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ORIGINAL PAPER

ANALYSIS OF THE INFLUENCE OF THE LOT SIZING ON THE EFFICIENCY OF MATERIAL FLOW IN THE SUPPLY CHAIN

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ABSTRACT. **Background**: Due to the rapidly changing needs of suppliers and customers classic methods of lot sizing do not work. Meanwhile, the target for logistics remains all the time the same: to realize the flow of materials in the supply chain as efficiently as possible. Today, efficiency is understood as the sum of two components: the effectiveness - understood as the degree of achieving the objective (i.e. customer service level indicator) and efficiency - understood as a way to achieve the objective, (i.e. total cost of the material flow in the supply chain). Simulation studies developed by authors was focused on the identification and analysis of both global and local conditions, the efficiency of material flow in the supply chain.
Methods: Simulation of material flow in the supply chain was carried out using the spreadsheet. In the analysis of results, statistical software Minitab 17 was used. Using correlation analysis examined the relationship between the cost of the material flow and the realized customer service level. On the base of methods ANOVA and Tukey Pairwise Comparisons determined whether there is a statistically significant relationship between the lot size in flow between companies in supply chain and the cost of that flow through the whole chain.
Results: The objective of the article is to identify the relations between the material flow lot size between particular companies in the supply chain and the flow costs and to identify the link in the supply chain that has the greatest impact on the customer service level and the flow total costs in the supply chain. Distribution of demand (category of goods) has an impact on the cost of the material flow in the supply chain. In both analysed distributions of demand (normal and exponential) was observed relationships proportional (what is beneficial for the whole supply chain is also beneficial to the each company in supply chain) as well as the relationship inversely proportional (that which is beneficial to the whole supply chain is bad for one of the companies in the supply chain or what is bad for the whole supply chain is beneficial to one of the companies in the supply chain). Regardless of the demand distribution, lot size in distribution phase has the greatest impact on cost of material flow in supply chain.
Conclusions: Distribution of demand is crucial in lot sizing in material flow in the supply chain. According to conducted research, it is possible to identify company, which has a crucial impact on the effectiveness and efficiency of material flow in the supply chain. The study shows that it is possible to indicate the global optimum in the supply chain. Usually, the global optimum is not the sum of local optima of material flow in the whole supply chain.

Key words: supply chain, efficiency of material flow, lot sizing, distribution of demand.

INTRODUCTION

Logistic activities and commercial exchange appeared at the same time in the human history. In one part of the world goods of certain kind were in excess, whereas there was a deficiency of the same kind of goods in another part of the world. These excesses and deficiencies might be also reverse and were related to the imbalance of demand and supply. This caused a necessity to exchange the goods (their flow) between both parts. Both the historic and the contemporary tendency is to minimise the component related to the cost of a certain goods size flow. This is referred to the material flow efficiency – it should be performed (effectiveness) by means of the possibly lowest resource outlays (efficiency). The material flow is considered to be more

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effective is the objective is fulfilled (effectiveness) by means of fewer outlays (efficiency). This task has remained valid throughout the years and is still an important problem to be solved in logistic activities.

The material flow costs include not only the cost of the mere goods relocation (transport) but also the costs of inventory management which are implied by the flow. The relationship between the costs is usually inverse proportional. The lower transport costs, the higher inventory management costs and reversely.

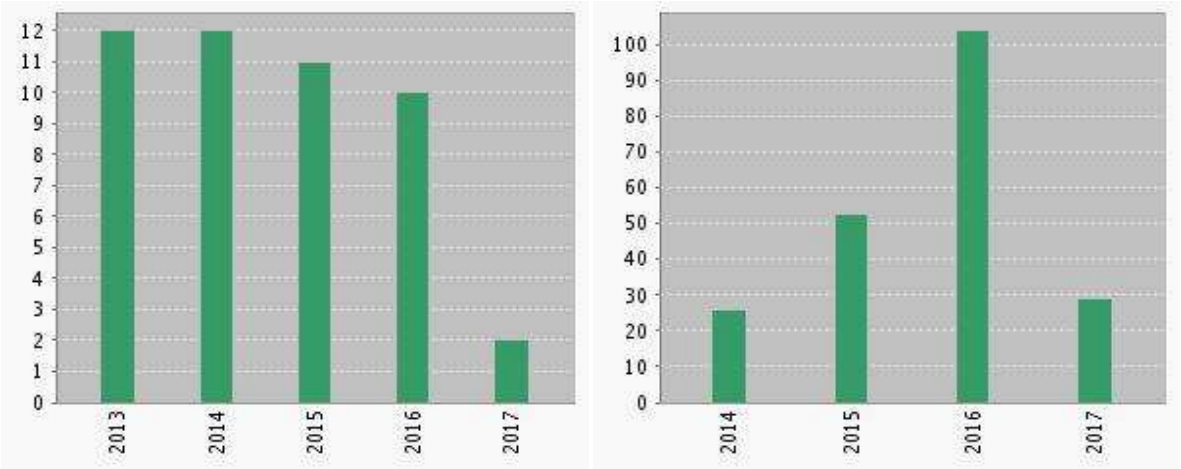
The objective of the article is to identify the relations between the material flow lot size between particular companies in the supply chain and the flow costs and to identify the link in the supply chain that has the greatest impact on the customer service level and the flow total costs in the supply chain.

THE DISCRIPTION OF MATERIAL FLOWS IN THE SUPPLY CHAIN

A general description of the issues related to the lot size formation

The issues related to the lot size specification is still of interest to both management theorists and practitioners. This is a basic problem in the area of the material stream flow management. Lot Sizing Problem – LSP or Economic Lot Scheduling Problem – ELSP [Roundy, 1989] are specialist literature entries that include the definitions of the specification of lot sizes and their locations for the sake of minising order/delivery costs. ELSP merely makes it possible to specify the material flow size between 2 cooperating companies in the supply chain. Multilevel Lot Sizing Problem – MLSP is a name of a group of methods that include the supply chain structure in specifying the material flow lot size. The issues related to specifying regardless of the scale scope are undoubtedly a really difficult and complicated problem to be solved [Chase et al., 1998].

In the Web of Science research database one found 47 articles published between 2013 and 2017 with an "economic order quantity" (EOQ) catchword included in their titles. The number of publications and citations is enlisted as presented in Figure 1.



Source: Web of Science

Fig. 1. Number of publications (on the left) and the citation number of the "economic order quantity" (EOQ) catchword (on the right)
Rys. 1. Liczba publikacji (z lewej) i liczba cytowań (z prawej) hasła „economic order quantity" (EOQ)

The number of publications has been quite stable – 10-12 publications annually in the analysed topics in the last 4 years. A citation curve (2013 – 0, 2014 – 26, 2015 – 53, 2016 – 104) tends to be apparently increasing and is extremely dynamic – every year the citation number gets doubled. In the next part of the literature review one will only mention the publications which have been cited at least 10 times – there are 7 publications in this list.

These 2 publications are most frequently cited: „Celebrating a century of the economic order quantity model in honor of Ford Whitman Harris" and "Retailer's economic order quantity when the supplier offers conditionally permissible delay in payments link to order quantity". The former one is a collection of articles on a large scope of inventory management [Cardenas-Barron et al., 2014] – 26 citations. The collection is authored by authors from 20 countries and forms a basis of creating new trends in the research on inventory management. The latter one is related to financing the transactions between business partners (payment delays) that are proceeded according to the EOQ method logic [Chen et al. 2014] – 25 citations. The publication entitled „An economic order quantity model with multiple partial prepayments and partial backordering" [Taleizadeh et al. 2013] should be considered to be quite significant as it is also devoted to payments in various conditions of the flow of goods between business partners – 16 citations.

The 4 consecutive publications are apparently less frequently cited. In the work entitled „An entropic economic order quantity (EnEOQ) for items with imperfect quality" the authors accept the heat flow in the thermodynamic system as a research model. This is intended to identify and analyse hidden inventory costs [Jaber et al., 2013] – 13 citations. In the article entitled „Economic order quantity models for imperfect items with buy and repair options" the same authors [Jaber et al. 2014] consider variants of replacing imperfect (faulty) items in supplies performed according to the EOQ model – 12 citations. In the work entitled „An Economic Order Quantity model with partial backordering and all-units discount" the previously partly mentioned authors [Taleizadeha, Pentico, 2014] consider the EOQ model functioning in the conditions of applying partial backordering and all-units discount – 11 citations. The last publication – 10 citations is the article entitled „A fuzzy vendor managed inventory of multi-item economic order quantity model under shortage: An ant colony optimization algorithm" which regards a multidisciplinary quantitative economic order model in the conditions of uncertain edge requirements [Nia et al. 2014].

Only one out of 47 selected articles is referred to simulation. This is a new work entitled „A multiproduct economic order quantity model with simulated annealing application" [Pereira, Costa 2017] in which simulation was applied to verify the supply lot sizing model of both one and numerous products.

To conclude the literature review one should notice that the actually cited publications are directly related to logistics (research conclusions). Nevertheless, at least half of them is predominantly focused on purely financial or mathematical problems. In view of the above, the simulation approach as a research method seems to be an innovative trend of such research. The authors of this article decided to perform their own research plan based on the simulation method (innovative research apparatus). In the light of other publications the authors' research criteria (customer service level, inventory costs – their collection and maintenance costs) also seem to better conform to the utilitarian and pragmatic requirements of logistics. The authors of this article seek to optimise costs in the supply chain with the consequence of the cost size in each company, i.e. they search for an answer to the question about how much a company needs to add to make the result optimal for the supply chain. In other words, one searches for an answer about how much each company needs to depart from its cost optimum to make the entire chain function in the best way.

Methods of specifying lot sizes in supply chains

In the work by Fechner and Krzyżaniak [Fechner, Krzyżaniak 2008] there is an example of how costs in a logistic chain might be reduced by appropriately applying a classical formula to the economic order size (supply). As regards to variant 1, the size of the production lot and its supply to the distributor are independently calculated as optimal ones. What characterises variant 2, is that the supplies to the distributor are performed in lots. Their size is specified both by a supplier and a receiver (economic lot value from the both partners' point of view). This ensures the lowest total cost of the goods inventory completion and maintenance by the distributor. As to variant 3, the producer starts production lots. Their size corresponds to the economic lot that ensures the lowest total cost of the production lot run, supplies to the distributor and the ready-made goods inventory maintenance by the distributor. According to the research results, the above activities might make it possible to increase the profit (margin) of all the partners. This is conditioned by certain partners' readiness to get compromised by decreasing their own margins or by agreeing to bear part of the costs of other partners. Ertogral, Darwish and Ben-Daya [Ertogral et al., 2007] developed a universal model of calculating the material lot flow size between the 2 nearest companies in the supply chain. The model aims at finding a production lot size and a supply lot with the possibly lowest costs of 2 partners. The analysis conclusions are oriented to the necessity to add real transport costs to the models which optimise the material flow lot size.

A broader approach based on the SCOR model logic is presented by Abdelsalam i Elassal [Abdelsalam, Elassal, 2014]. They developed a cost optimisation model of the entire supply chain in the function of the material flow lot size. In the model the supply chain total cost is presented as a sum of the costs borne by entities that execute distribution, production and procurement processes. A solution proposed by van Hoesel, Romeijn, Morales i Wagelmans [van Hoesel et al., 2005] is an example of the MSLP (Multilevel Lot Sizing Problem) methods which regard the supply chain structure in specifying the material flow lot size. The solution in the above model is the demand service costs. The demand is generated by the market in various material flow lot sizes.

The significance of the sustainable development concept is increased and this paid attention to reverse chains. The material replenishment (reapplication of raw materials from used goods) is characterised by imprecisely determined supply. This increased the difficulty in selecting the optimal material flow lot size at all the supply chain levels. Zhendong, Jiafu and Ou [Zhendong et al., 2009] presented a supply chain model with a closed loop. In the model the authors distinguished 4 possible variants of the material flow optimisation: problem with the the lot size specification in the case of the used goods utilisation, problem with the lot size specification in the case of the goods reuse, problem with the lot size specification in the case of the goods utilisation and reuse and problem with the lot size specification in the case of primary production and the used goods reuse.

EFFICIENCY OF A MATERIAL FLOW IN SUPPLY CHAIN

Businesses are under increasing pressure to improve the resource efficiency of their products and services [von Geibler at al., 2015]. In P. Drucker's view [Drucker, 1994] efficiency is a key enterprise development factor. It is applied to the enterprise self-fulfillment and its survivability. As regards to business entities such as supply chains, it is demanded by the high activity efficiency to intensify the activities. In turn, the low activity efficiency implies the activity limitation or stoppage [Kalauskaite, Buciuniene, 2008]. Enterprises might achieve their goals (survival and development) in changeable environment conditions only if their actions are effective at the strategic and operational level [Eling, Schaper, 2017]. A similar opinion is expressed by A. Koliński and B. Śliwczyński [Koliński, Śliwczyński, 2016].

As to the term „efficiency" one should mention that various approaches to its definition have been presented by numerous authors throughout the years. According to one group of authors the efficiency is a subjective category and does not have unambiguous empirical content [Pasour, 1981]. Other authors combine the term „ efficiency" with such countable categories as production activities and resources used in it [Kamerschen et al., 1991]. In the broadest dipiction the effectiveness might be equated with management rationality. This is O. Lange's approach to the term "efficiency". He defines it as a treatment method within the conducted business activities. This means that it is necessary to achieve the highest objective fulfillment level with a given resource outlay or, in other words, to use the least amount of resources to fulfil the objective [Lange, 1980.]

In view of the above considerations, efficiency of a material flow in supply chain will in this article be interpreted as a sum of two factors [Clermont 2016, Frankowska, Jedliński 2011]:

- effectiveness of action – ability to achieve set goals;
- efficiency of action – an optimal use of owned resources (may be related to the rationality of management, economy or profitability).

Two factors presented above could be treated as a special economic efficiency cases. The economic efficiency might be specified as a result of a business entity's activity. It is a result of the relation between the obtained effects and the borne costs [Farrel, 1957]. The most frequently used economic efficiency measures are: logistic cost level, general cost level, profit and sales profitability. The measures might be found in the work by G.J. Hahn and H. Kuhn [Hahn, Kuhn 2011]. The operational efficiency is most frequently expressed by means of such measures as customer service level, delivery time, prognosis accuracy, inventory level. These measures were applied by A. Koliński and B. Śliwczyński [2016] and M.S. Sodhi and C.S. Tang [2011].

ANALYSIS OF EFFICIENCY OF MATERIAL FLOW IN SUPPLY CHAIN

Description of a simulation model

In order to analyse the efficiency of material flow in the supply chain one developed a model of a supply chain fragment. It is constructed of two links: a producer and a distributor who services stochastic demand with respect to the availability of goods in the warehouse (rules of the MTS decoupling point). Due to the demand characteristics both supply chain entities used the ordering level model to control the material flow (the order will be placed after a specified information inventory level has been achieved.)

The material flow efficiency was investigated when there was changeable demand with an average value of 500 pieces daily (demand with no trend and no seasonality). The demand distributions were similar to the following theoretical distributions:

- normal distribution – the obtained empirical values: average = 48.71 pieces/day and standard deviation = 10.20 pieces/day reflects the demand on fast moving consumer goods;
- exponential distribution – the obtained empirical values: average = 52.92 pieces/day and standard deviation = 54.83 pieces/day reflects the demand on luxury goods.

The calculation model was developed in the MS Excel calculation sheet. The simulation is divided into 2 annual periods (each year lasts about 250 workdays). The first year is a warm up. Based on this period of time one calculated the material flow control parameters. The second year is a real simulation. One obtains results from the simulation for the sake of the material flow efficiency analysis. A variable in this model is a size of the material flow lot between a supplier and a producer and the producer and a distributor. 50 simulations were decided to be investigated in this model. The following 5 different material flow lot states between the distributor and the producer were decided to be investigated: EOQ (Economic Order Quantity) lots between 2 mutually

cooperating supply chain links, lots approximately +/-10% different than EOQ, lots approximately +/- 30% different than EOQ (five lot stages, 2 supply chain links, i.e. 52 options in the case of 2 demand distributions – normal and exponential).

One adopted the following indicators for the sake of the formed model. The indicators reflect the components of the material flow efficiency in the supply chain:

– activity effectiveness – customer service level as a quantitative performance stage (ratio of the number of pieces from the inventory to the number of ordered pieces) – it reflects the effectiveness in its operational dimension.
– activity efficiency – total costs of material flow (inventory replenishment costs, inventory maintenance costs, inventory shortage costs) – it reflects the efficiency in its financial dimension.

The results of 50 simulations are presented in the table and analysed as described in Chapter 1 and 2.

1. Analysis of results – total cost of material flow

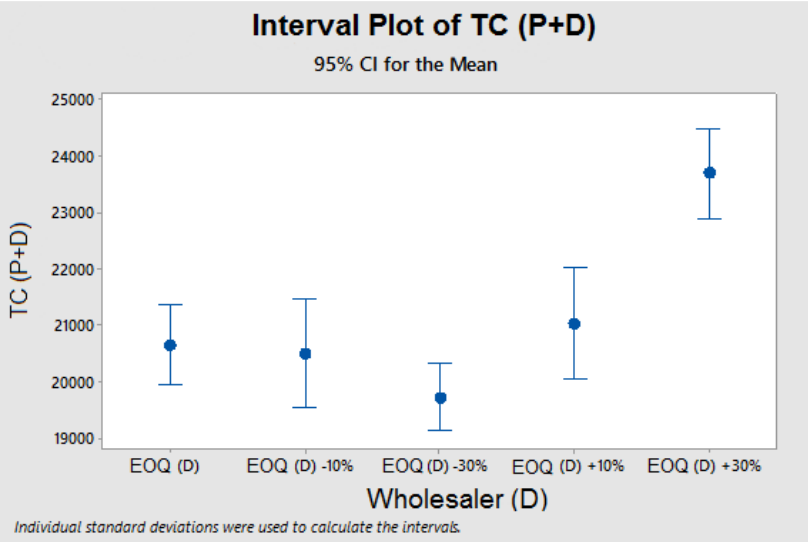
Before the main analysis was started, one had decided to verify the significance of result differences in the case of particular demand distributions. In order to perform it, one used the Tukey Pairwise Comparisons method and the results are shown in Figure 2.

Grouping Information Using the Tukey Method and 95% Confidence

Distribution	N	Mean	Grouping
EXP	25	23296	A
NOR	25	21122	B

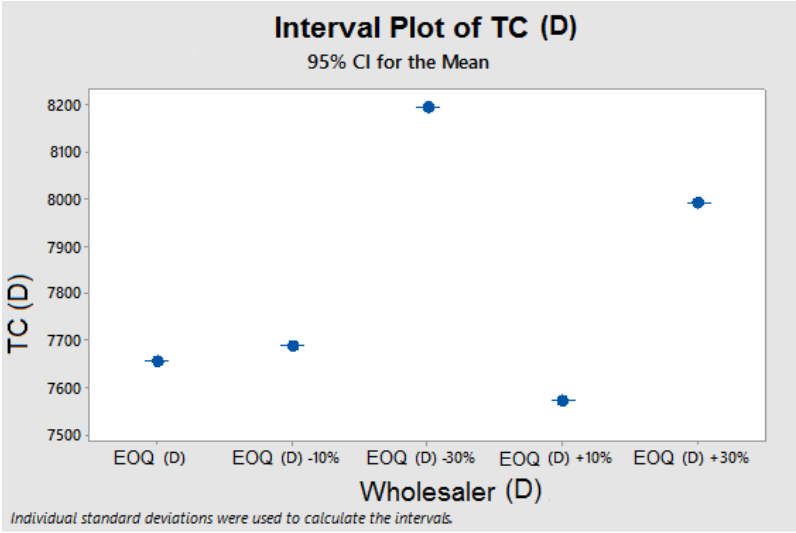
Source: Own study

Fig. 2. A comparison of the demand distribution by means of the Tukey method in the terms of TC (P+D)
Rys. 2. Porównanie rozkładów popytu metodą Tukeya dla średnich wartości miary TC (P+D)



Source: Own study

Fig. 3. A comparison of average TC (P + D) measurement values of various states of the distributor's lot size in the terms of normal distribution
Rys. 3. Porównanie średnich wartości miary TC (P + D) dla różnych stanów wielkości partii u dystrybutora w warunkach rozkładu normalnego



Source: Own study

Fig. 4. A comparison of average TC (D) measurement values of various states of the distributor's lot size in the terms of normal distribution

Rys. 4. Porównanie średnich wartości miary TC (D) dla różnych stanów wielkości partii u dystrybutora w warunkach rozkładu normalnego

The Tukey method analysis presents that apparently 2 separate result groups are formed by both distributions. In each case there are statistically important TC (P+D) values in the case of the factor called "demand distribution type". This confirms that it is necessary to distinguish 2 types of the result sets (in the case of particular distributions). Secondly, it is implied by the analysis that the material flow in the supply chain in the case of the demand with exponential distribution is more expensive than in the case of the demand with normal distribution. As a consequence, the further detailed analysis will be conducted separately in the case of the demand with both normal and exponential distribution. The normal distribution results will be analysed in the first place.

The result analysis was begun by identifying the influence of the distributor's supply lot size on the costs of material flow in the entire chain – TC (P+D) and its fragment (only distributor) – TC (D). The dependencies are illustrated in Figure 3 and 4.

While comparing the results in Figures 3 and 4, attention is paid to the EOQ lot size states: – 30% and +10%. In the first case they are lower (and the lowest of all 6 states at the same time) costs of the entire supply chain functioning (Figure 3). The lower costs are unfavourable to the distributor (Figure 4). As a consequence, the lot size decrease by 30% is a favourable solution to the entire supply chain but it is the worst material flow configuration option to the distributor. In the second case, the higher costs of the entire supply chain functioning are more favourable to the distributor (Figure 4). As a consequence, the lot size increase by 10 percent is the best material flow configuration option to the distributor, although this variant is slightly more unfavourable to the entire supply chain. The above description was made based on the charts in Figure 3 and 4. In order to confirm the observations one performed the ANOVA analysis. It confirmed the statistically different total costs in the case of particular material flow lot sizes.

The next analysis stage was to verify the influence of the size of the supply to the producer on the total costs of material flow in the supply chain. To indicate significant differences in flow costs of particular material flow sizes one applied the Tukey Pairwise Comparisons method (Figure 5).

```
Grouping Information Using the Tukey Method and 95% Confidence

Producer      N   Mean  Grouping
EOQ (P) -30%  5  21489  A
EOQ (P) -10%  5  21366  A
EOQ (P) +30%  5  21198  A
EOQ (P) +10%  5  20895  A
EOQ (P)       5  20661  A

Means that do not share a letter are significantly different.
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Source: Own study

Fig. 5. A comparison of various lot size states by means of the Tukey method for average TC (P+D) measurement values in the terms of normal distribution

Rys. 5. Porównanie różnych stanów wielkości partii metodą Tukeya dla średnich wartości miary TC (P + D) z pozycji producenta w warunkach rozkładu normalnego

As implied by the information in Figure 5, the size of the supply lot to the producer has no significant impact on the costs of material flows in the supply chain. All the results were classified to one group (A) by means of the Turkey method. This was independent of the EOQ (P) supply lot size.

While comparing the simulation results in the case of the exponential distribution demand, attention is paid to the EOQ lot size states EOQ(D): – 30% and +30%. In this case the entire supply chain functioning costs appeared to be reverse to the distributor's functioning costs. As a consequence, the lot size decrease is considered to be a favourable solution to the entire supply chain (EOQ (D) – 30%), but it is a more expensive material flow performance option to the distributor. If the lot size increase (EOQ (D) + 30%) is observed to be unfavourable to the entire supply chain, it is a less expensive material flow performance option to the distributor.

Similarly to the simulations of the normal and distribution, the size of the supply lot to the distributor with exponential distribution has no statistically significant influence on the material flow costs in the supply chain.

2. Analysis of results – customer service level

As regards to the research on the customer service level in the supply chain, one verified 2 ways of its performance:

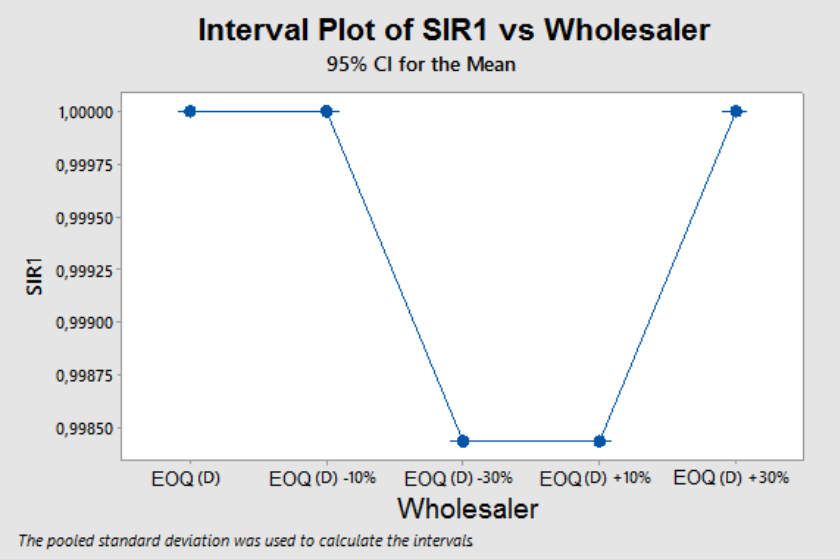
– SIR 1 – customer service level from a customer's point of view, the level is calculated only in the last supply chain link,
– SIR 2 – customer service level in the entire supply chain, the level is calculated as an average customer service level value of all the supply chain links.

Similarly to both costs and the customer service level, the size of the supply lot to the producer has no influence on the customer service level as offered in the supply chain (in the SIR1 and SIR2 approach). The above statement is true for the demand with normal and exponential distribution. Thus, the factor of the supply lot size will be excluded from further analyses. The next analysis part will be performed with the above assumption and with respect to the method of calculating the values of the customer service level indicators. The analysis will be conducted in the following dimensions:

– distribution – the influence of size of the supply lot to the distributor on the SIR1 indicator value,
– supply chain – dependency between the total costs of material flow in the supply chain and the SIR 2 indicator value.

As regards to the simulations performed in the case of the demand with normal distribution, the SIR 1 customer service level is always 100% independently of the material flow lot size. The Pearson's correlation coefficient in the case of the relationship between the SIR 2 indicator and the material flow costs is negative and equals -0,890 (statistically significant relationship, p-value=0). This means that the increase in the supply chain functioning costs is not related to the increase in the customer service level.

While analysing the simulation results in the case of the demand with exponential distribution, it is necessary to indicate various SIR 1 indicator values in the case of various sizes of supply lot to the distributor. The differences are presented in Figure 6.



Source: Own study

Fig. 6. A comparison of average SIR 1 measurement values of various states of the distributor's lot size in the terms of exponential distribution

Rys. 6. Porównanie średnich wartości miary SIR1 dla różnych stanów wielkości partii u dystrybutora w warunkach rozkładu wykładniczego

As implied by Figure 6, the lowest customer service level is offered, if the size of the lot supply to the distributor is EOQ (D) – 30% and EOQ (D) + 10%. The lowest customer service level (measured by the SIR 1 indicator) is in the case of the lowest costs of material flow through the supply chain. The Pearson's correlation coefficient is negative and equals -0,815 (statistically significant relationship, p-value=0) in the case of the demand with exponential distribution. As regards to both the demand with normal distribution and exponential distribution, the increase in the supply chain functioning costs is not related to the increase in the customer service level.

CONCLUSIONS

The first research stage is the results as described in this article. The research was intended to identify the dependencies between the material flow lot sizes between particular links in the supply chain and the flow costs. There are no hypotheses and no supposed direction or strength of the dependency. The researchers were oriented to identifying such a link in the supply chain that has the greatest influence on the customer service level and total flow costs (the costs are defined as cumulative costs in all the analysed supply chain links). The goal of the first research stage has been achieved.

The conducted research might lead to a conclusion that the supply chain cost results are determined by the material flow performance in the distributor's area. The change of the distributor's supply lot size has a statistically significant influence on the costs of material flow in the supply chain. The decrease in the distributor's supply lot size (EOQ (D) state – 30%) has an influence on the decrease in the material flow costs with respect to the entire chain but is unfavourable to the distributor. The distributor bears the material flow costs. The dependencies identified in the EOQ (D) state – 30% lot sizes are equal in the case of the demand in both normal and exponential distribution. Therefore,

the distributor takes the greatest responsibility for the effectiveness of material flow in the supply chain (its competitiveness).

The decrease in the material flow costs is not related to the decrease in the customer service level with respect to the entire chain (SIR 2 indicator). Furthermore, it is implied by the negative correlation (between the customer service indicator value and the material flow total costs) that it is feasible to increase the customer service level in the entire chain by decreasing the size of the lot supply to the distributor (this causes a cost decrease as described above). The decrease in the size of the lot supply has a negative influence on the customer service level (SIR1 indicator) only if there is a demand with exponential distribution.

As part of the next research stage, one plans to perform simulation research. The research will aim at performing further analyses of the influence of the size of the lot supply to the distributor on the costs of material flow in the supply chain with regard to changeable costs of inventory replenishment and changeable demand (this supply chain fragment seems to be the most interesting with regard to the further research). The above activities will make it possible to identify the edge conditions of a situation in which the information availability is more important than the material availability. The information availability influences the fact material flow.

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ANALIZA WPŁYWU WIELKOŚCI PARTII NA EFEKTYWNOŚĆ PRZEPŁYWU MATERIAŁÓW W ŁAŃCUCHU DOSTAW

STRESZCZENIE. **Wstęp:** Z uwagi na dynamicznie zmieniające się potrzeby dostawców i odbiorców klasyczne metody partiowania nie sprawdzają się. Tymczasem cel dla logistyki pozostaje cały czas ten sam (bez zmian): zrealizować przepływ materiałów w łańcuchu dostaw możliwie najbardziej efektywnie. Współcześnie efektywność jest rozumiana jako suma dwóch składowych: skuteczności – rozumianej jako stopień osiągnięcia celu, której doskonałym miernikiem jest osiągnięty poziom obsługi klienta oraz sprawności – rozumianej jako sposób realizacji celu, której doskonałym miernikiem jest poziom kosztów całkowitych przepływu materiałowego w łańcuchu dostaw. Badania symulacyjne autorów skoncentrowane są na identyfikacji i analizie zarówno globalnych jak i lokalnych uwarunkowań efektywności przepływu materiałowego w łańcuchu dostaw.
Metody: Symulacje przepływu materiałów w łańcuchu dostaw przeprowadzono z wykorzystaniem arkusza kalkulacyjnego. W analizie zbioru wyników wykorzystano oprogramowanie statystyczne Minitab 17. Za pomocą analizy korelacji zbadano zależności pomiędzy kosztami przepływu materiałowego a realizowanym poziomem obsługi klienta. Dzięki metodzie ANOVA oraz porównywaniu parami metodą Tukeya ustalono, czy istnieje statystycznie istotna zależność pomiędzy wielkościami partii przepływu materiałowego pomiędzy poszczególnymi ogniwami łańcucha dostaw a kosztami tego przepływu przez cały łańcuch.
Wyniki: Celem artykułu jest: identyfikacja zależności pomiędzy wielkością partii przepływu materiałowego pomiędzy poszczególnymi ogniwami w łańcuchu dostaw a kosztami tego przepływu, a także identyfikacja tego ogniwa łańcucha dostaw, które ma największy wpływ na poziom obsługi klienta i koszty całkowite przepływu w łańcuchu dostaw. Rozkład popytu (kategoria dóbr) ma wpływ na wielkość kosztów przepływu materiałowego danej wielkości partii w łańcuchu dostaw. W obu analizowanych rozkładach popytu (normalny, wykładniczy) zaobserwowano relacje proporcjonalne (to co jest korzystne dla całego łańcucha dostaw jest także korzystne dla samego ogniwa łańcucha dostaw) jak i relacje odwrotnie proporcjonalne (to co jest korzystne dla łańcucha dostaw jest niekorzystne dla samego ogniwa łańcucha dostaw). Niezależnie od wybranego rozkładu popytu o wynikach kosztowych realizacji przepływu materiałowego decyduje konfiguracja wielkości partii w obszarze dystrybucji (ogniwo dystrybutor).
Wnioski: Rozkład popytu ma kluczowe znaczenie w kształtowaniu wielkości partii przepływu materiałowego w łańcuchu dostaw. Dzięki przeprowadzonym badaniom możliwe jest wskazanie ogniw łańcucha dostaw, które mają kluczowy wpływ na skuteczność i sprawność przepływu materiałowego w łańcuchu dostaw. Z przeprowadzonych badań wynika, że istnieje możliwość wskazania optimum globalnego w łańcuchu dostaw. Optimum to zwykle nie jest sumą optimów lokalnych efektowności przepływu materiałowego wszystkich ogniw łańcucha dostaw.

Słowa kluczowe: łańcuch dostaw, efektywność przepływu materiałów, kształtowanie wielkości partii, rozkład popytu

ANALYSE DES EINFLUSSES DER LOSGRÖßE AUF DIE EFFEKTIVITÄT DES MATERIALFLUSSES IN DER LIEFERKETTE

ZUSAMMENFASSUNG. Einleitung: Angesichts der sich dynamisch verändernden Bedürfnisse von Lieferanten und Empfängern erweisen sich die klassischen Methoden der Losgrößen-Bildung als weniger brauchbar. Dabei bleibt das angestrebte Ziel der Logistik nach wie vor unveränderlich gleich, es gilt nämlich eine möglichst effektive Durchführung des Materialflusses in der Lieferkette. Die moderne Effizienz wird heutzutage verstanden als die Summe der folgenden Bestandteile: der Effektivität – verstanden als Grad der Zielerreichung, deren vollkommener Maßstab das erreichte Niveau des Kundenservices ist und der Fertigkeit – verstanden als Art und Weise der Zielverwirklichung, deren vollkommener Maßstab das Niveau der Gesamtkosten des Materialflusses in der Lieferkette ist. Die von den Autoren durchgeführten Simulationsversuche konzentrieren sich auf die Ermittlung und Analyse sowohl von globalen als auch lokalen effizienzmäßigen Abhängigkeiten innerhalb des Materialflusses in der Lieferkette.

Methoden: Die betreffenden Simulationen des Materialflusses in der Lieferkette wurden mithilfe der Kalkulationstabelle durchgeführt. Bei der Analyse der Ergebnissammlung benutzte man die statistische Software Minitab 17. Anhand der Korrelationsanalyse prüfte man die Abhängigkeiten zwischen den Kosten des Materialflusses und dem praktizierten Niveau des Kundenservices. Dank der ANOVA-Methode und des paarweisen Vergleiches laut der Tukey-Methode stellte man fest, inwieweit es eine statistisch relevante Abhängigkeit zwischen Losgrößen eines Materialflusses, ferner zwischen den einzelnen Gliedern der Lieferkette und den Kosten dieses Materialflusses innerhalb der ganzen Lieferkette gibt.
Ergebnisse: Das Ziel des vorliegenden Artikels ist es, die Abhängigkeiten zwischen den Losgrößen des Materialflusses, ferner zwischen den einzelnen Gliedern der Lieferkette und den Kosten dieses Materialflusses zu ermitteln und das Lieferketten-Glied, das den größten Einfluss auf das Niveau des Kundenservices und auf die Gesamtkosten des Materialflusses in der Lieferkette ausübt, festzulegen. Die Verteilung der Nachfrage (Güter-Kategorie) beeinflusst die Höhe der Materialfluss-Kosten innerhalb einer Losgröße in der Lieferkette. In den beiden analysierten (normalen und exponentiellen) Verteilungsfällen beobachtete man sowohl direkt proportionale (das, was für die gesamte Lieferkette günstig ist, ist ebenfalls günstig für das Einzelglied der Lieferkette), als auch umgekehrt proportionale Abhängigkeiten (das, was für die gesamte Lieferkette günstig ist, ist ungünstig für das Einzelglied der Lieferkette). Unabhängig von der ausgewählten Nachfrage-Verteilung entscheidet die Konfiguration der Losgrößen im Distributionsbereich (Vertriebs-Kettenglied) über die Kostenresultate des getätigten Materialflusses selbst.
Fazit: Die Nachfrage-Verteilung besitzt eine schlüsselhafte Bedeutung bei der Gestaltung der Losgrößen des Materialflusses in der Lieferkette. Dank der betreffenden Problemerforschung ist es möglich, die Lieferketten-Glieder, die einen schlüsselhaften Einfluss auf die Effektivität und Durchgängigkeit des Materialflusses in der Lieferkette ausüben, zu ermitteln. Den durchgeführten Forschungen kann man entnehmen, dass die Festlegung eines globalen Optimums innerhalb der Lieferkette als durchaus möglich erscheint. Das Optimum gilt gewöhnlich jedoch nicht als die Summe der Optima von lokalen Effektivitätsfällen des Materialflusses innerhalb aller Glieder in der der Lieferkette.

Codewörter: Lieferkette, Effektivität des Materialflusses, Gestaltung von Losgrößen, Verteilung der Nachfrage

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