptive has become a new competitive advantage of a company. Appropriately and successfully implemented changes can improve corporate performance. This paper aimed to evaluate how Slovak companies had been dealing with change in recent years; whether they had been prepared for it; what tools, methods and concepts they had used; and what ultimately had necessitated them from an economic point of view. The paper explored the current status of change management in the context of business processes particular to Slovak enterprises. A literature review concerning change and process management was provided in order to design appropriate research. The research focused on the level of process-oriented management of change in Slovak enterprises operating in different industrial sectors. The main research method was primary quantitative research via questionnaires. Outputs from the questionnaires were subsequently evaluated by contingency tables and the chi-square test which determined the level of significance via p-value. Research results presented in this paper confirmed a positive influence of business process change on process maturity and corporate performance. The paper contributed to the development of knowledge in the field of change management, namely, process-oriented change management. The creation of a change-based maturity model for enterprises was identified as a new direction for future work with practical implications.

KEY WORDS
Change Management, corporate performance, business processes

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Introduction

Within a modern enterprise, change is a constant process that can be managed and predicted. Business changes should not respond to changes in the environment, but the changes in the environment should be preceded. A frequency of change increases constantly. Although it is not possible to control all changes, the respective reaction can be managed and controlled. In response to the need of change in the business environment, change management as a managing task becomes one of the crucial operational and strategic conceptions for enterprises that want to achieve sustainable growth and the required level of competitiveness. Change management has been addressed by several authors. One of the most important efforts is by Kotter (2002; 2012) who published several bestsellers on leading change with a focus on leadership as well as psychological and social aspects of change management. From a methodological viewpoint, the change management process has been analysed by Armstrong (2008), Passenheim (2010), Drdla and Rais (2001), Kubickova and Rais (2012), Borovský (2005), Zauskova et al. (2013). The authors presented models consisting of a different number of steps.

However, change is two-faceted. The positive side of change is represented by a new opportunity, a chance for a new competitive advantage. The negative side, however, means a certain degree of uncertainty or, to put it otherwise, risks. Enterprises implement every change aiming to improve the future state of the business. Each case may have different improvement areas, yet the goal remains the same, namely, to sustain the business performance. Many authors agree on several available methods and tools focused on corporate performance measurement and management. Deficiencies of traditional performance management and measurement systems have been resolved through additional methods focused on business processes (Fauzia et al., 2017).

The influence of process management on corporate performance has been observed by Sujová and Marcineková (2014; 2015a; 2015b). It has been found that management of processes affects the level of corporate performance. Therefore, an investigation into change management in the context of business processes is plausible.

The current state of change management in Slovakia should be determined to better understand its development. This paper provides an evaluation of how Slovak companies have been dealing with changes in business processes during recent years; whether they have been prepared for it; what tools, methods and concepts they have used; and what ultimately has necessitated them from an economic point of view. Evaluation of data obtained from primary research of questionnaires by way of statistical methods in pursuit of statistical dependences enabled the verification of a hypothesis that changes in business processes had a positive influence on the profitability and economy in companies.

1. Literature review

Change management is a process aimed at ensuring the readiness of an organisation for change and the development of steps required for the change to be accepted and smooth (Armstrong, 2008). According to Demichela et al. (2017), even approaches to change management usually entail a risk-based decision-making strategy; thus, it is usually not enough to verify whether the modification of the process, equipment, or procedure can increase the prior level of risk and failure. This statement was fundamentally argued by Cao et al. (2003) who described change as a dynamic process encompassing different but interrelated forms of diversity. The Slovak business environment contains diverse change. Consequently, Fricova and Cepelova (2014) indicated change management as one of the most common topics of discussion in Slovakia. The variety of change stems from the uniqueness of every enterprise. As every entity has a distinct set of weaknesses and strengths, change can take different forms and occur in different areas, such as market conditions, process management, technological innovations, workforce demographics and diversity, an increased focus on customer and quality, economic environment, or shortage of talent.

Studies from different authors have shown a low success rate of change processes. According to Beer and Nohria (2000), the percentage of successful change implementation amounts to 30%. Also, the success rate may be significantly influenced by various fail factors that can take down the value of successfully performed changes to no more than 7%. The influence of a fail factor depends on the nature of the business, but the most common fail cases are caused by people and their resistance to organisational change (Kotter, 1995; Lines et al., 2015; Aleksic, Zivkovic & Boskovic, 2015; Božic & Rajh, 2016). Dobrovič and Timková (2017) state that enterprises often face obstacles to change management, such as inadequate planning, the absence of employee training in the respective field, insufficient time to adapt, employee resistance, inappropriate corporate culture lacking in checks and verifications within the change process, which can easily disrupt smooth implementation of change.

According to Sujová, Marcineková and Hittmar (2017), measuring, assessment, control, and further optimisation of internal processes are presumptions of effective change management and sustainable enterprise improvement. Vickery, Dröbe, Markland (1997) and Leong et al. (1990) claim that the growth of an enterprise is determined by a set of priorities that include flexibility. Process flexibility is an ability of an enterprise to rapidly adapt to changes in the product mix, which is one of the main priorities for growing the potential. Several authors name five key dimensions of an effective business process, including costs, delivery efficiency, quality, flexibility and innovation.

However, it is still difficult to manage business processes as basic enablers of an organisation's existence. One of the primary reasons for this complexity arises from the diversity of concepts used under the title of Business Process Management, such as Business Process Reengineering, Process Innovation, and Business Process Automation/Workflow Management (Rosemann et al., 2005). The most common challenges are found in areas of process modelling, process optimisation and business process maturity, which is defined as a state of being complete, perfect and ready, or else characterised as the level of process management.

In their work, Heller and Varney (2013) illustrated the basic levels of the business process maturity and the maturity gap (Fig. 1). Maturity models have five basic levels: initial, defined, organised, managed and optimised.

In the process maturity model, Level One is characterised by non-organised processes, where the output of the process is ensured by the actions and efforts of workers rather than unsecured processes. Enterprises often abandon processes; they are unable to repeat past successes. At Level Two, projects are planned, performed, measured, and controlled. Generally, processes are not extended beyond a department or business unit, and there is often little or no executive support. Level Three means that an organisation utilises processes that are defined, understood and documented through procedures, tools, and methods. Management takes place throughout the whole enterprise and processes are qualitatively predictable, but, generally, there are no enforcement measures. At Level Four, sub-processes contribute to the overall performance. They are controlled using statistical and other quantitative techniques, and performance is both controlled and predictable. At this top maturity level, processes are continually improved based on quantitative measures of common causes of variation in processes.

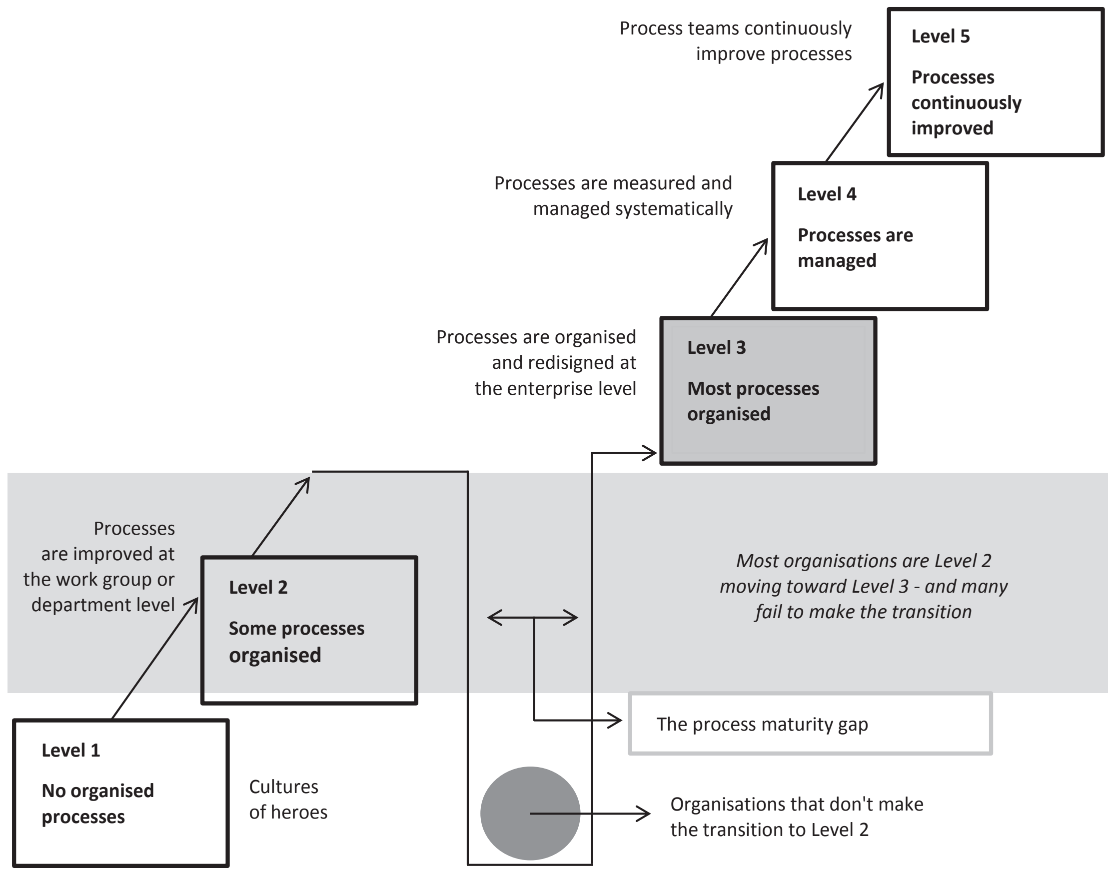

Fig. 1. Process maturity and the maturity gap
Source: (Heller & Varney, 2013).

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An organisation rapidly responds to changes and opportunities, and it openly shares learning and knowledge. Continuous improvement is a part of all employee roles (Heller & Varney, 2013). The maturity level of process optimisation should represent one of the main goals for enterprises, namely, the increase in the performance and the reduction of costs.

Process modelling is a fundamental activity for the understanding and communication of process information, and often a prerequisite for conducting analysis, redesign and automation (Dumas et al., 2013). As such, process models are used for many purposes, including increasing understanding of a process by knowledge workers, executing a process, sharing process information with customers, or for what-if analysis (Pinggera, 2014; Recker et al., 2009). However, in order to successfully serve potential uses, models should be understandable to their audience. Therefore, it is necessary and recommended to model the process and try to find the best solution before implementing any change.

Changes in business processes follow process improvement. According to defined defaults in processes, radical or optimising change can be proposed. Radical changes are represented by Business Process Reengineering defined by Hammer and Champy (2000) as a radical change of business processes in pursuit of dramatic performance improvement. The main principle of reengineering is the identification of outdated rules, methods and processes, and their radical change to new and more effective ones. The second extensive change is restructuration as a transformation change.

Optimisation of processes includes all activities aimed at improving the efficiency. This can be related to the use of the company's production resources with the possibility to accelerate the production process, to efficiently exploit the production potential, to increase revenues, to reduce production costs, and to better control the production process (Rut, 2017). Finding the optimal solution while maintaining the desired product quality level means to reduce important factors in the business process, including material and energy consumption, product development costs and time. Changing variables in process modelling results in a reduction in material inputs, production costs, shape, material properties of a product and a minimised optimisation task value at the end of the process (Sujová, Marcineková & Simanová, 2016). Sujová and Marcineková (2015a) define the best-known concepts and methods for process optimisation as follow: Balanced Scorecard (BSC), Six Sigma, Activity Based Costing (ABC), European Foundation for Quality Management (EFQM), Total Quality Management (TQM), Total Productive Maintenance (TPM), Kaizen, Method 5S, ISO Norms, Benchmarking, and Process controlling.

Many organisations realise the importance of business processes in delivering high-quality products and services (Indulska et al., 2009). Prevention of a decrease in quality during production as well as supportive and operational processes are the main target for achieving operative quality management, and the most commonly used method is measurement and evaluation of the process capability (Simanová & Gejdoš, 2015). Gejdoš and Simanová (2017) believe that fluctuation of the quality mark values is a natural part of the process. Even though it is impossible to achieve its absolute uniformity, it is necessary to monitor this value as systematic causes in the production process can result in the process with variability values so diversified that its performance would be very low, with defects in output, increasing overall costs and unproductive losses. Consequently, the implementation of the process-oriented management of changes can be considered in this area as a complicated, demanding and challenging task.

2. Research methods

The main research method was primary quantitative research conducted using questionnaires. The research focused on the level of process-oriented management of change in Slovak enterprises operating in different industrial sectors. The first database of enterprises comprised the data of the Statistical Office of the Slovak Republic, which was subsequently verified by Internet databases in order to select existing companies. The core sample or the population size (N) of the survey amounted to 2525 enterprises. A representative sample (n) consisted of 524 enterprises, which was also the number of completed questionnaires. According to the calculation of the minimum statistical research sample, it was a representative sample at 99% confidence and 4% of the standard deviation. It should be noted that N represents the population size, r is the fraction of responses, Z(c/100) represents the critical value for the confidence level c.

The questionnaire consists of five general classification questions and 30 business-area management issues. The questionnaire was published online, and the data collection took place in the first half of 2017.

Enterprises were interviewed directly using a structured interview and indirectly via e-mail communication with managers. Answers from the questionnaire were processed and evaluated by way of a chosen statistical method: descriptive statistics, contingent method, and a chi-squared test. A chi-squared statistic was used to calculate a p-value to the chi-squared distribution.

Chi-squared is a Pearson's cumulative test statistic; Oi is an observed frequency, Ei is the expected frequency (theoretical) asserted by the null hypothesis, and n is the number of cells in the table. The outcome p-value helped to confirm or deny the primary hypotheses between the selected questions.

The hypotheses for the evaluation of relationships between selected question pairs were determined as presented in Tab. 1.

3. Research results

This part of the paper presents selected results of the primary research conducted through an online questionnaire. In the first step, data of general classification questions were analysed by descriptive statistical tools. The results presented in Tab. 2 help to improve the understanding of the nature of the representative sample.

According to the first part of Tab. 2, judging by the average number of employees, the sample consisted of small to large enterprises. The largest group in the sample comprised of enterprises with the average number of employees ranging from 0 to 10 with the response frequency of 237, which represented 45.2% of the total sample. In conclusion, the Slovak business environment is dominated by small businesses.

The second part of the table presents the structure of the capital in the analysed enterprises. As data suggest, even though Slovakia has been a part of the EU for ten years, foreign investments are rarely channelled to smaller enterprises that could contribute to the growth of the gross domestic product. It seems that foreign investors are not interested in Slovak small businesses. There are two possible reasons:

- Slovak small enterprises and the related business environment (legislation, competition, availability of qualified workforce etc.);
- limited management skills and appetite for change (missing strategic leadership) leading to the little incentive for change versus strategic behaviour of investors to ignore small enterprises.

The last part of the table analysed the ROE score. From the total number of enterprises that took part in the survey, 91.6% had a positive ROE score in 2015. However, more than 56% of the sample reached ROE up to 4%.

The next part of this paper focuses on the analysis via contingencies and the chi-square test in order to verify the existence of relations between the selected survey questions regarding changes in business processes.

The first cross-table (Tab. 3) provides the analysis and evaluation of questions Q4: "What types of

Tab. 1. Main hypotheses of the research

1	**The relation between the use of new concepts and methods for process improvement and the level of process optimisation (Q6-Q14)** H0: The use of new process management concepts and methods does not influence on the level of optimisation (business process maturity) H1: The use of new process management concepts and methods influences the level of optimisation (business process maturity)
2	**The relation between the use of models for process optimisation and the level of process optimisation (Q6-Q16)** H0: The level of process optimisation does not depend on the use of at least one model for analysis and optimisation of processes H1: The level of process optimisation depends on the use of at least one model for analysis and optimisation of processes
3	**The relation between the achieved ROE value and the level of process optimisation (Q6-QD)** H0: There is no statistical dependence between the individual levels of process optimisation and ROE reached H1: A statistical dependence exists between the individual levels of process optimisation and the reached ROE
4	**The relation between changes made and analysis carried out before the change process (Q11-Q4)** H0: There is no significant dependence between the change type and the performed analyses made before or in its preparation. In other words, specific changes do not require specific analysis before executing H1: A significant dependence exists between the change type and the performed analyses made before or in its preparation. In other words, specific changes do require specific analysis before executing

Tab. 2. Descriptive statistics of the survey (relative and absolute frequencies) from a total of 524 enterprises

Observed frequencies Question A: "What is the average number of employees in your enterprise?"		
0 to 10 employees	45.23%	237
11 to 20 employees	12.40%	65
21 to 50 employees	14.12%	74
51 to 250 employees	15.08%	79
over 250 employees	13.17%	69
Observed frequencies Question C: "What is the ownership of your enterprise?"		
net domestic capital	70.80%	371
the domestic capital prevails	16.41%	86
foreign capital prevails	7.44%	39
net foreign capital	5.34%	28
Observed frequencies Question D: "What was the ROE of your company in 2015?"		
negative value / ROE < 0 /	8.40%	44
positive value – from 0% to 2%	24.24%	127
positive value – from 2% to 4%	24.05%	126
positive value – from 4% to 7%	21.95%	115
positive value – from 7% to 10%	10.31%	54
positive value – over 10%	11.07%	58

Tab. 3. Contingencies Q11-Q4

Contingencies Q11-Q4		Observed	Analysis before the change									
	What types of changes have been made over the past 10 years?		SA	AP	AFF	FA	AK	ABP	ASaPZ	Other	total	[%]
		Financial restructuring	22	18	12	59	47	20	54	0	232	17
		Transformational restructuring	17	15	4	21	12	9	17	1	96	7
		Radical reengineering	12	9	2	12	15	14	18	0	82	6
		Gradual improvement	63	42	18	139	100	69	129	2	562	42
		Incremental changes	23	18	9	58	40	36	56	2	242	18
		We did not make any changes	3	3	6	20	28	8	48	16	132	10
		Total	140	105	51	309	242	156	322	21	1346	
		Proportion [%]	10	8	4	23	18	12	24	2		
		Expected	Analysis before the change									
	What types of changes have been made over the past 10 years?		SA	AP	AFF	FA	AK	ABP	ASaPZ	Other	total	[%]
		Financial restructuring	24.1	18.1	8.8	53.3	41.7	26.9	55.5	3.6	232	17
		Transformational restructuring	10.0	7.5	3.6	22.0	17.3	11.1	23.0	1.5	96	7
		Radical reengineering	8.5	6.4	3.1	18.8	14.7	9.5	19.6	1.3	82	6
		Gradual improvement	58.5	43.8	21.3	129.0	101.0	65.1	134.4	8.8	562	42
		Incremental changes	25.2	18.9	9.2	55.6	43.5	28.0	57.9	3.8	242	18
		We did not make any changes	13.7	10.3	5.0	30.3	23.7	15.3	31.6	2.1	132	10
		Total	140	105	51	309	242	156	322	21	1346	
		Proportion [%]	**10**	**8**	**4**	**23**	**18**	**12**	**24**	**2**		
		the expected values are lower than the actual ones										
		the expected values are higher than the actual ones										

changes have been made over the past ten years?" and Q11: "What analyses have been made before implementing the change, in its preparation?" The following abbreviations were used for names of analyses: SA – SWOT analysis, AP – portfolio analysis, AFF – force field analysis (enabling vs deterrent forces for change), FA – financial analysis, AK – analysis of competition, ABP – analysis of business processes, ASaPZ – satisfaction analysis and customer needs, other. Both questions had multiple answers. The main aim was to determine the existence of a statistical significance between them and to reject or accept the H1 hypothesis.

According to the results, the most common change was the gradual improvement with the answer frequency amounting to 42% of the total answers. By this type of change most enterprises meant financial analysis, analysis of competition and customers, and also analysis of business processes. On the other hand, the lowest frequency amounting to 6% was observed by the radical re-engineering change, which is lower than the frequency of the answer "we did not make any changes", namely, 10%. One interesting finding was enterprises without any change. However, even such enterprises have been making analyses of their financial situation, competition and customer needs.

According to the calculated p-value, p = 1.94E-19 (0.000000000000000000019398), this dependence is very strong and, therefore, it is possible to refuse the H0 hypothesis and accept the H1 with almost 100% significance. In conclusion, the choice to undertake an analysis before implementing a change depends on the type of change.

Tab. 4 analyses the relationship between questions 6 "At what level do you optimise processes?" and 14 "What new concepts and methods have you used to improve processes?". The table uses abbreviations for the new concepts and method names: BS – Balanced Scorecard, SS – Six Sigma, PC – Process Controlling, TQM – Total Quality Management, K – Kaizen (continuous improvement of business processes), B – Benchmarking, N – none of the methods and concepts. Enterprises could mark more than one answer in question 14.

As the results suggest, 50.2% (263 from 524) of enterprises use new concepts and methods to improve processes but still have room for improvement; 7% have a built-in mathematical model for calculating total costs up to delivery; 15.6% have modern technology available to create efficient business processes for employees; 15.8% have business standards and processes linked to the identified business success factors and customer requirements; 10.1% have a change management programme that ensures employee loyalty; and 15.8% cannot identify their level of process optimisation. The results also suggest that comparing observed versus expected values of the cell where Q14N and Q6-6 answers cross, the observed value is much higher than statistically expected. Possibly, enterprises that do not use any of the methods and concepts for process improvement do not achieve any level of process optimisation. Compared to the expected statistical frequencies, the number of enterprises that responded to this combination amounted to 53% of the whole sample, and the total count was 66.3% higher than expected.

However, this assertion had to be verified statistically by means of a p-value, which was calculated using the chi-square test. The calculated p-value for this table was p = 0.000000426, so the relationship between the level of process optimisation and the use of new concepts and methods for improvement was statistically significant. Consequently, the hypothesis H0 could be rejected as H1 was true, namely, the use of multiple concepts and methods for process improvement had a significant impact on the level of process optimisation. On the other hand, more than 53% of the enterprises did not use any concept or method to improve their processes.

The next table (Tab. 5) compares the question 6: "At what level do you optimise processes?" with the question 16: "Do you use some of the following models to analyse and optimise processes?". The main aim was to determine if the use of models for analysis and optimisation of processes influenced the level of process optimisation in the surveyed enterprises. The following abbreviations are used in the table: DRM – Diagnostic Reference Models (reference tables, relational databases, OLAP cubes), IM – Information Models (ARIS, Matis, FirstStep, CimTool, IDEF, UML), DS – Dynamic Simulation (integration of fuzzy logic, genetic algorithms), IM – Integrated Methods (GIM, SIM, GI-SIM, IMF-M methodology), DABP – business processes do not get analysed, O – other. Enterprises could mark multiple answers in question 16.

Based on Tab. 5, 46.2% (242 from 524) of enterprises use models to analyse and optimise processes but still have room for improvement, 1.4% have a built-in mathematical model for calculating total costs up to delivery, 13.4% have modern technology available to create efficient business processes for employees, 13% have business standards and pro-

Tab. 4. Contingencies Q6-Q14

Contingencies Q6–Q14		Observed frequency	14. What new concepts and methods have you used or employed to improve processes?								
			BS	SS	PC	TQM	K	B	N	other	total
6. At what level do you optimise processes?	1	Optimisation options have been identified (we know areas that require improvement)	13	10	37	20	26	21	135	1	263
	2	We have a built-in mathematical model for calculating total costs up to delivery	2	3	3	5	5	7	12	0	37
	3	Employees have modern technology available to create efficient business processes	2	3	9	7	10	12	38	1	82
	4	Business standards and processes are linked to the identified business success factors and customer requirements	4	2	13	12	8	7	37	0	83
	5	We have a change management programme that ensures employee loyalty	3	2	7	8	2	7	23	1	53
	6	None of these options applies	0	0	0	2	4	0	73	4	83
		Total	24	20	69	54	55	54	318	7	601
		Expected frequency	14. What new concepts and methods have you used or employed to improve processes?								
			BS	SS	PC	TQM	K	B	N	other	total
6. At what level do you optimise processes?	1	Optimisation options have been identified (we know areas that require improvement)	10.5	8.8	30.2	23.6	24.1	23.6	139.2	3.1	263
	2	We have a built-in mathematical model for calculating total costs up to delivery	1.5	1.2	4.2	3.3	3.4	3.3	19.6	0.4	37
	3	Employees have modern technology available to create efficient business processes	3.3	2.7	9.4	7.4	7.5	7.4	43.4	1.0	82
	4	Business standards and processes are linked to the identified business success factors and customer requirements	3.3	2.8	9.5	7.5	7.6	7.5	43.9	1.0	83
	5	We have a change management programme that ensures employee loyalty	2.1	1.8	6.1	4.8	4.9	4.8	28.0	0.6	53
	6	None of these options applies	3.3	2.8	9.5	7.5	7.6	7.5	43.9	1.0	83
		Total	24	20	69	54	55	54	318	7	601
		Proportion [%]	**4**	**3**	**11**	**9**	**9**	**9**	**53**	**1**	

the expected values are lower than the actual ones

the expected values are higher than the actual ones

cesses linked to the identified business success factors and the customer requirements, 8.2% have a change management programme that ensures employee loyalty, and 16% cannot identify their level of process optimisation. While most enterprises reported Levels Four and Five of process maturity, they can hardly be considered mature enough due to observed overlapping features of Levels One to Three.

In most cases, no model is used, and in exceptional use cases, it is a simple model based on a Diagnostic Reference Method. Diagnostic Reference Models are also used by enterprises at process maturity Levels One and Three.

The comparison of observed and expected frequencies demonstrated a result very similar to the previous analysis. Therefore, it is possible to conclude that enterprises without models for process analysis and optimisation achieve no process optimisation. The p-value for this table (Tab. 5) amounts to p = 0.000167445, which means the H0 hypothesis is rejected while the H1 hypothesis holds true. It follows that using models for process analysis and optimisation is important to reach a higher level of process maturity.

Tab. 6 analyses the relationship between the level of process optimisation and ROE. The analysis aimed to determine if the level of process optimisation

Tab. 5. Contingencies Q6-Q16

Contingencies Q6-Q16

6. At what level do you optimise processes?		Observed frequency	16. Do you use some of the following models to analyse and optimise processes?						
			DRM	IMO	DS	IME	DABP	O	total
	1	Optimisation options have been identified (we know areas that require improvement)	50	10	9	11	145	17	242
	2	We have a built-in mathematical model for calculating total costs up to delivery	5	4	3	3	16	1	32
	3	Employees have modern technology available to create efficient business processes	20	6	3	3	36	2	70
	4	Business standards and processes are linked to the identified business success factors and customer requirements	13	5	4	6	39	1	68
	5	We have a change management programme that ensures employee loyalty	9	2	0	1	30	1	43
	6	None of these options applies	3	0	1	0	74	6	84
		Total	100	27	20	24	340	28	539

6. At what level do you optimise processes?		Expected frequency	16. Do you use some of the following models to analyse and optimise processes?						
			DRM	IMO	DS	IME	DABP	O	total
	1	Optimisation options have been identified (we know areas that require improvement)	44.9	12.1	9.0	10.8	152.7	12.6	242
	2	We have a built-in mathematical model for calculating total costs up to delivery	5.9	1.6	1.2	1.4	20.2	1.7	32
	3	Employees have modern technology available to create efficient business processes	13.0	3.5	2.6	3.1	44.2	3.6	70
	4	Business standards and processes are linked to the identified business success factors and customer requirements	12.6	3.4	2.5	3.0	42.9	3.5	68
	5	We have a change management programme that ensures employee loyalty	8.0	2.2	1.6	1.9	27.1	2.2	43
	6	None of these options applies	15.6	4.2	3.1	3.7	53.0	4.4	84
		Total	100	27	20	24	340	28	539
		Proportion [%]	**19**	**5**	**4**	**4**	**63**	**5**	

the expected values are lower than the actual ones

the expected values are higher than the actual ones

influenced the ROE of the surveyed enterprises. According to the comparison of expected and observed frequencies in Tab. 6, a higher than expected observed value for the option "Optimisation options have been identified (we know areas that require improvement)" was among enterprises with ROE from 4% to over 10% and a superior process. This finding suggests that such enterprises are better at eliminating bottlenecks because they have either optimised processes already or have no knowledge/information about processes that could be optimised. However, the positive ROE result means that the first option – the processes have already been optimised – is more likely. Enterprises with ROE 0% – 2% either have optimisation possibilities identified or prefer modern technology for employees. Enterprises with ROEs 4% – 7% and 7% – 10% are most mature, and their observed frequencies are higher than expected in 4 different levels of process optimisation.

The p-value for this table is p = 0.0480, making this dependence statistically significant. This means that the H0 hypothesis is rejected, while the H1 hypothesis holds true. Furthermore, the optimising tools and their use has a significant influence on the ROE. Table 6 clearly suggests that enterprises with a negative ROE score either use none of these tools or know about process-related issues yet take no action.

The last figure (Fig. 2) shows that many enterprises with the ROE value 0 – 7% much more regularly monitor processes than the enterprises with the ROE value 7% – 10%. This finding can be explained by an assumption that enterprises with

Tab. 6. Contingencies Q6-QD

Contingencies Q6 - Q D

Observed frequency			D - What was the ROE of your company in 2015?						
			ROE < 0	0% to 2%	2% to 4%	4% to 7%	7% to 10%	over 10%	total
6. At what level do you optimise processes?	1	Optimisation options have been identified (we know areas that require improvement)	24	65	56	45	19	24	233
	2	We have a built-in mathematical model for calculating total costs up to delivery	1	2	5	7	6	9	30
	3	Employees have modern technology available to create efficient business processes	3	17	18	15	8	7	68
	4	Business standards and processes are linked to the identified business success factors and customer requirements	3	13	18	18	8	6	66
	5	We have a change management programme that ensures employee loyalty	1	9	10	15	5	3	43
	6	None of these options applies	12	22	19	15	7	9	84
		total	44	128	126	115	53	58	524
Expected frequency			**D - What was the ROE of your company in 2015?**						
			ROE < 0	0% to 2%	2% to 4%	4% to 7%	7% to 10%	over 10%	total
6. At what level do you optimise processes?	1	Optimization options have been identified (we know areas that require improvement)	19.6	56.7	56.3	51.4	24.1	25.9	234
	2	We have a built-in mathematical model for calculating total costs up to delivery	2.5	7.3	7.2	6.6	3.1	3.3	30
	3	Employees have modern technology available to create efficient business processes	5.7	16.5	16.4	14.9	7.0	7.5	68
	4	Business standards and processes are linked to the identified business success factors and customer requirements	5.5	16.0	15.9	14.5	6.8	7.3	66
	5	We have a change management programme that ensures employee loyalty	3.6	10.4	10.3	9.4	4.4	4.8	43
	6	None of these options applies	7.0	20.1	20.0	18.2	8.6	9.2	83
		total	44	127	126	115	54	58	524
	Proportion [%]		**8.4**	**24.24**	**24.05**	**21.95**	**10.31**	**11.07**	
	the expected values are lower than the actual ones								
	the expected values are higher than the actual ones								

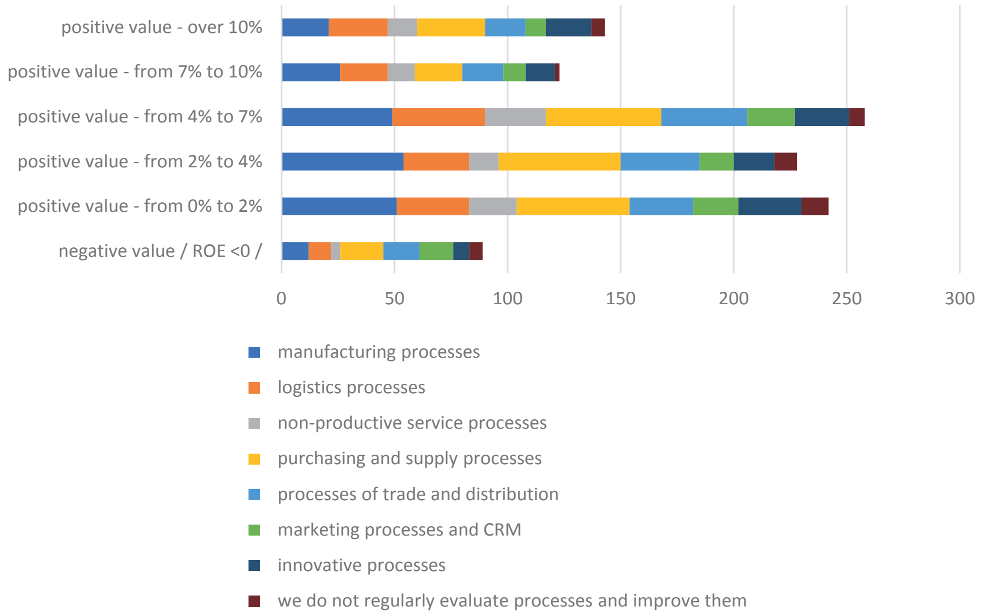

Fig. 2. Regularly monitored processes divided by enterprise ROE

a lower ROE have not reached a higher maturity level of process optimisation and, therefore, must allocate much more attention and financial means to process monitoring, which could be a reason of a smaller ROE value.

4. Discussion of the results

Previous research used the Capability Maturity Model (CMM) to describe the degree, to which an organisation applies formalised processes to the management of its various business functions (Marcineková & Sujová, 2015a; 2015b). The popularity of this model is growing; it gets implemented in different process areas. The CMM integration in management aims to improve the level of processes. This study demonstrated that the model could be considered for adoption by many Slovakian enterprises but mainly small businesses. This research also revealed possibilities to implement process-oriented change management under Slovak market conditions and confirmed the result of another research (Sujová & Marcineková, 2014) stating that a low level of process management (maturity) is typical of enterprises with lower performance. A qualitative level of process management has a direct influence on corporate performance. We can also assume that the overall level of maturity in Slovak enterprises corresponds to the findings, and the calculated p-value has a significant relationship with the use of new methods and models in the field of process improvement. A positive impact on corporate performance made by modern methods for business process management was also confirmed by Marcinekova and Sujova (2015a). The research also indicated that process controlling, Kaizen, TQM and benchmarking were among methods mostly used by small Slovak enterprises. However, many enterprises (almost 50%) did not use any modern method (Sujova & Marcinekova, 2015b).

The mentioned findings lead to a conclusion that aiming for higher corporate performance, Slovak enterprises should focus on the improvement of internal processes using modern conceptions and management methods. Process improvement requires greater attention to process analysis. The research indicated that 63% of enterprises do not analyse processes at all. Besides, the existing competition gap should be used by small enterprises as an opportunity for future development of performance growth.

Conclusions

The quantitative research focused on change management and its impact on the business success (economics) of enterprises operating in Slovakia. The research results suggest that change management has a major positive influence on Slovak enterprises. According to the multiple cross-table analyses, the contingency method and the chi-square test p-value statistically confirmed that the implementation of new concepts and methods of process improvement could increase the existing maturity level of process optimisation. Even though many companies do not optimise processes at all, there is a large group of enterprises that have successfully crossed the maturity gap between Levels Two and Three. Results also confirmed a positive influence of models used for process optimisation analysis. Besides, the achieved level of maturity influences the ROE indicator. The relationship between changes and analysis means that a proper analysis can uncover business process areas that require improvement. In summary, the ROE mirrors efforts of Slovak enterprises in the field of process optimisation. Therefore, enterprises should focus their efforts on a "level jump" aiming to achieve the highest possible process maturity level for staying competitive and profitable, which are the crucial survival criteria.

The presented research and its results contributed to the development of a new approach to change management, namely, process-oriented management of change. It was confirmed, that effective changes should be managed based on process principles and focused on the improvement of business processes. This is the way towards sustainable corporate performance.

The research also revealed a new direction for future scientific work, including practical implications, consisting of the development of a new change-based maturity model for smaller enterprises using larger successful enterprises as a benchmark.

However, caution is required in the adjustment of the maturity model for small enterprises against large firms (benchmark) as stated in the paper, the approach to change is complicated, demanding and challenging. Therefore, change management capability gaps should be viewed as the business environment complexity particular to small enterprises and different from large companies.

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Annex: Questionnaire 1

Selected questions from the Questionnaire Change Management in Slovakia that were evaluated in the research paper (Questions: A, C, D, 4, 6, 11, 14, 16).

A. What is the average number of employees in your business?
(select one option)
- ☐ 0 to 10 employees
- ☐ 11 – 20 employees
- ☐ 21 – 50 employees
- ☐ 51 – 250 employees
- ☐ over 250 employees

C. What is the ownership of your business?
(select one option)
- ☐ net domestic capital
- ☐ the domestic capital prevails
- ☐ foreign capital prevails
- ☐ net foreign capital

D. What was the ROE of your company in 2015?
(select one option)
- ☐ negative value / ROE < 0 /
- ☐ positive value – from 0% to 2%
- ☐ positive value – from 2% to 4%
- ☐ positive value – from 4% to 7%
- ☐ positive value – from 7% to 10%
- ☐ positive value – over 10%

4. What types of changes have been made over the past ten years?
(multiple answers can be selected)
- ☐ financial restructuring
- ☐ transformational change restructuring
- ☐ radical re-engineering change
- ☐ gradual improvement
- ☐ incremental, i.e. unplanned but necessary changes
- ☐ we did not make any changes

6. At what level do you optimise processes?
(select one option)
- ☐ optimisation options have been identified (we know areas that require improvement)
- ☐ we have a built-in mathematical model for calculating total costs up to delivery.
- ☐ employees have modern technology available to create efficient business processes.
- ☐ business standards and processes are linked to the identified business success factors and customer requirements.
- ☐ we have a change management programme that ensures employee loyalty.
- ☐ none of these options applies.

11. What analyses were made before the change was implemented, in its preparation?
(multiple answers can be selected)
- ☐ SWOT analysis
- ☐ portfolio analysis
- ☐ field strength analysis (factors for and against change)
- ☐ financial analysis
- ☐ analysis of competition
- ☐ analysis of business processes
- ☐ satisfaction analysis and customer needs
- ☐ other (please specify): ______________________

14. What new concepts and methods have you used or employed to improve processes?
(multiple answers can be selected)
- ☐ Balanced Scorecard (BSC - Balanced Scorecard)
- ☐ Six Sigma
- ☐ process controlling
- ☐ Total Quality Management (TQM)
- ☐ Kaizen (constantly improving business processes)
- ☐ benchmarking
- ☐ we do not use any of these methods and concepts
- ☐ other: ______________________

16. Do you use some of the following models to analyse and optimise processes?
(multiple answers can be selected)
- ☐ Diagnostic Reference Models (reference tables, relational databases, OLAP cubes)
- ☐ Information Models (ARIS, Matis, FirstStep, CimTool, IDEF, UML)
- ☐ dynamic simulation (integration of fuzzy logic, genetic algorithms,
- ☐ integrated methods (GIM, SIM, GI-SIM, IMF-M methodology)
- ☐ other. Specify what: ______________________
- ☐ we do not analyse business processes

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Coexistence of the BRC Standard for Packaging and the Lean Manufacturing methodology

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ABSTRACT
This study aimed to explore the potential impact of the Lean Manufacturing methodology on the implementation and functioning of the BRC Standard for Packaging. The study highlighted many issues where the Lean Manufacturing concept supports and opposes the BRC Standard for Packaging. A framework for the coexistence of both approaches was determined. The study was of a conceptual nature; it adopted an analytical approach. The approach was based on in-depth consideration of each requirement in the BRC Standard for Packaging s and an assessment of the coherence with the Lean Manufacturing methodology. As a result, many conclusions, clues and challenges were found. The article indicates several areas, in which Lean Manufacturing supports the BRC Standard for Packaging, attributing a special positive role to Lean Tools & Techniques. Also, it indicates six areas, in which the BRC Standard for Packaging contradicts the Lean Manufacturing approach. A comprehensive analysis of the coexistence of both management systems allows a better understanding of challenges while implementing both of them in an organisation. The presented concept of the coexistence of both systems is valuable for management.

KEY WORDS
BRC Standard for Packaging, Lean Manufacturing, Lean Principles, Lean Tools & Techniques, quality management system, system integration

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Introduction

Managers are interested in the integration of the Lean Manufacturing approach with the quality management system of the BRC Standard for Packaging. Processes in individual organisational units of a company should coexist creating a coordinated organism and producing top quality products. Naturally, a management system should be complete and include all relevant aspects required to produce a valuable production output.

The article aimed to investigate the potential impact of the Lean Management methodology on the BRC Standard for Packaging. This study determined areas, in which the Lean approach may have had a positive impact on the BRC Standard for Packaging, as well as fields having major discrepancies. Additionally, it defined areas of conflict between the Lean Manufacturing and the quality management system of the BRC Standard for Packaging. The study also aimed to outline a framework for the coexistence of both approaches. The study refers to the BRC Standard for Packaging, which is formally known as the BRC Global Standard for Packaging and Packaging Materials.

The article contains a conceptual study and adopts an analytical approach considering formalised requirements of the BRC Standard for Packaging as well as a conceptualisation of the Lean Manufacturing methodology. Lean Manufacturing is reduced to its crucial elements, namely, the Five Lean Principles (Womack & Jones, 1996) and Lean Tools & Techniques systematised into three groups. Both systems were mutually confronted, and their coexistence was assessed in terms of the coherence and challenges during their implementation in an organisation. The confrontation between Lean principles, tools and techniques and requirements of the BRC Standard for Packaging exposed different types of potential impact. The impact was finally systematised and presented in a matrix. Another result of the conceptual work was the recommended framework for organisations using the BRC Standard for Packaging and considering to incorporate Lean Manufacturing. It should be noted that in the process of conceptual inductive investigations, the effective and efficient functioning of the BRC Standard for Packaging system was a prevailing frame of analysis.

Quality management systems, such as the BRC Standard for Packaging or ISO 9001: 2015, need to be constantly developed to meet new challenges of today's dynamic business environment. Many institutions issuing new versions of standards fail to keep up with the production and business needs of modern enterprises. Lean Manufacturing has a potential to enhance quality management systems, and thus, new opportunities generated by Lean philosophies should be discovered and implemented.

1. Lean Manufacturing framework

Organisations often operate in environments characterised by intense competition, continuous technological progress, new consumer requirements, and scarce natural resources (Bhasin, 2012). There has been an increase in consumer demands, which presently relate to not only quality but also the environment, OHS, and sustainability (Souza & Alves, 2017, p. 2668).

The term Five Principles of Lean Manufacturing appeared for first time in 1996 in the book "Lean thinking" written by Womack & Jones. The authors summarised a comprehensive Toyota Production System by just five principles, which are easy to understand in any business environment.

The Five Principles include:

- determine the value from the customer's standpoint (value),
- identify the value stream (value stream),
- value stream optimisation (flow),
- pull: make to demand (pull),
- continuous improvement (perfection) (Womack & Jones, 1996).

Determining the value from the customer's standpoint is a process fundamental for production. Manufacturers and service providers research the market to create products and services that generate maximum benefits for final customers. The value ultimately appears when a customer makes a buying choice and consumes/exploits the product. In the logistics chain, customers are end-users, so the value created is aimed at meeting their expectations. In the age of the Internet, which is a relatively new distribution channel, determining what a consumer expects from a product or service seems to be easier (Loane et al., 2014, p. 2).

Defining the customer groups, which the product or service aims to target, is one of the most important tasks for the team responsible for new product development and launch. The decisions related to new products and services have a profound impact on risk, performance and costs. To determine the product profile, the first step is to collect data representing the different types of customer needs, which the product or service aims to address. This is done by researching client needs, interests, etc. (Yu et al., 1999, p. 5).

The second principle is about identifying the value stream (Womack & Jones, 1996). This principle implies the analysis of material flow and information necessary to deliver the product to the customer. The advantage is the possibility of visualising the value flow and thus enabling each employee to get acquainted with the value stream (Rother & Shook, 1998). The most common method used for analysing the material and information flow is the Value Stream Mapping (VSM) (Manjunath & Shiva Prasad, 2014, p. 100).

Despite the great potential of Lean strategies in performance improvement, there have been many reports of failures due to the confusion about what and how to adopt tools in a specific environment. The implementation of an inappropriate Lean strategy for a given situation can sometimes lead to an increase in waste, cost and production time of a manufacturer. Because of inappropriate selection of lean strategies, changes may cause disruptions in the very process it meant to improve. Therefore, it is crucial to have a systematic method to implement appropriate lean strategies based on identifying wastes in manufacturing processes. As manufacturers who seek advice regarding an investment in new Lean strategies may desire a certain theoretical ground to ensure that their investment decisions are logically sound, it is necessary to develop a methodology to implement appropriate Lean strategies along with proper methodology to evaluate the continuous performance improvement (Karim & Arif-Uz-Zaman, 2013, p. 24).

Value stream optimisation is another principle identified by Womack & Jones (1996). Production processes are perceived from a customer's perspective as streams of values. Value streams are sequentially arranged actions that must be completed so that resources (materials, work and information), can be transformed into products or services expected by customers (Szkudlarek & Zarzycka, 2011, p. 164). By optimising the value stream, the efficiency of the entire process is increased, which is de facto the main goal of Lean. Ensuring the continuity of flow is a key issue of industrial engineering and operational management. Product volatility, which is nowadays natural (constant changes in packaging, designs, graphic design, packaging logistics, etc.), forces production companies to be flexible while maintaining a high level of quality and low failure rate of processes. All this makes the design of production systems more complicated. Product variation may also require frequent adjustments to the production system to maintain high performance. The implementation of the general framework and procedures for the design and engineering of production systems helps eliminate bottlenecks throughout the entire production chain (Chatzopoulos, 2014, p. 180).

The assumption of making to demand is to produce exactly as much as the customer needs. Essentially, the "pull" or "push" system is the concept of material flow between production lines. The "pull" system is one of the Lean Manufacturing tools that implies regulating the flow of unfinished goods in the factory and from external contractors. An effective "pull" system only produces what is needed at the right time. Inventories are maintained at a minimum to meet uncertainties in demand and supply, which is why the use of this system minimises overproduction (Jamaliah et al., 2016, p. 7699).

There are some analogies between "pull: making to demand" and Available To Promise (ATP) – "possible to promise". ATP is a system for providing a control mechanism that calculates whether the desired products from the customer's order can be delivered within the required time. The ATP system also checks the capacity of the plant infrastructure (machines, personnel). Thanks to the professional implementation of the ATP system, it is possible to immediately change the order schedule and help enterprises to establish the right balance between low warehouse costs and high order completion rates (Tinnefesld et al., 2011, p. 1).

The concept of pull is an extremely effective way to organise the production system, but it requires the involvement of the entire production process and auxiliary processes as well as the implementation of high work standards.

Continuous improvement is a routine process of systematically seeking and implementing new and improved working methods. Real sources of advantage can be found in the management's ability to consolidate technologies and production skills throughout the company. Competencies that enable individual enterprises to adapt quickly to changing opportunities while providing a competitive advantage. The strategic goal of an industrial production initiative is to build the ability to quickly and effectively implement improvements as routine activities. To develop this capacity, senior management must provide the organisational vision necessary to guide both business objectives and operational efficiency improvements. Management must enable the development of infrastructure ensuring that the company's strategic production goals are met, and that the efficiency of its production processes is continuously improved (Butler et al., 2018, p. 5).

The Lean Manufacturing methodology is focused on continuous improvement, and not only on correcting errors (Bhasin & Burcher, 2006). The Lean Manufacturing methodology also encourages the improvement of those processes that already work well, so that they are even faster and more effective (Hines et al., 2004). This, in turn, satisfies more customers. Thanks to the benefits gained, more and more enterprises are deciding to implement Lean Manufacturing. The natural effect is the increased demand for Lean Manufacturing specialists who know the methodology, particular techniques, and, most importantly, can implement them effectively.

The twenty-first-century manufacturing is characterised by customised products. This has led to the complex production planning and control systems making mass production of goods challenging. Many organisations, particularly automotive, struggled in the new customer-driven and globally competitive markets. These factors present a big challenge to organisations to look for new tools and methods to continue moving up the ladder in the changed market scenario. While some organisations continued to grow on the basis of economic constancy, others struggled because of their lack of understanding of the changed customer mindset and cost practices (Fullerton et al., 2003). To overcome this situation and to become more profitable, many manufacturers turned to "Lean Manufacturing". The goal of Lean Manufacturing is to be highly responsive to customer demand by reducing waste. Lean Manufacturing aims to produce products and services at the lowest cost and as fast as required by the customer (Bhamu & Sangwan, 2014, p. 876).

According to scholars, the success of Lean Manufacturing stems from a combination of practices, policies, and philosophies (Simons & Zokaei, 2005, p. 194). While philosophies and policies are very closely related to the Five Lean Principles, practices consist of dozens of daily management methods of the whole organisation, top management, and machine operators (Hines & Rich, 1997; Piercy & Rich, 2015). Lean practices form a separate management toolbox. All of them are subordinated to the practical implementation of Lean Principles and philosophies. Lean Tools & Techniques are referred to standardised work, Just-in-Time supply systems, visual control and many other important tools for Lean issues. In the manufacturing companies, for example, 5S, Kanban, QFD, Poka-Yoke and SMED are used particularly often (Gálová et al., 2018; Shah & Ward, 2007).

Depending on the role they serve in the production system, the tools can be categorised as (1) "diagnostic" – subordinated to the analysis and identification of the system, (2) practical methods of information of the material flow, which can be perceived as "in stream", and (3) methods devoted to organising the workforce for "continuous improvement". The separation of these three types is useful for the investigation of their influence on the BRC Standard for Packaging.

2. BRC Standard for Packaging

Food distribution companies constantly improve the quality of their products, which is why they subject their suppliers to a growing number of controls. At the turn of the millennium, the largest distribution networks on the British market have set a standard that included requirements to ensure the highest quality of offered products. The development of the BRC Global Standards was initially associated with the need to comply with legal requirements, but it quickly turned out that they bring significant benefits to both producers and retailers in the UK, which aroused international interest in this system. The purpose of the audit for the BRC Standard for Packaging is to prepare a report that contains comprehensive information on the functioning of the audited entity. The report includes the assessment of compliance with individual points of the standard. The standard is structured in such a way as to enable objective assessment of operating systems and procedures used by the audited entity. The lead auditor is delegated by the certification body (third party) and tasked to provide an objective and a professional analysis of the company, with a particular emphasis on food safety. Audits conducted by contractors are aimed at checking compliance with contractual requirements and verifications of respect for the work environment (Arfini & Mancini, 2014, p. 1).

The BRC Standard for Packaging is the first industrial quality management system dedicated to the packaging industry. It is a useful tool for packaging sector companies aimed at building and improving quality management systems. The basic requirements of the BRC Standard for Packaging are in line with the requirements of the ISO 9001 system; however, they are strictly adapted to the packaging industry. The safety and quality requirements correspond to the legal requirements in this respect. For many companies, the similarity between ISO 9001 and the BRC Standard for Packaging is appealing as the documentation of these two systems can be compatible with each other with no need for duplication.

The BRC Standard for Packaging covers all important areas in the field of packaging quality assurance. In addition, particular emphasis is placed on issues directly related to food packaging and food safety. In particular, the BRC Standard for Packaging focuses on issues related to the involvement of top management, risk analysis, internal audits, traceability, cleaning, process monitoring and personnel training.

Many packaging companies partly operate according to the requirements of the BRC Standard for Packaging. However, not all companies are aware of the benefits of a professionally operating system based on the BRC Standard for Packaging. This system is mainly used in enterprises that are suppliers to customers in the United Kingdom. The popularity of all BRC Global Standards is growing, so it can be expected that the BRC Standard for Packaging will become more widespread in the packaging industry (Kawecka, 2014, p. 17).

The quality management system of the BRC Standard for Packaging (formerly BRC/IoP Packaging and Packaging Materials) was created in 2002. It contains requirements for packaging manufacturers, packaging materials intended mainly for food and cosmetics. The BRC Standard for Packaging is one of the leading standards adopted by major retailers and packaging companies from around the world. The fifth edition is obligatory from the beginning of 2016.

The BRC Standard for Packaging was established to help producers meet their legal obligations, as well as to ensure the protection of consumer interests. This quality management system pays special attention to the qualitative and functional aspects of packaging. It contains requirements for safety, production environment and laboratory testing of packaging.

One of the goals of the BRC Standard for Packaging is the systematic training and improvement of professional skills of management and its employees. In this concept, the attitude of the organisation plays a very important role. One of the main goals of the methodology is to implement the systemic thinking among the personnel so that the company is treated as a whole and not only as a part for which individual units are responsible. Adopting such an attitude allows to learn from mistakes and appreciate own success because it is the final product or service that is the value that determines the market and economic success (Kwiatkowski et al., 2017, p. 160).

The BRC Standard for Packaging includes requirements not only for the materials used to produce food packaging but also for other raw materials not necessarily applicable in the FMCG industry (glass, plastic, wood, paper, aluminium, steel). The system also defines two levels of safety risk, which is determined by the final use of the packaging material. Packaging for food storage has a higher level of risk compared to other types (Malon Group, 2018).

Based on the BRC Standard for Packaging, the operation is based on five key factors:

- quality policy: for the packaging quality management system to be as effective as possible, the company's management should construct an ambitious, realistic and clear quality policy;
- risk analysis: the basic elements of the programme is risk and threat assessment based on legal principles;
- technological schemes: determine product flow, control and critical points in production processes, and compliance of requirements for quality management and good safety practices;
- process monitoring: an indispensable element of the quality management system functioning in the field, product control and testing, as well as control of the processes themselves;
- product development: defines the requirements related to the creation and design of the product and the expectations of its subsequent distribution (BRC Global Standars, 2015);
- workforce training and development.

Obtaining a certificate confirming compliance with the BRC Standard for Packaging is associated with many benefits for a company. The standard is particularly focused on the safety and quality of packaging. Its requirements are based on principles of the Hazard Analysis and Critical Control Points (HACCP) and also complement the already existing management systems, including ISO 9001. The standard facilitates a company in constant observation of all activities, which enables quick correction of possible irregularities and thus increase client trust. This quality management system is also associated with benefits for business associates as standardised reports make it possible for a contractor to know exactly whether the company meets all the requirements (Malon Group, 2018).

3. Challenges arising from the coexistence of both systems

A good reputation is a key condition for the existence of modern enterprises in the market. No company will achieve a good reputation without effective quality management that mainly aims is to build trust among customers and generate value for them through offered products or services. It is a difficult and long-lasting process because the trust gained by a producer or a service provider is built over the years through reliable and timely cooperation. Quality policy plays a key role in this process. The lack of a fair and honest quality policy that would clearly define a value for customers incapacitates trust-building efforts of a company. Therefore, a special approach to the process of developing and implementing a quality policy is required (Bacoup et al., 2018). It is important for the top management to be able to effectively convey their expectations and the adopted development vision to managers of individual organisational units. It is also important to set quality targets in consultation with the most important employees in the company and to monitor the quality processes on an ongoing basis, which plays a key role in the effective implementation of a quality policy (Molenda, 2015, p. 219).

The examination of the similarities and differences between Lean Management and a Quality Management System highlights a close relationship, which raises a key question about their potential linkage: if both a Quality Management System and Lean Management are complementary and mutually reinforcing, why are they not used as an integrated combination? There is irony in the fact that a Quality Management System and Lean are both intended to improve the production processes of the firm whereas, in reality, they are two parallel systems and governance structures driven by two different departments, resulting in wasted resources because they are not properly aligned (Bacoup et al., 2018, p. 24). The relation to the food industry makes it natural that the BRC Standard for Packaging focuses on risk analysis. Correct identification of hazards and dangers increases the likelihood of continuous, uninterrupted flow of materials. One of the obligatory system documents is technological schemes that identify the flow of materials. They represent the path of a product from raw materials to the finished result. They depict critical and control points as well as other activities characterising the specificity of a given enterprise. Well-designed diagrams identify threats (in reference to the HACCP plan) and facilitate the understanding of the relationships between individual processes taking place in an organisation as well as present the flow of materials in a graphical sequence.

Operating in highly competitive markets, modern organisations must be able to adapt in order to respond quickly to changing business conditions. Organisations operating in international markets should demonstrate flexibility and an innovative business strategy in order to remain competitive. The organisational structure can increase or hinder the company's ability to innovate. Static and hierarchical organisational structures may not provide the necessary flexibility to maintain organisational competitiveness. The key challenge is to create an organisational structure that promotes innovative employee behaviour. When organisations promote an environment conducive to innovation, employees interact more often to create new knowledge, develop their capabilities and find optimal solutions to problems (Gaspary et al., 2018, p. 2).

The former focus on automation was to increase efficiency and reduce costs. Today, global competition forces manufacturers not only to reduce costs but also to improve the quality of products and processes. Thus, the goal of implementing more modern systems has been redefined. Highly automated processes ensure high quality at a constant level. However, increasing the degree of automation also increases the chances of error. When deciding to implement production for consumer demand, particular attention should be paid to monitoring and control. Integrated process monitoring is a good method to diagnose non-optimised process conditions, followed by optimisation and feedback that is a response to the company's needs. Humanity has begun to develop automation to avoid dangerous or unpleasant manual operations and increase efficiency. Whenever possible, people implement devices and technologies replacing physical work, often using natural energy. The production pulled by consumer demand significantly improves the ergonomics of work. Manual work is gradually eliminated and replaced by integrated systems requiring gradually less human interference. Implementation of modern systems to the enterprise requires the involvement of all production processes. Its implementation is not easy, all the more so as it requires constant monitoring and control; however, achieving the goal the company will notice relatively large benefits in functioning (Voltaire et al., 2011, p. 511).

Product development and the entire sequence of activities related to its implementation are inextricably linked to continuous improvement. An enterprise that wants to exceed customer expectations improves its products or offers a new version of products. Over the years, many procedures have been formalised and described to diagnose the correct path of the company in order to properly produce a new product. Both in the scientific and industrial approach, great emphasis is placed on the conceptual phase and project plans leading to the right decision. The guidelines should contain a transparent process flow comprising four main stages – planning and clarifying tasks, conceptual design, exemplary project and detailed design (Vielhabera & Stoffels, 2014, p. 253).

4. Determination of supporting and conflicting fields

The issue of mutual coexistence of the BRC Standard for Packaging and Lean Management is systematically studied considering concrete elements of the management concepts. The BRC Standard for Packaging is considered on the level of particular requirements which should be implemented in an organisation. Lean Manufacturing is conceptualised as Five Lean Principles (Womack & Jones, 1996) and additional three types of Lean Tools and Techniques. All of them were juxtaposed, the comprehensive and in-depth analysis of all combinations was made. The identified interactions between Lean Manufacturing and the BRC Standard for Packaging are summarised in Tab. 1.

As indicated in the Tab. 1 many kinds of relationships can be found between requirement groups of the BRC Standard for Packaging and the Lean Manufacturing methodology. When the Lean methodology coexists with the BRC Standard for Packaging in an organisation, both positive and negative impacts are possible. They concern all standard requirement groups and are affected by the implementation of Lean Principles and Lean Tools & Techniques.

A "quality policy" is one of the nodal points of a standardised Quality Management System, including the BRC Standard for Packaging. The BRC Standard for Packaging states that a company has to announce a documented policy expressing its intention to produce safe and legally compliant products (BRC Standard for Packaging 1.1). The Lean methodology also has some critical philosophy which should be applied to the whole organisation. This philosophy of understanding is the value and the pursuit of perfection. The understanding of value to be coherent with the BRC Standard for Packaging should seriously take into consideration product safety. Clearly defined as well as documented formal organisational structures are inevitably required by the system (BRC Standard for Packaging 1.3). At the same time, the Lean Manufacturing emphasises the need for flexibility in adapting to changing demands of production. The focus is on value streams, not organisational functions, including cross-functional collaboration across all departments. There is a potential conflict between the BRC requirement of formal organisational structures and the Lean Principle of continuous value flow. Diagnostic Lean tools can be adopted in a structured management system to carry out the management review (BRC Standard for Packaging 1.2).

The BRC Standard for Packaging requires a serious focus on hazards and probability of their occur-

Tab. 1. Influence of Lean Manufacturing on requirements of the BRC Standard for Packaging

Chapters of the BRC Standard for Packaging	Five Lean Principles					Lean Tools & Techniques		
	Value	Value stream	Flow	Pull	Perfection	Diagnostic	In stream	Continuous improvement
Senior management commitment	N, D		C		S	D		
Hazard and risk management system		M				D		S
Product safety and quality management	N, D		C	C	N		C	C
Site standards		M					S	
Product and process control	N		C	N	C	S		
Personnel					S		S	

Legend: **empty cell** – no conflict in the coexistence, no serious negative/positive influence; **S** – supportive; **C** – conflicting, a distinctive negative influence, limitation and/or blocking may occur; **D** – can be deployed to specificity of a formalised system and support it; **M** – mutually supportive, where not only Lean supports the BRC Standard for Packaging but also the reverse influence is expected; **N** – possible negative impact and misconceptions, especially on the operational level of an organisation, mostly in understanding basic framework issues.

rence. Team collaboration, which is typical for all improvement Lean tools, appears as supportive for the risk team management according to the BRC Standard for Packaging (BRC Standard for Packaging 2.1). For risk analysis (BRC Standard for Packaging 2.2), some Lean diagnostic tools can be supportive; one of them, for example, is the mapping of the value stream (VSM). However, these tools should be mostly deployed for the specific use within the BRC Standard for Packaging. Hazard and risk analysis and management are based on existing processes, a deep understanding of the value stream seems substantially consistent.

The BRC Standard for Packaging as a management system for product quality and safety practices is building upon ISO 9001 principles; therefore, all consequences of formalisation eventually appear. Documented procedures are required directly by the BRC Standard for Packaging (3.1). The Lean approach aims to eliminate all unnecessary work and documenting records can be perceived as adding no direct value to customers. As they consume workforce effort and time, if not clearly demanded by customers, Lean treats them as *muda* (waste). Therefore, many possible conflicts may appear on the operational level within an organisation. These contact points may systematically induce inner organisational tensions.

The BRC Standard for Packaging "Site Standards" refers to the physical surroundings of a process, factory indoors, tools, equipment, etc. In this area, Lean 5S (6S) techniques seem to be totally supportive. It can noticeably support the maintenance of buildings and equipment, cleaning, pest control as well as waste management, which is the essence of this chapter (BRC Standard for Packaging, Chapter 4). At the same time, Chapter 4 requirements of the BRC Standard for Packaging are coherent with the value stream understanding (the 2nd Lean Principle). Particular requirements of the BRC Standard for Packaging are closely associated with the flow of processes.

Chapter 5 of the BRC Standard for Packaging refers to product design and process control. It is symptomatic that a large part of requirements concern inspections, measurements, testing, calibration, legality, etc. The Lean manufacturing promotes a proactive and preventive quality approach, and too many inspections are highly inadvisable. Lean avoids inspections as they represent a reactive approach that does not directly add value to customers. In Lean, it is essential to establish a smooth and continuous flow and stop the production line when a problem is detected. Inspections with related documentation and recording eventually retard the value stream flow. Corrective actions should take minimum time and keeping tact time is important for the flow efficiency. On the other hand, when it comes to product design, one Lean technique, QFD, is particularly supportive. QFD is an analytic/diagnostic Lean tool. The extensive requirements on product and process control may also be a barrier to continuous improvement. Improvement ideas generated by employees might be difficult to implement due to the standard's requirements or legal constraints. This might be a factor blocking creativity and innovation in companies.

The methodology of the Lean approach can noticeably support the fulfilment and assurance of Chapter 6 of the BRC Standard for Packaging. An experience of standardised actions can be essential in training (BRC Standard for Packaging 6.1) together with the TWI method, and personal safety (BRC Standard for Packaging 6.2) together with the 5S (6S) method. In the field of hazards to human health, strict adherence to the rules is crucial; therefore, the pursuit of excellence that is right for Lean is clearly favourable and supportive. Chapter 6 of the BRC Standard for Packaging includes many detailed restrictions at work, which need to be very closely met, such as rules for drinking and smoking, and 5S habits and culture are highly supportive.

5. Discussion

According to the conducted analysis, there are several potential negative relationships between the BRC Standard for Packaging and Lean (see „C" in Tab. 1). Most of them are connected to the third Lean Principle, related to the fast and smooth flow of value/production stream along the production system. At the same time, a relatively large number of positive relationships were identified in 12 fields (Tab. 1). It is noticeable that mostly Lean Tools & techniques have a potentially positive influence on the management system of the BRC Standard for Packaging. There is no doubt that the Lean Manufacturing can coexist with the BRC Standard for Packaging within an organisation and may enhance the formalised system of the BRC Standard for Packaging. The critical examination of both concepts encourages how the two management approaches can function together.

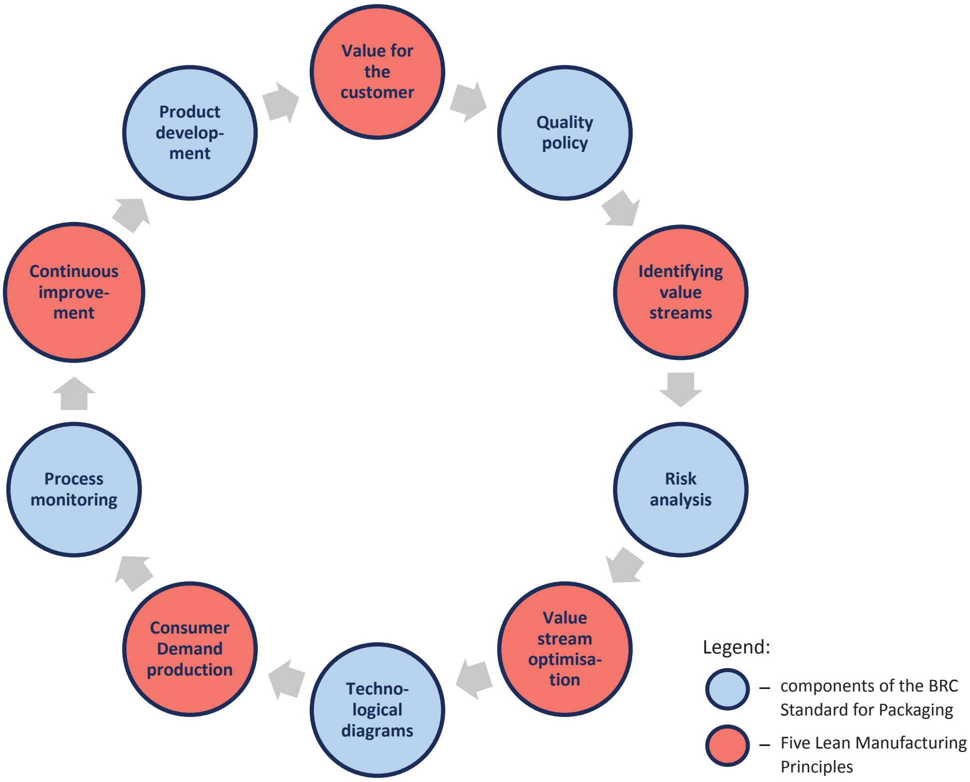

Fig. 1. Life cycle of the BRC Standard for Packaging with the Lean Manufacturing approach

Source: elaborated by the author based on (BRC Global Standards, 2015).

The Five Lean Manufacturing Principles can be successively combined with the guidelines contained in the BRC Standard for Packaging. The following schematic diagram illustrates how the different stages of both methodologies can influence one another and complement each other.

Generating customer value is a fundamental principle both in the Lean Manufacturing and in the BRC Standard for Packaging, which is why it should be included in the company's quality policy. This, in turn, should affect the value stream mapping, including risk analysis and flow continuity. Technological schemes in an enterprise should define theoretical models of processes that should be designed in such a way that the production system is consumer driven, i.e. it minimises the costs associated with storage and influences the efficiency and predictability of manufacturing processes. Process monitoring should be conscious and continuous, done in a harmonised and non-disruptive way in respect of manufacturing processes. Continuous improvement, as a routine process, should be implemented permanently in the culture and reflected in the behaviour of the enterprise. A professionally managed organisation should never block creativity and innovation of staff. Product development should receive special care from the entire organisation. Product development in the operating cycle should be inextricably linked to the creation of customer value. All processes taking place in an organisation should be systematically verified. Corrective and preventive actions should be introduced on an ongoing basis to ensure the likelihood of the proper functioning and high customer satisfaction.

Conclusions

The Five Lean Manufacturing principles can be used in the context of integration with elementary components of the BRC Standard for Packaging. The integration of both concepts is possible since they share the same goals, namely: ensuring high-quality products that create value for customers.

The article points to a synergistic platform between the quality management system of the BRC Standard for Packaging and the Five Lean Manufacturing principles. Discussing the links between these two concepts presents the main goal of the BRC Standard for Packaging, i.e., – integrating critical processes, increasing the safety of food packaging and the successive improvement of the quality of manufactured products. However, a special role is given to Lean tools that can significantly support both the implementation and operation of the BRC Standard for Packaging in an enterprise.

The Five Lean Manufacturing Principles generate the potential for improvement of the BRC Standard for Packaging. The paper identifies the common denominators of both methodologies, whose effective implication will contribute to increasing the efficiency of a company with an integrated quality management system in the production process.

The BRC Standard for Packaging and the Lean Manufacturing approach have a lot in common. Their main goal is to improve the functioning of a company, which is why individual components of both methodologies are consistent. The managers of individual cells in enterprises should combine individual task functions in a process approach and cultivate this way of thinking among all staff. The adaptation of preventive actions, having their sources in both concepts, increases the probability of proper processes related to the continuous improvement of the whole organisation.

The analytical and conceptual work carried out on the integration of both approaches is important, because these issues are vital to companies operating in the packaging production sector. This work consists of the rapid and effective improvement of operational efficiency and competitiveness. Further research is needed on how to solve the issues raised in this article, first of all regarding the negative impact on the Quality Management System. It should be emphasised that both the Lean Manufacturing and the BRC Standard for Packaging can be subject to adjustments. The areas identified as supporting the BRC Standard for Packaging, or supporting each other, require the development of many practical details for coexistence. It is a very important topic, which should be the subject of further research. This study is an introductory discussion on the vivid managerial issue of the smooth and mutually beneficial coexistence of the Lean Manufacturing methodology and formalised systems, such as the BRC Standard for Packaging.

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Seru production as an alternative to a traditional assembly line

Patryk Zwierzyński, Hesham Ahmad

ABSTRACT
The article presents the concept of seru production and a simple simulation experiment to check the application effectiveness of the seru production concept in the assembly line of finished products. The article presents the concept of seru production created by Japanese electronics manufacturing companies in the 90s. The simulation experiment showed, better results using the seru production concept compared to a traditional assembly line. Three types of production cells were used and each option turned out to be better than a traditional assembly line.

KEY WORDS
seru production, production management, simulation

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Introduction

The currently prevailing market conditions can be described as unstable. The reason behind the restless market is mainly factors, such as short product life cycle, a variety of existing products and those required by consumers, and the need to adapt to these requirements. Meeting customer requirements require a high degree of production flexibility, reducing production costs and production batch size and shortening delivery times (Gálová et al., 2018). The concentration of future operations and the development strategy (businesses, regions) containing key factors for technological development can contribute to the ultimate success. In the context of prospective management of the technological development, a selection of key factors can form the basis for the construction of the desired development scenarios for an object or system (Nazarko et al., 2017). An important element of a company's operation is to anticipate the future and opportunities that may arise. Knowledge concerning the current trends in technological development is also necessary. The concepts allowing to predict the future state of technology include technology assessment, technological forecasting, and technological foresight (Halicka, 2018).

Many approaches have been developed to improve the competitive ability in an unstable market. They help companies to manage decisions and organise production processes. Lean management and agile management are among the most commonly used concepts. These concepts are very well known and widespread among enterprises

Seru production is one of the newer Japanese concepts of production management. The main premise of the Japanese method used to organise cheese production was the transformation of traditional assembly lines into production cells. The cellular arrangement of production is considered an ideal combination of lean and agile models (Yin et al., 2012).

The transformation of traditional production lines into cell production is mainly caused by changes in the market, which force the producers to change the management approach to the production process, enabling a quick response to market opportunities, as well as customer requirements. Seru production seems to be a response to such changes taking place in the environment surrounding a company (Zwierzyński, 2018, p. 530).

The article is divided into three parts. The first part presents the concept of seru production as an alternative to traditional production lines. The second part presents a simple simulation experiment and the achieved results. In the last part, a short summary of the article is given.

1. Seru production

Wemmerlöv and Hyer described seru production as a production type that belongs to the cell production group, whose main assumption is the creation of production sites for a family of parts or products with similar process requirements, clustering of various processes in close proximity, and designing supporting social engineering systems (Zwierzyński, 2018).

Transformation of an assembly line into seru cells, which was initiated in Sony factories, was considered by Kaku an innovation of assembly systems and has been widely applied in the Japanese electronical industry (Kaku, 2017).

Villa and Taurino indicated the following reasons for the emergence of seru production in Japan (Villa & Taurino, 2013):

- customer requirements,
- low flexibility of an assembly line,
- a long period of stagnation in Japan after 1991,
- low morale of employees working on traditional production lines,
- Toyota Production System (TPS) restrictions,
- globalisation and increased competition.

Despite using Toyota's concept in the production of goods, the changing environment and customer requirements forced Sony to reorganise its production line, which lacked the flexibility to take advantage of the emerging market opportunities. At that time, Yamada Hitoshi divided a production line of one of the offered products into many smaller lines creating production cells (Zwierzyński, 2018). A detailed description of the introduction of the seru production concept and its management mechanisms has been offered by Yin, Stecke and Kaku (Yin et al., 2008), and Stecke, Yin, Kaku and Swink (Yin et al., 2012).

The concept of seru production is similar to assembly cells — a widely used assembly system in Western industries. The type and method of using equipment, machines and tools are less important in the concept of seru production compared to cell production. As an assembly system focused on a human being, a seru cell is an old-fashioned factory where a craftsman independently assembles an entire product from the beginning to the end. The arrangement of production according to the seru concept is considered an ideal combination of lean and agile models.

One of the main assumptions of the seru production concept is to transform a traditional production line into many short lines eventually leading to the creation of cells with one employee. The Japanese form of cell production has been clearly developed as an alternative to the Toyota Production System. An example of the transformation of a cheese production line is given in Fig. 1.

By removing a traditional assembly line and creating seru cells, it is possible to reduce the number of employees while maintaining or increasing efficiency. The Japanese concept of seru production assumes that seru cells should be cheap, repeatable, and suita-

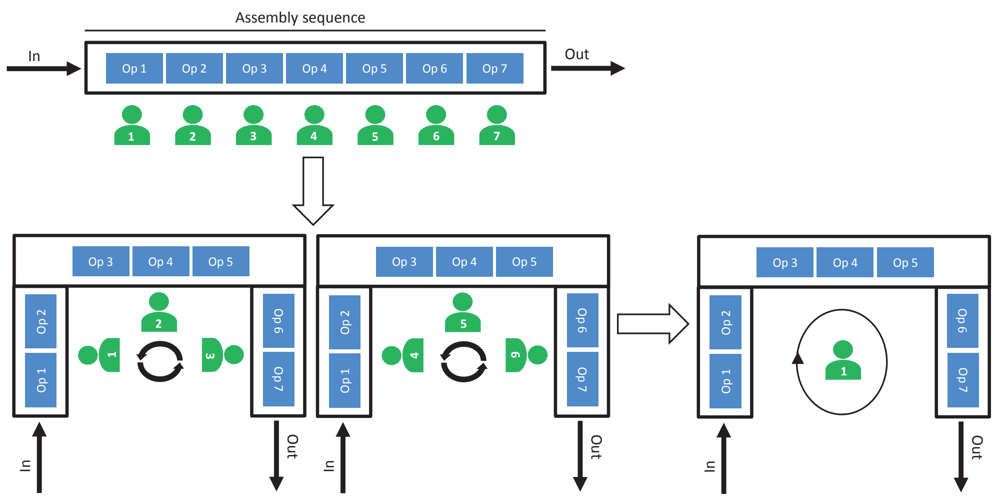

Fig. 1. Conversion of the assembly line to seru cells

Tab. 1. Results achieved by Sony and Canon after the implementation of seru production

SONY	CANON
Increased productivity Employment reduced by 25% The length of assembly lines reduced by 35000 m Improved product quality Required space decreased by 710 000 sq. m	Increased productivity The length of the assembly lines reduced by 20000 m Required space decreased by 720 000 sq. m Employment reduced by 25% Costs decreased by 230 billion yen Order fulfilment time reduced by 30%

ble for many tasks. Seru cells are easily adapted to different production depending on the product range.

Many scientists argue whether seru production is a new concept or something that belongs to the cellular production arrangement. Indeed, there are very many features common to both forms of production management. Nevertheless, seru production differs from cell production by one essential feature, namely, employee competencies. The concept of employee competencies is the subject of interest for many scientific publications. The colloquial, everyday approach uses the notions of competencies, skills, qualifications, authorisations and duties interchangeably (Gudanowska et al., 2018). In seru production, a significant role is attached to employee skills with the aim of having staff able to perform many activities in different production cells. Fig. 1 shows the limitation of the number of workers in converting an assembly line into seru cells. In the last case, one employee performs the activities previously performed by many employees. An example of using such an approach is presented later in the publication.

The seru production concept has been widely used in the Japanese electronics industry. The best described and documented cases involve Sony and Canon. The results achieved by these enterprises are presented in Tab. 1.

Seru application history is still not long enough to solve many of the production problems. Many factories could not improve their performance by implementing seru production methods, mainly because most manufacturing managers are unfamiliar with the basic knowledge of seru production, and because the implementation of seru production differs from factory to factory with different conditions and market environments (Liu et al., 2014). Other research has argued that the implementation of seru production systems might be associated with additional cost for training and assigning multi-skilled workers, which need special care to be minimized (Ying & Tsai, 2017).

Hence, this article aims at enhancing the understanding and implementation of seru production in both academia and industry.

2. Computer simulations

Due to their potential to efficiently solve complex problems, computer simulations have gained and continue gaining importance and popularity. The growing popularity of this research method has contributed to the development of newer programming languages and tools that enable the performance of increasingly complex and demanding simulation experiments.

Simulations of production processes are a form of experiments on a computer model. The goal of the experiment is to answer the question of how a change in the production process will affect results. Implementation of computer solutions in production engineering allows reducing costs incurred by enterprises due to wrong decisions when planning and modernising production. Simulation experiments are also helpful in shortening production time, planning new products and selecting production strategies by enterprises (Kikolski, 2016).

Simulation programs offer great opportunities to analyse even the smallest changes in production processes. When creating a model, it is important to decide whether the primary phenomena are events or whether the continuity of change is important (Badura, 2017). Adding a warehouse between operations, changing the order of production processes, or even changing the amount of one-time goods to individual positions can give positive results. A change in the arrangement of production is also a change that can produce positive results. However, this is a big upgrade, and the use of simulations seems to be the best solution.

The author of the publication used the Simul8 simulation program to carry out a simple simulation experiment. The program has a simple assembly process of the finished product using a traditional assembly line.

SIMUL8 simulation software is a product of the SIMUL8 Corporation used for simulating systems that involve processing of discrete entities at discrete times. This program is a tool for planning, design, optimisation and re-engineering of real production, manufacturing, logistics or service provision systems. SIMUL8 allows its user to create a computer model, which takes into account real life constraints, capacities, failure rates, shift patterns, and other factors affecting the total performance and efficiency of production.

This model makes it possible to test real scenarios in a virtual environment, for example, simulate planned function and load of the system, change parameters affecting system performance, carry out extreme-load tests, verify by experiments the proposed solutions and select the optimal solution. A common feature of problems solved in SIMUL8 is that they are concerned with cost, time and inventory.

3. Simulation experiment

Simul8 simulation software has been mapped to a simple assembly line of the finished product. The assembly process of product A is implemented in six consecutive assembly operations. Each assembly operation on the assembly line takes an average of one minute. The components are delivered to the plant once a day in an amount of 200 pieces. The plant works five days a week, eight hours a day. Each operation is performed by one employee. Employees work for eight hours, and their availability is 100%. The experiment assumes that the conversion of the assembly line into cells does not generate higher costs, the time of performing the activities is unchanged, and the work efficiency does not change. Fig. 2 shows the mapping of the production process in the Simul8 software.

In the traditional assembly line, 753 pieces of the finished product were made. In the next steps of the simulation experiment, the assembly line was converted into seru cells. First, two shorter assembly lines were created (Fig. 3), where each of the employees performed two assembly operations.

The next step was to convert the assembly process into three seru cells, with two employees performing three assembly operations. The mapping of this process in the Simul8 software is shown in Fig. 4.

The last step was to convert the assembly process into six seru cells, serviced by one employee performing six assembly operations. The mapping of this process in the Simul8 software is shown in Fig. 5.

4. Discussion of the results

The results obtained from each option are shown in Fig. 6. Six indicators were compared, namely, produced, stocks, the average time in the process, the average waiting time in the process, cost and the use of employees. One can notice a high improvement in the results achieved in the cellular organisation compared to the results of the traditional assembly line.

In a traditional assembly line, the manufactured products do not exceed 800 pieces, amounting to only 753 pieces per week. Such an arrangement of the production causes the accumulation of stock, increases the average production time, and limits the use of employees.

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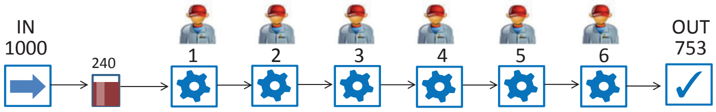

Fig. 2. Product A assembly line

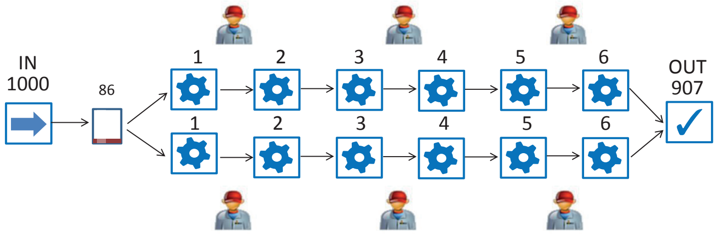

Fig. 3. Seru production 1

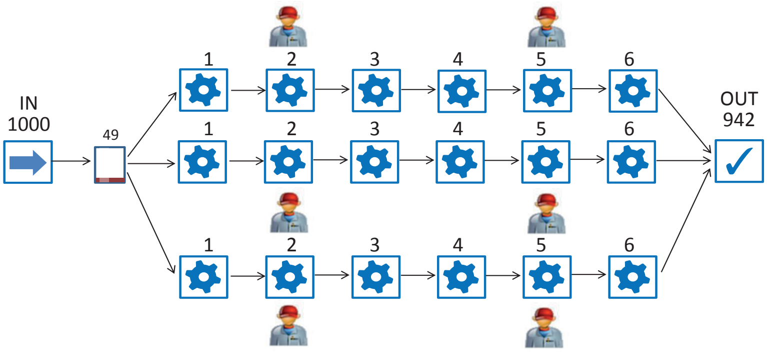

Fig. 4. Seru production 2

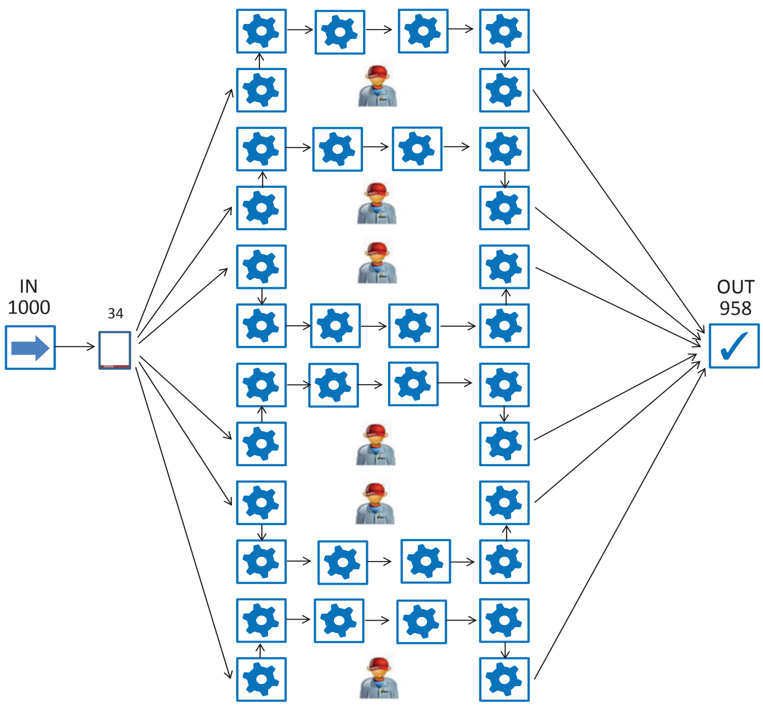

Fig. 5. Seru production 3

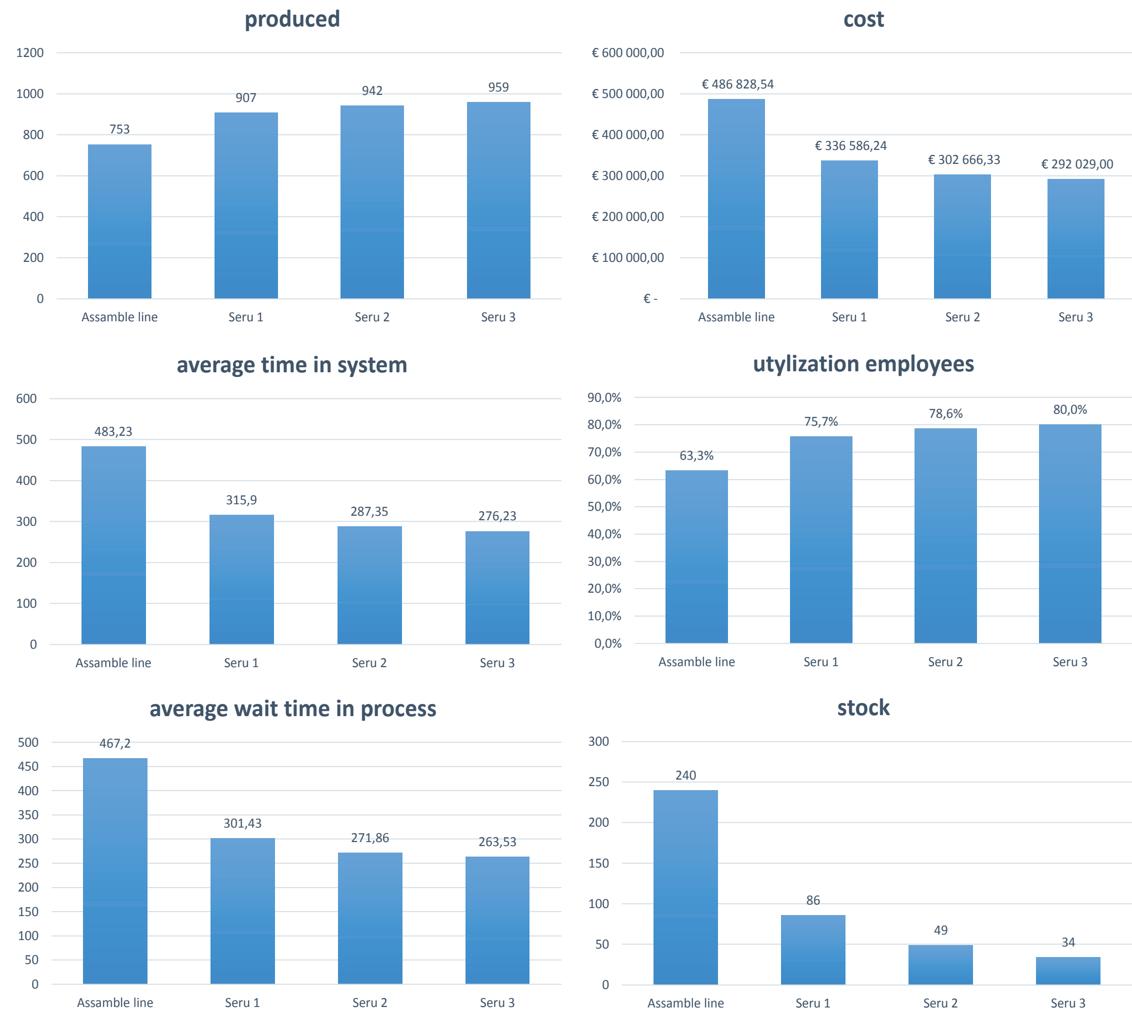

Fig. 6. Results

When seru cells are used, improvements are clearly visible. The number of finished products in each of the options exceed 900, and the remaining indicators demonstrate improvement. Increased production when using the seru production concept is visible already at the state of the division of the line into two cells operated by three employees in each. Conversion of the line into cells resulted in an increase in finished products by 154 items. The division into smaller cells operated by a smaller number of employees resulted in an increase in production by 189 items and 206 items, respectively.

After the assembly line was converted into seru cells, the cost of production decreased as well. Costs of the production line amounted to EUR 486 828.54, and in the case of two production cells, it was reduced to EUR 336 586.24, which amounted to a cost reduction of approximately 31%. The division of lines into smaller production cells also reduced the production costs by 38% and 40%, respectively, compared to the assembly line.

In each case, the use of seru production reduced the average time of product manufacture from the moment a component is delivered to the enterprise. In a traditional assembly line, the average product assembly time was 483.23 minutes. After converting the assembly line into production cells, the average time was 315.9, 287.35, and 276.23 minutes. Accordingly, the average time in the system can be reduced by 2077 minutes or by about 43%.

The use of employees increased together with the division of the assembly line into production cells. Initially, the average use of employees on the assembly line was 63.3%. The seru production concept allowed to increase the use of employees 80% for the case of six cells.

The average waiting time was reduced in every case of seru production. In a traditional assembly line, the average waiting time was 467.2 minutes. After converting the assembly line into production cells, the average time was 301.43, 271.86, 263.53 minutes. As can be seen, the average waiting time can be reduced by 203.67 minutes or by about 43%.

The components required for a finished product were delivered each day in quantities of 200 items and stored at the warehouse. The use of a traditional assembly line resulted in their accumulation and related costs. At the end of the simulation period, there were 240 items at the warehouse. The conversion of the assembly line into production cells has allowed reducing the component storage by 154 items for the case of two cells, 191 items for the case of three cells, and 206 items for the case of six cells.

Comparing individual forms of mobile organisations, the differences between the results achieved are not as large. Therefore, a more profound analysis of the profitability of transforming larger production cells into smaller ones should be carried out. When conducting a more accurate simulation experiment, one should consider the efficiency of more activities performed by one employee.

Conclusions

The article aimed to review the literature in the field of seru production and make this topic more relevant to readers. The literature review confirmed the author's belief regarding the need to change the way production in enterprises is organised. The changing market conditions force companies to think about how to achieve a competitive advantage in the market. One of the ways may be to transform a traditional assembly line into seru cells.

The results achieved by Japanese electronics companies are convincing. This form of production arrangement can be an alternative to traditional production lines. The author of the article, however, did not find successful examples of seru production implementation in other types of industry. Therefore, it should also be considered whether this method could be used in other types of industry.

The article also presented a simple simulation experiment. This experiment only concerned the assembly process of one product and did not consider many complex factors. The assembly process consisted of six activities performed by six employees. The purpose of this simulation experiment was to check the efficiency of transforming traditional production lines into seru cells.

The results obtained using Simul8 software allowed stating that this form of production arrangement can be more effective than traditional production lines. The comparison of the results received using a traditional assembly line production cells showed improvement possibilities. The results of the six analysed indicators in each case were definitely better when using the cellular method of production. The experiment resulted in reduced stocks, average time in the process, average waiting time in the process, and cost. The use of employees, as well as the number of finished products, was improved.

The decision regarding the number of cells as well as people working in these cells is, however, more difficult. The results achieved in three different seru production options are very similar to each other.

However, determining the cost-effectiveness of converting a traditional production line into seru cells is a complex problem. The author is aware that such a simple experiment can only serve as means for future research and the reflection on the subject of cheese production.

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Facility layout design – review of current research directions

Mateusz Kikolski, Chien-Ho Ko

A B S T R A C T
The article discusses the topic of designing the optimal distribution of workstations within a production plant. A review focused on publications on this subject in the Scopus database, covering the years 1975–2017. The article presents a facility layout problem and basic principles of optimisation methods for the distribution of workstations within the factory. The author proposes a methodology for designing the optimal distribution of workstations using available optimisation methods and computer simulation. Also, directions for further research are indicated.

K E Y W O R D S
facility layout, production lines design, production optimisation, workplace planning

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Introduction

Contemporary production companies must quickly adapt to the changing requirements of customers, i.e. implement structural and technological changes and production projects related to manufacturing of new products (Koliński & Tomkowiak, 2010). The dynamic development of technology, under conditions of globalisation and strong competition, determines the use of new, innovative, efficient and more profitable solutions in the field of production engineering (Halicka, 2016a). The correct division and organisation of the workflow within a given production unit is the basis for the functioning of production processes (Kosieradzka, 2008).

Important factors enabling the improvement of the manufacturing process are the planning of rational material flows in the production process, aimed at reducing production-in-progress stock (Wolniak, 2013), and the correct distribution of production infrastructure inside a plant (Staniewska, 2015). These factors are related to facility layout.

Continuous improvement could be regarded as a principle for an enterprise's survival (Godinho Filho et al., 2016). Improvements can be carried out at any stage of the manufacturing process. From the point of view of a manufacturing company, the productivity of a production line is a key parameter (Brundage et al., 2016). The performance analysis, which assesses the level of production, the average level of stock as well as the profit rate is of great importance in the design and operation of production lines (Gálová et al., 2018). The essence of production line improvement lies in the continuous analysis of carried out processes. Facility layout, elements that make up the production line, plays a crucial role in production improvement.

Determining and defining emerging problems is decisive and allows choosing the best optimisation solution while improving production performance (Kikolski, 2018). Methods for the optimisation of production lines mainly focus on the improvement of line performance or increasing the speed of its operation (Azadivar & Wang, 2000).

The main factors determining the structure and organisation of production lines are design goals, required or available infrastructure and the number of products manufactured. How to utilise available infrastructure to effectively produce required products has been considered as a goal of facility layout design (Friedrich et al., 2018).

1. Characteristics of the facility layout problem

The basic objective of planning the deployment of workstations is to develop a system that would be the most suitable for production and bring savings. Among the types of workstation placement, one can distinguish process-oriented locations such us nesting system – related machines in production sockets, the product such us flow system – machines arranged according to the order of tasks and production lines such us grouping of machines into lines for similar products. Firstly, the main optimisation problem is the location of the devices. The arrangement workplaces facing the product have a problem, namely, a proper balancing of the production line (Zwierzyński, 2018). In the case of specialised industries, the appropriate distribution of production departments is also paramount: important departments should be located close to each other and separate those departments that should not be in close proximity (Kikolski, 2018).

One of the key elements of production optimisation is proper planning and scheduling of production tasks and the deployment of workstations. The production efficiency depends largely on the location of the production equipment within the plant. There is also a close relationship between the manufacturing process and the available surface (John & Jenson, 2013). Appropriate placement of machines within a production line considers the optimal use of available space, time and cost of material flow, and production flexibility. The incorrect layout of workplaces results in possible losses (Piskrzyńska & Cieślar, 2015). There are many factors affecting the shape and manner particular to the operation of production lines, including the number of working shifts, the size of production batches and their nature (variable or constant size of the lot), and types of transport and storage. Due to a large number of possible connections between positions and the resulting differences in their mutual location, the optimisation problem is usually solved with one (or several, together) criteria (Lis & Santarek, 1980):

- minimisation of transport or mass of transported details,
- minimisation of transport routes,
- minimisation of the number of transport operations,
- minimising transport costs,
- minimising the costs of locating positions,
- minimisation of total transport costs and location of stands.

The optimal placement of workplaces should shorten the production cycle, reduce production costs or improve the use of production resources (Hu et al., 2011; Vergara & Kim, 2009).

2. Literature review

To identify methods used for the optimisation of the workstation distribution, a bibliometric analysis was made, which enabled the assessment of the dynamics of changes in the number of publica-

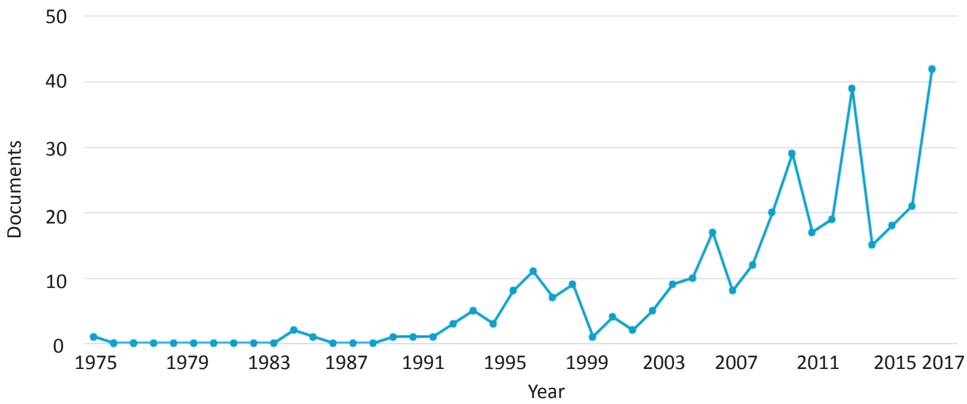

Fig. 1. Number of publications indexed in 1975–2017 in Scopus database referring to the facility layout optimisation

Source: elaborated by the authors based on (http://bazy.pb.edu.pl).

tions in the examined period. Due to the size and availability, the publications were reviewed in the Scopus database. The database search was focused on the problem of facility layout optimisation mentioned in keywords, titles and abstracts. The analysis covered the years 1975–2017. 341 studies were found registered in the Scopus database for the analysed period. The importance of the topic is constantly growing. This statement is supported by the growing number of studies available in Scopus database from one year to another. The number of publications in particular years of the analysed period is shown in Fig. 1.

In the first part of the surveyed period, the increase in the number of publications was slow. The first study available in the database comes from 1975, but in the next fifteen years, only five articles were published in the field of facility layout optimisation. The last 25 years indicate a sudden increase in the interest in the discussed topic. The number of research works on the problem of workstation distribution optimisation underwent a steady increase. Also, research efforts intensified at the beginning of the second decade of the 21st century, when the number of studies increased threefold in comparison to the period preceding 2010.

Main thematic areas of the highlighted articles available in the Scopus database were Engineering, Computer Science, Decision Science and Mathematics, amounting to a total of 84,5% of all publications. The indicated thematic areas include both methods of solving (methods) and presenting (models) problems related to the optimisation of the layout of the production halls.

The final stage of the bibliometric analysis concerned the evaluation of the coexistence of words and their co-classification. The method used to analyse the coexistence of words was based on counting the sequence of words appearing in the text. This method allows the classification of research sub-areas based on the co-occurrence of words. Using the VOSviewer software, a bibliometric map was developed, which is a visualisation of the results received from the analysis of coexisting words. The size of the circles reflects the number of specific words, while the distance between the circles depends on the number of co-occurrences (Halicka, 2016b). The results of the article analysis are presented in Fig. 3.

The analysis of the coexistence of words made it possible to identify five clusters that together contained 41 words/terms. The proposed cluster names refer to most of the terms of a given cluster. The analysis of the coexistence of keywords identified by the authors of articles resulted in the following clusters:

- Cluster I – ways for presenting the layout of workplaces,
- Cluster II – methods of system optimisation,
- Cluster III – factors affecting the distribution of workstations,
- Cluster IV – ways for formulating problems related to the arrangement of objects,
- Cluster V – study objects.

According to the literature review, main problems related to the design and operation of production lines were (Teunter et al., 2008; Zawadzka, 2007) determining the number of machines within a line, the location of inter-operation buffers and their size, and the layout of machines and stations working within a plant. Appropriate optimisation methods are necessary for the elimination of the problems men-

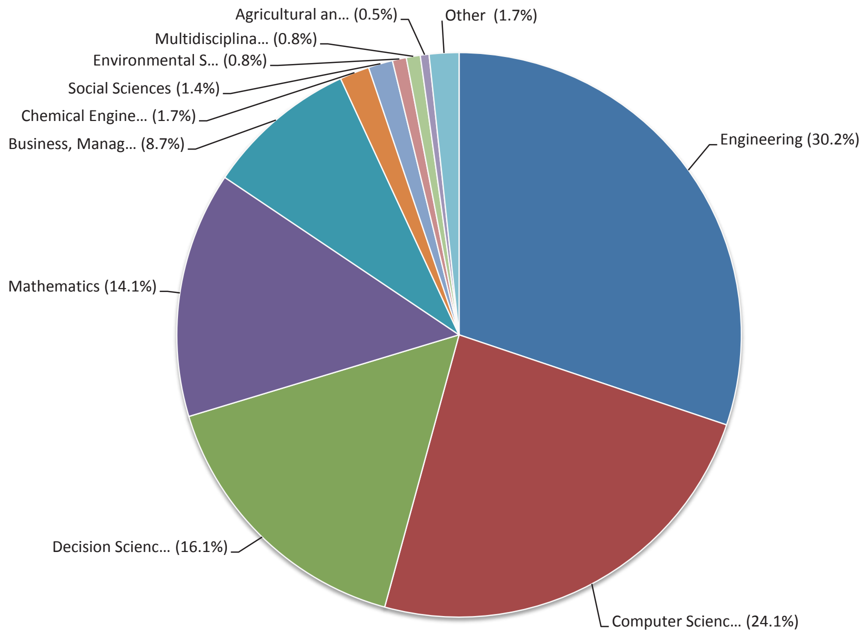

Fig. 2. Most popular subject areas of articles indexed in Scopus database referring to the layout optimisation

Source: elaborated by the authors based on (http://bazy.pb.edu.pl).

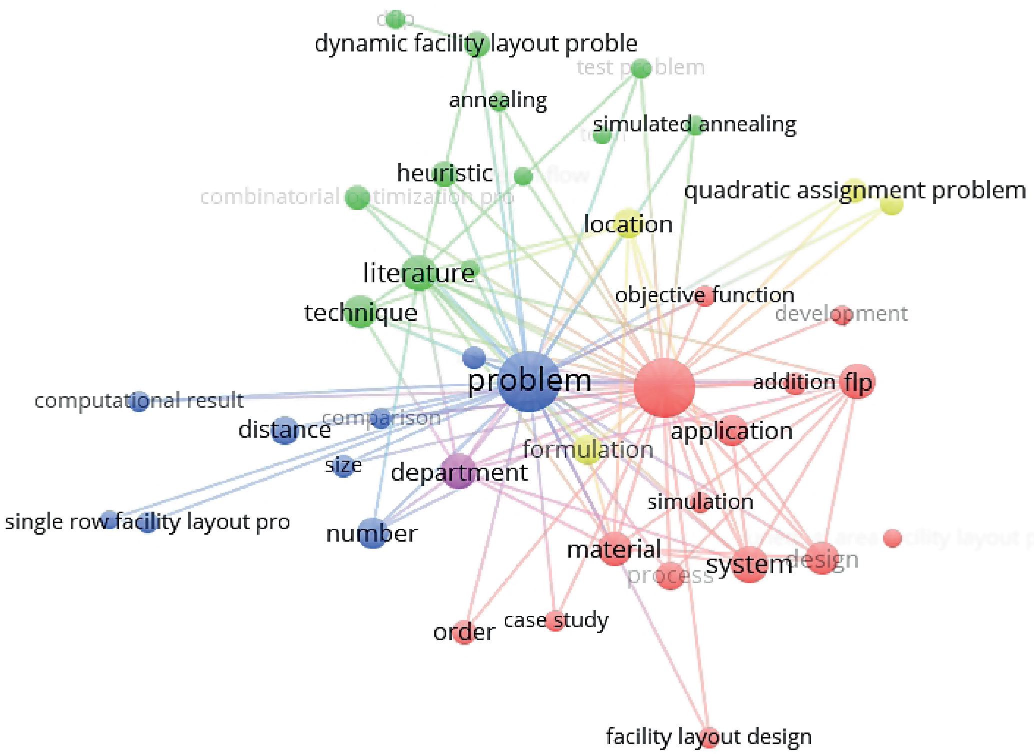

Fig. 3. Map of co-occurrence with research areas related to the scope of the facility layout optimisation problem from Scopus database in 2012–2017

Source: elaborated by the authors based on (http://bazy.pb.edu.pl) with the use of the VOSviewer software.

tioned earlier related to the design and operation of production lines.

Optimisation methods for production processes are, considered an important tool for continuous improvement of product quality (Radziszewski et al., 2016). They include the modelling of input and output parameters and the determination of optimal conditions (Mukherjee & Pradip, 2006). There are many ways to optimise the placement of workstations. For example, Santarek and Lis distinguished 86 methods (Lis & Santarek, 1980). They selected four criteria for the classification of the methods, namely, the accuracy of obtained solutions, the manner in which positions were set up, the type of placement received, and the form of the presentation of the set-up positions. The mentioned classifications included numerical parameters of the method and their operational properties and did not consider the characteristics of the manufacturing process. Methods for workstation layout optimisation are constantly modified and developed. Among the currently available methods used to optimise the deployment of workstations, the following can be distinguished (Sa'udach et al., 2015; Aydinel et al., 2008; Khan, 2004; Burduk et al., 2016; Wu et al., 2007; Mahdavi et al., 2009; Zielecki et al., 2014; Kowalski et al., 2016; Ojaghi et al., 2015; Ertay et al., 2006; Abdinnour-Helm et al., 2000; Hassan et al., 1986):

- mathematical methods,
- CORELAP,
- Schmidgall's triangles,
- Systematic Layout Planning (SLP),
- COFAD,
- BLOCPLAN,
- SHAPE algorithm,
- Graph-Based Theory (GBT),
- strategies for minimising transport costs,
- CRAFT,
- ALDEP,
- LAYOPT.

Existing methods for the optimisation of workstation can be divided into strict and approximate methods, of which strict methods can be applied only in the case of the limited choice of the workspace (Santarek, 1987). The wider application of methods occurs in the case of approximate methods, among which one can distinguish methods with limited and unlimited possibility to choose places.

The large number and variety of available optimisation methods may generate difficulties related to the choice of the appropriate method depending on the type and characteristics of the manufacturing process (Halicka et al., 2015). It is necessary to create a solution supporting the selection of an appropriate method to optimise the deployment of workstations, enabling the improvement of manufacturing processes. Also, despite the diversity and a large number of methods used to optimise the distribution of workstations, there are often no clear rules related to them.

An important factor is the limitations and strengths of the methods used for the optimisation of facility layout, which have been presented in the literature, as well as the appropriate indication of problems that can be solved with their help. Main features of production lines that are important in determining the best optimisation method are as follow (Rekiek et al., 2002):

- topology of the manufacturing process,
- designation of available equipment,
- connections between devices,
- method and location of stock storage,
- material transfer – the determination of transport routes,
- lot size,
- batch processing time,
- number of working shifts,
- resource constraints,
- time limits,
- costs.

It should also be noted that other methods are used when reorganising and designing new production lines (Lis & Santarek, 1980). The set of methods used to optimise the distribution of positions within a production line is the basis for developing a solution to support the design of production lines. Selected optimisation methods were used to develop the original methodology for the design of the optimal distribution of workstations, which would allow accelerating the design of new or the improvement of existing production processes.

3. Proposal of an original methodology for the facility layout design

Available studies indicate that many production companies have little knowledge in the field of planning and production control, and optimisation methods are used rarely or not at all. The theory and methods for solving optimisation problems are either unknown or improperly understood by practitioners (Siderska & Jadaan, 2018). Another indicated problem is the belief that theoretical situations are not sufficiently similar to those found in practice (Rekiek et al., 2002). The reason for this situation may be the lack of a comprehensive look at the problem related to choosing of the right method for the optimisation of the workstation deployment and the lack of a tool to support the selection and the use of the optimisation method to solve a specific problem.

The methodologies used to optimise the facility layout have some limitations (related to failure to adapt to current trends in the design of manufacturing processes, among other things, and a decision problem related to the selection and application of appropriate optimisation methods to specific features of the manufacturing process); consequently, they must be further developed.

The literature review revealed a methodology for designing the arrangement of objects based on the Systematic Layout Planning. However, it has a number of limitations, the most important of which is narrowing down the research to the use of one approach in the deployment of workstations (Yang et al., 2000).

Lis and Santarek (1980) prepared a general scheme of the methodology for designing the deployment of workstations based on the operational research strategy. The authors stated that the indicated scheme could be used in the design of new production cells or the remodelling of existing ones, but they did not indicate differences between the two. The proposed methodology scheme consists of five main stages, namely, the formulation of project task, the construction of a mathematical model, the solution of the task, model adjustments and solution evaluation, and project implementation. The discussed methodology does not specify the method for selecting the optimisation method depending on characteristics of the manufacturing process. The authors acknowledged a large number of available methods and indicated that their variety imposes to choose one. However, a particular method or a group of methods is not chosen dependent on the characteristics of the manufacturing process. Therefore, it is necessary to prepare a methodology that considers the knowledge about the type and characteristics of the manufacturing process, the criterion of optimisation, limitations of the production process, and available methods of optimisation. The methodology should consist of a description of the stages, activities and activities used to clearly describe how to optimise the design of workstations. It should also include a set of methods that can be applied depending on the specific characteristics of manufacturing processes.

The initial research assumed that the original design methodology (Fig. 4) would consist of two blocks: a part supporting the design of a new layout of workstations and a part dedicated to the reconstruction of the existing layout of the stands.

From the standpoint of a factory, studies are desirable regarding non-interference with the operation of the production line (Pałucha, 2011). The problem of the deployment of workstations can be modelled using various types of tools, including spatial, structural and mathematical models (Jakowska-Suwalska & Wolny, 2009). Currently, digital models depicting the existing infrastructure are a popular tool used in the optimisation of manufacturing processes and the positioning of workstations within production lines (Ryan & Heavey, 2006; Matuszek & Kurczyk, 2017). Planning research based on simulation models can greatly contribute to the development of efficient production lines. Research that does not interfere with the work of the manufacturing process requires the development of a methodology that considers the use of a model simulating the operation of production lines and containing process parameters. A correctly constructed simulation model allows predicting the effects of changes and the choice of the optimal decision variant.

In the part supporting the design of a new workplace layouts, key elements are gathering and analysing the parameters of the projected placement (identifying the number of positions and establishing connections between positions) and choosing the method for optimising the distribution of positions are using which the layout of the production line implemented in the digital model would be designed (phase I). The next steps are the analysis of the developed model and the comparison of the results obtained and the selection of the best solution (phase II).

The second part (reorganisation of the facility layout) consists of four main stages containing elements of the digital model structure pertaining to the tested object, the diagnostics and optimisation phase, and the evaluation of the obtained results:

- construction phase (I) – containing the examination of the current configuration of workstations and the construction of the model;
- diagnostic phase (II) – including the analysis of the simulation model (measuring the effective-

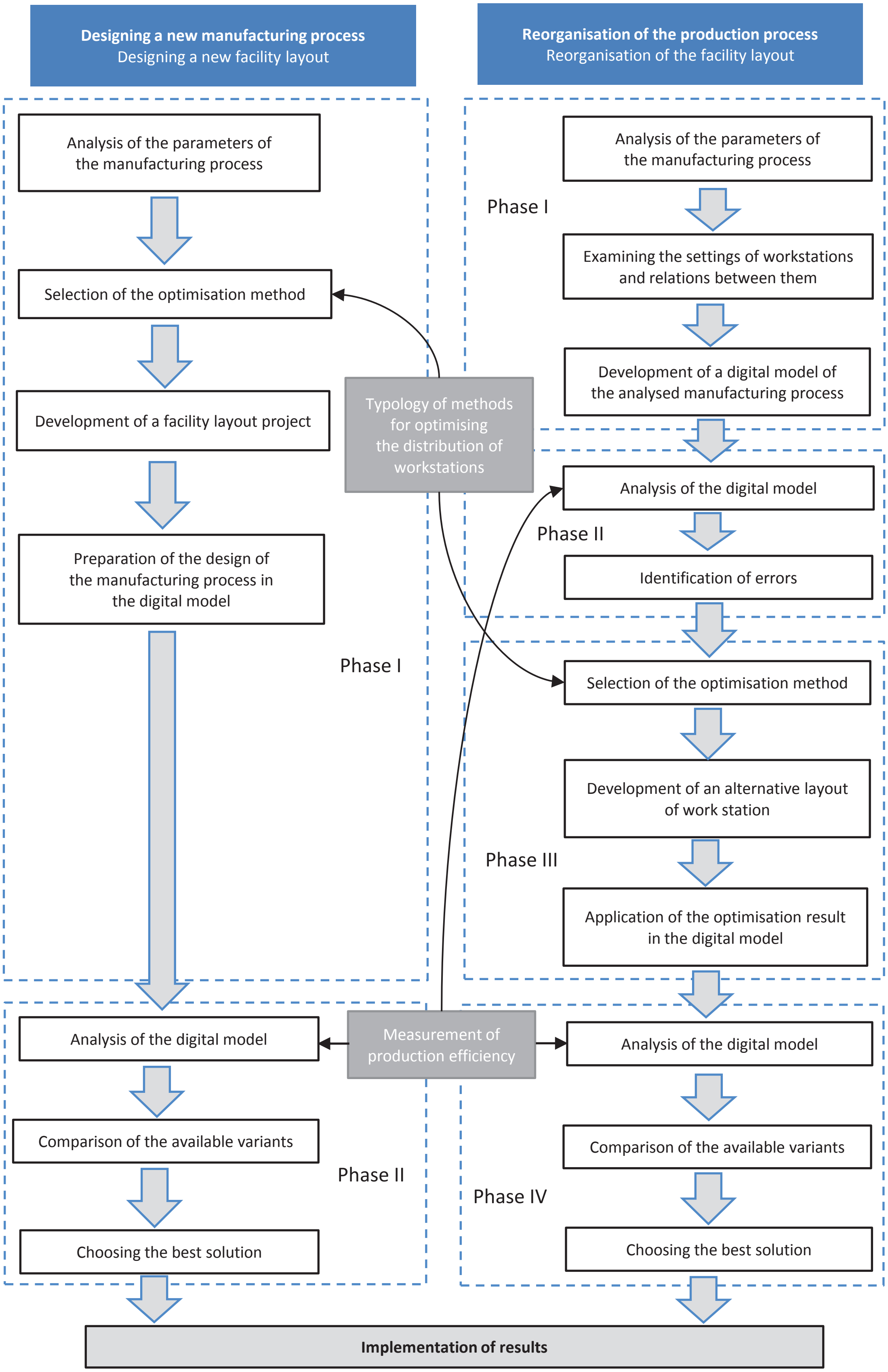

Fig. 4. Proposed preliminary diagram of the methodology for designing the optimal placement of workplaces

ness according to the index chosen by the designer while the indicators help in making decisions and conducting activities aimed at better and more efficient functioning of the production line) and identification of weaknesses (bottlenecks) of the production process;
- optimisation phase (III) – consisting of the selection of methods for optimising the deployment of workstations, developing an alternative solution and introducing results in a simulation model;
- control phase (IV) – comparison of the results obtained and selection of the best solution (if several are available).

The general diagram showing the elements of the methodology identified during the previous research is presented in Fig. 4. In the course of the research, the methodology will be detailed, and the relationships between particular elements will be analysed at a greater depth. It is also not possible to exclude the distinction or deletion of certain elements.

As mentioned before, there are many ways to optimise a facility layout, but there is no clear procedure for choosing methods that allow optimal placement of workstations. Therefore, the key element of designing the optimal distribution of workstations will be the original typology of methods for optimising the distribution of workstations, which, among other things, will consider the following: the type and characteristics of the manufacturing process, factors affecting the shape of the production line, and an optimisation criterion. The proposed typology will allow the selection of the best method for the optimisation of the distribution of workstations depending on characteristics of the manufacturing process. Choosing the right method will be a multi-stage task:
- phase I: defining the type of the designed production line;
- phase II: determining factors affecting the distribution of workstations;
- phase III: determining the optimisation criterion;
- phase IV: selecting the method for the optimisation of the deployment of workstations depending on the characteristics of the manufacturing process.

A multi-stage selection of the method used in the design or optimisation of production lines will allow narrowing down the choice of methods from the available number before the implementation in the simulation model.

Conclusions

The continuous need to effectively respond to competition and the growing pressure made by customers on product quality demands for the use of optimisation methods in production processes are fundamentally important for the production unit.

Problems related to planning and placement of production positions are not a new topic in the academic circles as these issues have been the subject of scientific research in response to constantly increasing competition between enterprises. The pressure to improve the technological processes of enterprises and competition in the market is also reflected in scientific research centred around production. A literature review on methods for the optimisation of workplaces indicated a constant and growing interest in the analysed topic. A review of publications in Scopus database was made with the aim to identify methods for optimising the facility layout and examine the dynamics of changes in the number of publications on the subject in question in 1975 – 2017. Research efforts related to methods used to optimise production processes have intensified in recent years. The analysis and use of optimisation methods, as well as the introduction of methods and the creation of new algorithms, is a constant research challenge.

Designing the deployment of workstations requires a two-pronged approach, namely, focusing on the design of new production lines and the reorganisation of existing systems. The literature review also unveiled a close relationship between scheduling and scheduling production tasks, and the facility layout designing. Available optimisation methods focus on improving selected process features. From the point of view of a production line technologist, it is crucial to choose a method or a set of methods with the greatest possible amount of available data.

Optimisation methods help to create a workstation layout scheme that allows the design of facility layout, including distances between machines, machine distances from transport routes or construction elements of production halls. An important condition for obtaining the intended effects is proper identification and quantification of emerging problems, as well as an appropriate selection of methods and tools leading to their solution.

The article is an introduction to further work related to the identification and classification of methods for optimising the distribution of workstations. The set of optimisation methods and tools was created as the basis for a further search for instruments to improve production processes and a base for in-depth research related to the optimisation of production processes. Focusing on the use of the chosen method, basic methods were indicated for the optimisation of production lines and the introduction to the original methodology.

Further research will include, inter alia, the development of the authors' typology of methods for optimising the distribution of workstations, considering the characteristics of the manufacturing process and optimisation criteria, as well as the verification of the authors' methodology for designing the optimal facility layout.

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