CONCEPT OF DISTRIBUTION NETWORK CONFIGURATION IN THE CONDITIONS OF CENTRALISED FORECASTING

Mariusz KMIECIK

Silesian University of Technology, Faculty of Organization and Management, Poland;
mariusz.kmiecik@polsl.pl, ORCID: 0000-0003-2015-1132

Introduction/background: The article presents a literature analysis related to the concept of distribution network configuration. The main determinants of network configuration and their impact on key solutions used in networks are also indicated. As a key solution related to the correct management of demand, including forecasting, the author considered centralisation in networks. The article also presents the results of research carried out on 5 distribution networks, in which the correlations between the elements of their configuration and the results of forecasts made using the tool previously created by the author are examined.
Aim of the paper: The purpose of the article is to present the concept of distribution network configuration in the conditions of centralised demand forecasts, with the central unit at the level of logistics operator. In addition, the article will consider the hypothesis regarding whether the configuration of the distribution network affects the accuracy of forecasts.
Materials and methods: The purpose of the article and verification of the hypothesis was carried out with the help of literature studies, results of the conducted case study, and on the basis of the results of forecasts obtained using the prognostic tool created by the author in the R environment.
Results and conclusions: The article demonstrates the basic ability of a logistics operator, working in MDP in the distribution network, to make forecasts and analyse the distribution network. In addition to that, the article presents results indicating that a properly selected configuration of the distribution network has a positive effect on the accuracy of forecasts contained in it.

Keywords: distribution network, forecasting, logistics operator, network configuration.

1. Introduction

The concept of configuration is used in many disciplines of science; however, for each specific one it must take the appropriate dimension (Frefercik et al., 2018). It is often referred to as the arrangement of individual parts that create a whole in an inseparable form, or an arrangement of elements that can change in different ways under the influence of certain circumstances (Kawa, 2011). Undoubtedly, it is a definition that focuses on the spatial positioning of nodes in the distribution network. Another definition, to which the author of this article is more inclined, regards configuration as a creation of connections, not only related to geographical positioning, but also to the appropriate level of relationships and flows occurring in the network. According to this approach, configuration is defined as: common clusters of attributes or relationships that are internally consistent (Miler, and Mintzberg, 1984). The configuration focuses on where to place individual activities in the enterprise value chain (Porter, 2001). It belongs to one of the main tasks of managing supply chains and distribution networks (Chandra, and Grabis, 2007), and the configuration problem itself is considered a strategic level problem in enterprises (Truong, and Azadivar, 2003; Tsiakis and Papageorgiou, 2008). In relation to the distribution network, the following configuration dimensions shall be indicated, which should take into account: network structure, network flows, and relationships and characteristics of services provided in the network. A configuration that incorporates many different aspects is called multi-configuration by some authors (Shishebori, and Babadi, 2018). It can be stated that network configuration is a strategic decision with a long-term nature and period of impact on enterprises (Kot et al., 2009). Among the goals of distribution network configuration, one can indicate, among others: minimising significant logistics costs, maximising customer service level, maximising profits generated by logistics (Bendkowski et al., 2010), as well as increasing network flexibility (Wasiak et al., 2019) and adapting the network to changing demand (Melacini, and Tappia, 2018).

By analysing the literature, the author identified 6 main determinants of distribution network configuration, and also indicated 4 main configuration solutions as a response to the needs of network configuration (Figure 1).

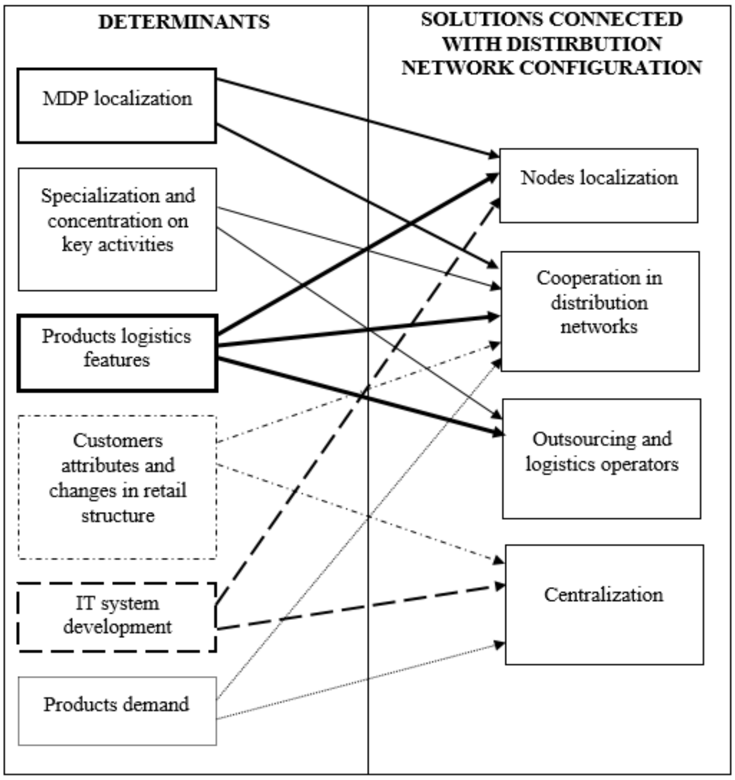

Figure 1. Distribution network configuration determinants and their influence on solutions connected with configuration.

The location of the MDP (Material Decoupling Point) determines the appropriate location of nodes in material flows and, in a way, enforces the use of certain forms of cooperation that are designed to enable actions specific to the appropriate forms and locations of the MDP (e.g. postponing the production of finished products or quick response to market demand in the MTO environment). The specialisation of enterprises and the focus on key activities affect the use of outsourcing services by enterprises in the network, and the presence of logistics operators in networks (Faur, and Bungau, 2019; Kramarz, M., and Kramarz, W., 2019). This determinant also results in new forms of cooperation that should be concluded between enterprises and their partners in the field of providing services. Product logistics characteristics determine the location of nodes in the network. Product features associated with, for example, its low transport or storage compliance may force a closeness between individual enterprises. The specific features of the products additionally enforce improved cooperation in the network to provide them to customers. Dealing with product flows with specific characteristics may also imply the need to use the services of specialised enterprises. Customer attributes and changes in the structure of retail trade, in particular the growing requirements and development of online commerce, make it necessary to change the strategy of cooperation in the network. This determinant also results in activities related to the decision to centralise or decentralise network activities. The development of IT systems results in changes in the requirements concerning the geographical location of nodes, where problems related to spatial distance are beginning to lose their significance. In addition, system development affects networking, which, supported by appropriate data exchange software, can evolve to a high level and bring great network benefits. IT systems and ways of collecting and transferring data also affect solutions related to centralisation (e.g. collecting data in a central link and sending data using EDI). Demand for products translates into the need to develop appropriate cooperation methods, in particular for products with irregular demand, so as to ensure them at the right time on the market, as well as to improve the effectiveness of forecasts for the implementation of centralisation solutions.

The author considers centralisation to be one of the most important configuration solutions. Centralisation is, from the author's point of view, a more appropriate concept in relation to forecasting in distribution networks. Centralisation is often only associated with the geographical positioning of warehouses (Schmit et al., 2015) and the associated stock management (Stevic et al., 2018). The opinion of the author is that this is not the right approach. Centralisation, in the opinion of the author, should be considered as a concentration of activities in one, separate and formalised cell (Droge et al., 1989), or as a consolidation of decisions made (Jonsson, and Mattsson, 2009). The main prerequisites for centralisation include (Szozda, and Świerczek, 2016): the diverse nature of individual activities, which are typical for many different organisational units operating in subsequent stages of product flow, the lack of separate units responsible for coordinating processes related to managing demand for products from other processes, as well as the vertical nature of organisational structures, which intensifies the phenomenon of independent decisions regarding demand management in individual entities. Actors operating in centralised distribution networks are divided into (Kawa, 2011): central enterprises, as well as suppliers, recipients, selected or collaborating competitors and other entities. The central link is one of the most important elements in distribution networks. Its occurrence is one of the basic forms of their coordination (Kramarz, 2018). The central entity in the literature has many names. There are terms such as integrator (Brzóska, 2007; Czakon, 2010; Schweizer, 2005) or leader (Ciesielski, 2009). Central enterprises are also known as orchestrators or hub companies (Czakon, 2015), or as flagship units, coordinators, creators or conductors (Barczak, and Walas-Trębacz, 2011). However, one of the common concepts is to combine the concept of the central link of the network with the concept of the flagship enterprise. According to some authors, due to the broad decision-making role of such an enterprise, it can be additionally treated as a network leader (Kramarz, M., and Kramarz, W., 2015), and the very shape of the network centre depends on the shape of the flagship enterprise and the characteristics of the MDP. The flagship enterprise is usually a large enterprise that deliberately creates a network in its environment to achieve its own goals and easily acquires a qualified workforce (Anokhin et al., 2019). It does not necessarily have to be related to logistics; its core activity can be directed to another industry. A flagship enterprise that implements processes related to logistics can be defined as a logistics node, which is responsible for the synchronisation of material flows and the coordination of tasks ordered to partners in the network (Kramarz, M., and Kramarz, W., 2015). It is characterised by its reputation (Xiaotong, 2019), and also by its market size (Bakhtiyari, 2015). Such an entity takes responsibility for the quality of the product delivery process to the customer (Kramarz, 2016).

Centralisation in demand management in the distribution network, including forecasting, should match stocks forming in and between individual links in the network, in order to meet the final demand of customers, and thus prevent a situation of shortage of stocks or their increased level. It also helps to create and adapt the forecast by accessing current information on demand and stock levels in individual links. The main driving force of centralisation is the transparency of activities (Ekinci, and Baykasoglu, 2016). Retailers and suppliers use demand information to create their own stock plans. A characteristic feature of centralisation is the consolidation of activities related to product demand management and their grouping into a separate functional area. The degree of centralisation indicates at what level decisions are made, who has power and the ability to influence others, and who has the right decision-making powers (Szozda, and Świerczek, 2016). Centralisation actions are also justified in ecommerce impact nowadays (Yang et al., 2020).

2. Methods

The chosen research methods included a literature analysis and a case study based on 5 distribution networks, in which functioned a logistics operator located at the MDP, as well as results from the built-in forecasting tool and results of the questionnaire (Table 1).

Table 1.
Research methods used in the paper

Research method	Brief description
Literature review	Analysis of the literature on elements of distribution network configuration, but also the characteristics of enterprises that are able to reconfigure the network.
Case study	Case study in 5 distribution networks, in which the logistics operator provides outsourcing services to manufacturers located at the MDP.
Results from the forecasting tool (developed in the R environment)	The results of forecasts placed automatically using the script created by the author in the adaptive R programming environment. In the script, the author used 16 different forecasting algorithms, of which the one with the highest degree of matching was chosen for individual time series.

The logistics operator in the distribution networks under consideration provides logistics services, on an outsourcing basis, for production enterprises that produce finished products in accordance with the push strategy for distribution centres of large retail networks and wholesalers, as well as directly to points of sale (POS). Logistics services provided by the operator are adequate to the attributes of 3PL operators since this operator functions as a separate link in the network. They mainly concern the implementation of warehouse processes related to the receipt, manipulation in the warehouse, storage and release of products, processes related to co-packing and co-manufacturing, as well as physical distribution of products, including transport planning and transportation of products to destinations. Information on the demand for products flows directly to the manufacturer from the network link, which is the next recipient of the product after the link constituted by the logistics operator. This information is a peculiar forecast related to the expected demand of subsequent links in the distribution network. In order to meet the demand and meet the requirements of its customers, the manufacturer forecasts production volumes based on historical data related to the sale of individual SKUs (Stock Keeping Units). The forecast made this way is usually based on distorted information about demand, which is distorted by subsequent links in the network and does not include activities related to its artificial creation by various links. The logistics operator gets information on the quantity of products that it has to take from the manufacturer, and then about the quantities it has to issue to individual points. In some situations the operator in the warehouse also performs additional functions that are required by customers in the network. These are functions related to co-packing, which involve changing the logistic unit in cartons and creating sets from various products, which is related, among others, to the creation of promotional sets, as well as functions related to co-manufacturing, where the operator takes over from the manufacturer the simple production tasks that they carry out on the created production lines in the warehouse.

3. Results

The overall structure of the network is presented in Table 2. The structure includes the SKU (Stock Keeping Units) in individual networks, as well as shares in assortment releases to individual network nodes.

Table 2.
Research methods used in the paper

No.	Quantity of SKU in network	Quantity of assortment groups	Assortment characteristic (main activity)	Number of nodes			Percentage of release directly from operator [%]		
				Distribution centres	Wholesalers	POS	Distribution centres	Wholesalers	POS
1	1,362	19	Chemicals and cosmetics.	322	0	14,695	78.39	0	21.61
2	1,152	15	Beverages and sweets.	132	231	17,343	25.15	19.08	55.78
3	415	12	Construction supply industry.	111	8	2,110	2.68	0.14	97.18
4	60	5	Sweets.	25	0	15	98.95	0	1.65
5	272	9	Chemicals.	180	0	8,180	100.00	0	0

The best results in terms of forecasting demand in the distribution network were obtained by distribution network No. 5, with an estimated MAPE of 13.58%. Subsequently, according to the verifiability of the forecasts, distribution network No. 2 – 17.52%, distribution network No. 4 – 17.58%, distribution network No. 1 – 17.76% and distribution network No. 3 – 37.43%. Forecast results are mostly similar. The following analysis is intended to show the reasons for discrepancies in forecasts in networks 5 and 3. The abovementioned relationships between the elements of the network structure and the verifiability of forecasts were tested using Pearson's r coefficient (r).

In the first step, the correlation between the impact of the share of products from the AX group (compared to the total number of products from the A group), as well as products from the AX and AY groups (also compared to the total products from A), and the prognostic errors of individual networks were found. The analysis showed a medium level correlation. The impact of the AX group on forecast errors was $|r| = 0.44$, and the impact of products from the AX and AY groups on the verifiability of forecasts was $|r| = 0.41$. Such a low result is caused by the fact that the forecasts for the least important products from the C group are highly verifiable. Attention should be paid to the operator's ability to forecast the most important products for the network from group A. The analysis also showed no relationship between the size and range of the assortment and the verifiability of the forecasts (correlations respectively: $|r| = 0.14$ and $|r| = 0.09$). This is mainly due to the individual approach when making forecasts for each product. Regardless of the number of SKUs, the proposed script puts individual forecasts for all available time series.

Elements that, in the author's opinion, additionally significantly affect the quality of forecasts, are also forms of cooperation between the production enterprise and the operator, as well as forms of relationships occurring in the network. These factors specify the elements that have the greatest impact on them. These elements received adequate weights and then were rated on a scale of 0 to 3 (where: 0 – needs immediate improvement, 1 – needs improvement, 2 – medium level, 3 – relatively satisfactory level). The results are presented in Table 3 and Table 4.

Table 3.
Examination of networks – cooperation between the manufacturer and the operator

The evaluated element of cooperation between the manufacturer and the operator	**weight**	**Distribution Network No.**				
		1	**2**	**3**	**4**	**5**
Exchange of information on changes in the designation of production and warehouse references	0.2	1	2	1	2	2
Exchange of information on sales picks	0.2	1	1	1	2	2
Sending aggregate forecasts	0.1	3	2	0	2	3
Frequent direct contact	0.1	2	3	1	3	3
Rare stock exchanges	0.15	1	1	2	3	3
Inclusion of an operator in the flow of information	0.25	1	1	0	2	3
Final evaluation		**1.3**	**1.5**	**0.8**	**2.25**	**2.6**

Table 4.
Examination of networks – relationship level

The evaluated element of cooperation between the manufacturer and the operator	**weight**	**Distribution Network No.**				
		1	**2**	**3**	**4**	**5**
Exchange of information on changes in the designation of production and warehouse references	0.2	1	2	1	2	2
Exchange of information on sales picks	0.2	1	1	1	2	2
Sending aggregate forecasts	0.1	3	2	0	2	3
Frequent direct contact	0.1	2	3	1	3	3
Rare stock exchanges	0.15	1	1	2	3	3
Inclusion of an operator in the flow of information	0.25	1	1	0	2	3
Final evaluation		**1.3**	**1.5**	**0.8**	**2.25**	**2.6**

Based on the results of the assessment of individual factors, as well as the obtained results of forecasts, individual networks were assessed (from 1 to 5) depending on the assessment and the result of the forecast (1 – the lowest result, 5 – the highest result) – Table 5.

Table 5.
Examination of networks – summary

Distribution Network No.	Number of points		
	Forecast verifiability	**Level of operator and manufacturer cooperation**	**Network relationship**
1	**2**	2	2
2	**4**	3	4
3	**1**	1	1
4	**3**	4	3
5	**5**	5	5

The considerations show that some of the elements of the distribution network configuration affect the results of the forecasts. Such elements are, primarily, the forms of relationships occurring in the network, as well as cooperation models adopted by individual links of the network and the manufacturer themselves. These elements also include distribution strategies adopted in the network and the percentage shares of the distributed assortment relative to individual links, as well as the fact of considerations on direct distribution, and as one of the most important elements – the way of flow and collecting information on demand.

4. Discussion

The analysis also showed a strong relationship ($|r| = 0.99$) between the MAPE level and the share of POS directly supported by the operator. This correlation is statistically significant. Statistical significance is demonstrated by a result of $p < 0.05$. In a given case, the significance was at $p = 0.001992$. This correlation means that the greater the share in the network of endpoints directly served by the operator, the more difficult it is to make a correct forecast. These results were also confirmed when checking the correlation between the MAPE level for individual networks and their participation in releases to distribution centres and wholesalers, as well as participation in releases to POS. Correlation analysis demonstrated a strong relationship between these factors. It can be concluded that the greater the share of physical distribution of products directly to centres and wholesalers, the smaller the forecast errors ($|r| = 0.87$), and the greater the share of product distribution from the logistics operator directly to POS, the greater the forecast errors ($|r| = 0.87$). This is due to difficulties in direct contacts with POS. Information on demand is very disrupted in these cases, and the information provided is heterogeneously chaotic. Additionally, there is no logistics operator feedback for direct distribution to POS. Relationships with the distribution centres look different. These centres usually collect aggregate information on demand at individual sales points and forward it in a pre-processed form to the manufacturing enterprise. Wholesalers act in a similar way in estimating the volume of demand for their customers. Thus, it can be concluded that the verifiability of forecasts is influenced by such elements as the degree of centralisation in the network, where networks have a lower degree of centralisation (i.e. more dispersed and chaotic information flows) and adopted models of interaction and cooperation in networks.

In the current configuration of the distribution network, the forecasts made are not satisfactory in the perspective of forecasting the demand for the entire network. In the current form, the forecasts at the presented level can be used mainly to improve operational and decision-making processes undertaken only at the level of the 3PL operator. However, taking into account the hypothesis confirmed by the author about the impact of network configuration on the verifiability of forecasts, as well as the fact of confirming the operator's basic ability to generate forecasts, the author considers it correct to introduce a solution into the network based on centralisation of forecasting. Such considerations should mainly concern checking the legitimacy of recognising the 3PL operator as the central unit, and by verifying the attributes of market enterprises forecasting demand and comparing them with the attributes of the operator.

5. Summary

The article showed the concept of network configuration and its centralisation as one of the most important solutions that are determined by changes in the network. The article achieved its purpose, which was to demonstrate the concept of central forecasting in distribution networks with a logistics operator as a unit acting as the central link. The article also confirmed the hypothesis regarding the impact of network configuration on the accuracy of forecasts.

The results in the presented form, as well as the use of the forecasting tool created by the author in current network configurations, can lead to improvement of the operator's working activity. In order to implement it in the network, it would be necessary to reconfigure the network related to, among others, the centralisation of information flows on real demand volumes and additional information that may affect its volume. The need for centralisation was demonstrated during the analysis of the distribution network.

In the opinion of the author, the article is an interesting area for deepening research in the field of network configuration and network centralisation. At a later stage, the author intends to analyse the attributes of 3PL operators operating in MDP and compare them with central enterprises and those that, within their activities, forecast demand in the distribution network. This will outline the overall picture of network configuration for the needs of centralised forecasting.

References

1. Anokhin, S., Wincent, J., Parida, V., Chistyakova, N. and Oghazi P. (2019). Industrial clusters. *Flagship enterprises and regional innovation, vol. 31*, p. 105.
2. Bakhtiyari, S.V. (2015). Customer relationship management at big bazaar. *Asia Pacific Journal of Marketing & Management Review, vol. 4*, pp. 15-16.
3. Barczak, B., and Walas-Trębacz, J. (2011). Uwarunkowania tworzenia relacji partnerskich w ramach sieci dostaw. *International Journal of Management and Economics, vol. 32*, p. 39.
4. Bendkowski, J., Kramarz, M., Kramarz, W. (2010). *Metody i techniki ilościowe w logistyce stosowanej. Wybrane zagadnienia.* Gliwice: Silesian University of Technology Publishing House.
5. Brzóska, J. (2007). *Modele strategiczne przedsiębiorstw energetycznych*. Gliwice: Silesian University of Technology Publishing House.
6. Chandra, C., and Grabis, J. (2007). *Supply Chain Configuration: Concepts, Solutions, and Applications.* New York: Springer-Verlag.
7. Ciesielski, M. (2009). *Instrumenty zarządzania łańcuchami dostaw.* Warsaw: PWN.
8. Czakon, W. (2010) Model operatora a orkiestracja sieci. In: J. Pyka (ed.), *Modele, metody i narzędzia zarządzania organizacjami.* Katowice: Towarzystwo Naukowe Organizacji i Kierownictwa.
9. Czakon, W. (2015). “Droga po strukturze” – od strategii współdziałania do strategii sieci. *Prace Naukowe WWSZiP No. 32*, p. 71.
10. Droge, C., Germain, R., and Daugherty, P. (1989). *Servicing the exchange relationship: organisational configuration and its effects on intra-firm and buyer-seller communications*. Annual Conference of Council of Logistics Management, St. Louis, p. 4.
11. Ekinci, E., and Baykasoglu, Z. Modeling complexity in retail supply chains. *Kybernetes vol. 45*, p. 308.
12. Faur, M., and Bungau, C. (2019). Outsourcing towards greater agility through investigating decoupling points in leagile supply chains. *MATEC Web of Conferences, vol. 290*.
13. Freferick, S., Lim, W.T., and Srai, J.S. (2016). Examining the anatomy of last-mile distribution in e-commerce omnichannel retailing – a supply network configuration approach. *International Journal of Operations & Production Management*, p. 1738.
14. Jonsson, P., and Mattsson, S.A. (2009). *Manufacturing, planning and control.* London: McGraw-Hill, p. 79.
15. Kawa, A. (2011). *Konfigurowanie łańcucha dostaw. Teoria, instrumenty i technologie.* Poznań: Poznań University of Economics Publishing House.
16. Kot, S., Starostka-Patyk, M., and Krzywda, D. (2009). *Zarządzanie łańcuchami dostaw*. Częstochowa: WWZPCz.

17. Kramarz, M. (2014). *Elementy logistyczne obsługi klienta w sieciach dystrybucji. Pomiar, ocena, strategie.* Warsaw: Difin.
18. Kramarz, M. (2016). Doskonalenie logistycznej obsługi klienta z perspektywy przedsiębiorstwa flagowego sieci dystrybucji wyrobów hutniczych. *Zeszyty Naukowe Politechniki Częstochowskiej, No. 24*, p. 225.
19. Kramarz, M. (2016). Problem odporności w koordynacji sieci dystrybucji. *Studia Ekonomiczne, Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach, No. 351*, p. 36.
20. Kramarz, M., and Kramarz, W. (2015). Strategie logistycznej obsługi klienta z perspektywy przedsiębiorstw flagowych. *Zeszyty Naukowe Politechniki Śląskiej, No. 83*, p. 324.
21. Kramarz, M. and Kramarz, W. (2019). Managing the flow components in supply chains. *Metabk, vol. 58*, pp.158-160.
22. Melacini, M., and Tappia, E. (2018). A critical comparison of alternative distribution configurations in omnichannel retailing in terms of cost and greenhouse gas emissions. *Sustainability, vol. 10*, p. 3.
23. Miller, D., and Mintzberg, H. (1984). The case for configuration. In: D. Miller, P.H. Friesen (eds.), *Organisations: a quantum view.* Englewood Cliffs: Prentice-Hall.
24. Porter, M.E. (2001). *Porter o konkurencji.* Warsaw: PWE.
25. Schmitt, A.J., Sun, S.A., Snyder, L.V., and Shen, Z. (2015). Centralisation versus decentralisation: risk pooling, risk diversification and supply chain disruptions. *Omega, vol. 52*, pp. 201-212.
26. Schweizer, L. (2005). Concept and evolution of the business models. *Journal of General Management, vol. 31*.
27. Shishebori, D., and Babadi, A.Y. (2018). Designing a capacitated multi-configuration logistics network under disturbances and parameter uncertainty: a real-world case of a drug supply chain. *Journal of Industrial Engineering International, vol. 14*, pp. 66-67.
28. Stevic, Z., Mulalic, E., Bozickovic, Z., Veskovic, S., and Dalic, I. (2018). Economic analysis of the project of warehouse centralisation in the paper production company. *Serbian Journal of Management, vol. 13*, pp. 47-62.
29. Szozda, N., and Świerczek, A. *Zarządzanie popytem na produkty w łańcuchu dostaw.* Warsaw: PWE.
30. Truong, T.H., and Azadivar, F. (2003). *Simulation based optimisation for supply chain configuration design.* Proceedings of the 2003 Winter Simulation Conference.
31. Tsiakis, P., and Papageorgiou, L.G. (2008). Optimal production allocation and distribution supply chain networks. *International Journal of Production Economics, vol. 111*, p. 469.
32. Wasiak, M., Jacyna-Gołda, I., Markowska, K., Jachimowski, R., Kłodawski, M., and Izdebski, M. (2019). The use of a supply chain configuration model to assess the reliability of logistics processes. *Maintenance and Reliability, vol. 21*, p. 368.

33. Xiaotong, B., Ke, B., and Xinyu, W. (2018). Theoretical and empirical research on cultivating the core competencies of the enterprise. *Advances in Social Science, Education and Humanities Research, vol. 176*, p. 1258.
34. Yang, Ch., Zhenyu H., and Zhou, S.X. (2020). Multilocation newsvendor problem: centralization and inventory pooling. *Management science*, pp.1-16.