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IMPACT OF CHANGE IN THE STRUCTURE OF DISTRIBUTION SYSTEM ON INCURRED COST

Bożena Zwolińska[1], Edward Michlowicz[2]
[1,2]AGH University of Science and Technology, Faculty of Mechanical Engineering and Robotics, Cracow, Poland
[1]e-mail: bzwol@agh.edu.pl
[2]e-mail: michlowi@agh.edu.pl

Abstract: *In multi-tier distribution, in addition to suppliers and consumers there are also intermediaries who participate in the transfer of products from manufacturers to end consumers. The choice of the distribution system depends on the optimisation of the performance indicators for servicing an area, taking into account the technical capabilities of the individual logistics chain links. The paper compares two typical distribution structures in the construction sector. The choice of the structure is a function of the manufacturer's economic and organisational determinants. The paper presents a model representing the costs of two typical distribution structures in the construction sector. The choice of the structure depends on the company's outsourcing policy and total costs of all three major system components: the distribution network, transport network, and warehousing. Rationally built and implemented functioning models are a key element of business success in the marketplace. The choice of a suitable strategy is difficult, as it depends on many dynamically changing parameters which directly affect costs. In addition, the relations between the system elements are very complex and interdependent*

Key words: *distribution structure, cargo flow process, cost model in supply chain.*

1. Introduction

In a global market over-saturated with products, manufacturers fiercely compete not just within the same industry. Quality, price and availability are the main criteria of product choice by consumers. The companies, aware of the "struggle" for customers, want to eliminate wastefulness in the entire logistics chain (not only in selected areas such as procurement, distribution or production). Only comprehensive elimination of *muda* (Womack & Jones, 2003), a Japanese word meaning "wastefulness" in lean management enables a company to become competitive. Limiting the losses resulting from processes which do not add value (NVA) to the product at each stage of the logistics chain brings financial benefits (Womack & Jones, 2003). Currently, the TSL (Transport – Shipping – Logistics) market puts a lot of emphasis on minimising the physical distribution costs. These distribution costs are a sum of all the costs resulting from maintenance and servicing of linear and nodal infrastructure. Factors such as market sector, industry, product type (Ambroziak & Lewczuk, 2009), variety (range) of distributed products, demand (taking into account the seasonality, if any), customer service level, KPI – *Key Performance Indicators* (Zwolińska, 2012) and others have a significant impact on the choice of an appropriate physical distribution structure.

The most important thing for the consumer is product availability according to the 7R principle: the right product, in the right quantity, at the right price, of the right quality, at the right place, delivered to the right customer at the right time. Customers are interested in the effectiveness of the distribution system (Markusik & Kowalska, 2011) and not in the processes and flows which occur within it. It is the manufacturer who is responsible for meeting the customer's requirements; in order to increase (or maintain) its attractiveness in the marketplace, the manufacturer has to maximise the effects of its actions. The required product availability indicators can be achieved if there is an uninterrupted flow of materials and information in an optimally-designed distribution system (Jacyna-Gołda, 2015).

The paper presents a model of two exemplary systems of physical distribution in the construction products sector. The statistics for one of the leading Polish manufacturers of construction products have been analysed. The considered data include the number and size of purchases generated by end customers. The analysed systems have a three-tier distribution structure (Ambroziak & Tkaczyk, 2015; Ambroziak & Jachimowski, 2010), (Figure 1). The first example is the distribution channel with a warehouse-distribution centre. The manufactured products are sent first to the distribution centre and then to the distributors according to the demand. In this case, the distribution centre performs the warehousing and shipping function, and its main task is to both manage and plan the deliveries and shipments. In addition, the distribution centre is responsible for maintaining an adequate inventory level (Ambroziak & Jacyna, 2011; Kisperska-Moroń, 2010).

The second case is the distribution channel without a warehouse-distribution centre, where the warehousing and shipping functions are performed by the partners. The number of partners depends on the territorial range and on the number of shipments generated by the distributors' orders. The presented model is based on the number of shipments resulting from the number and size of orders and costs resulting from these orders. The model describing the costs generated at individual levels (I – customer level; II – distributor level; III – distribution centre level in variant one, and III – partner level in variant two) is examined from the bottom up i.e. from the level of the customer to the level of the manufacturer.

2. Data analysis

The choice of distribution strategy depends not only on the features and parameters of the distributed products but also on the business relations between the manufacturer and the intermediary (or intermediaries), (Ambroziak & Lewczuk, 2009). Start-ups face the dilemma of choosing the suitable distribution channel and managing the flow of products in that channel (Nowakowski, 2011). It is not possible to explicitly assign specific physical distribution solutions to industries or market sectors (Mindur, 2014; Pyza, 2011). Each business builds its own distribution structure depending on its capacity, available finances, and market expansion (Szymoniuk, 2013). There are two structures of physical distribution in the construction sector which feature seasonality. Figure 1 presents the typical, most frequently encountered distribution channels in the construction sector.

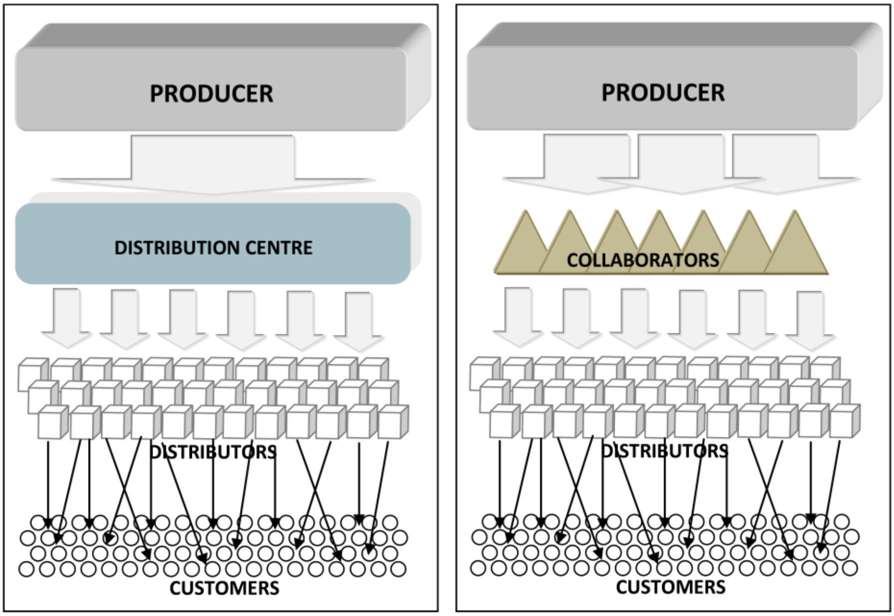

Fig. 1. Flow diagrams in examined distribution channels

In the first stage, the development of models which define the costs at individual levels included a preliminary analysis of the collected data. The analysed data related to the number and size of individual purchases by individual customers in the last link of the logistics chain. The timeframe was twelve months from January to December 2015. As a result of a wide range of distributed products, as a first step the data were divided into four product groups (G_1, G_2, G_3, G_4). The main division criterion was use of construction products: outdoor or indoor. Basic and auxiliary products were distinguished in both groups. Each group featured seasonality during the year. As a result of this classification, the groups have an identical seasonality.

Figures 2 and 3 present the number of products sold classified to groups G_1, G_2, G_3, G_4 during one year by weight (in Mg) and by the number of packagings sent (Euro-pallets). One packaging means a homogeneous product placed on a Euro-pallet. The discrepancies in trends (increasing, decreasing) for the weight vs. packagings graphs in individual groups is a result of orders for lightweight but bulky products, such as glass wool used in thermal insulation.

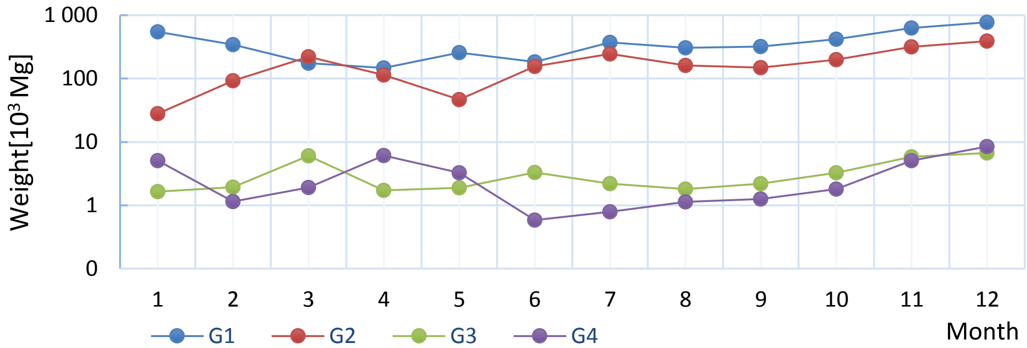

Fig. 2. Products distribution graph

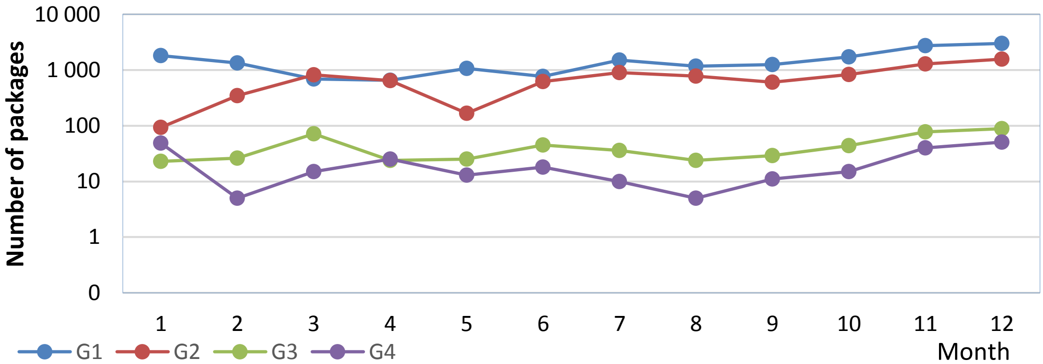

Fig. 3. Packagings distribution graph

In the case of multidimensional sets, it is advisable to divide them into subsets according to measurable or non-measurable (subjective) parameters. In the examined case, in the next step, the customers were divided into twelve groups according to their geographical locations in Poland. The aim of this classification was to distinguish a possible number of partners servicing a supply area which would account for the achievable demand throughput. Then, the demand variability indices for the individual product groups (G_1, G_2, G_3, G_4) were determined. The variability index was calculated according to the formula:

$$V_i = \frac{\delta}{\bar{a}} \cdot 100\% \qquad (1)$$

where:
δ – standard deviation,
$\bar{a}$ – annual average consumption of product group.

The determined variability index is a destimulant, because the greater the V_i, the lower the partner's stability of distribution of a product group.
Figures 4 through 7 present the demand variability indices for twelve territorial partners in four separated product groups.
In product group G_1 the least variability index is 50.25% for partner 3, and the greatest 177.13% for partner 7. Partners 2, 8 and 11 did not have any orders in this product group.
Partners 5 and 10 did not have any orders in group G_2 during the twelve months, and in case of the remaining partners the variability index was from 54.66% to c. 115%.
In group G_3 there were eight cases of absence of orders i.e. partners 1, 2, 3, 5, 6, 9, 10 and 11 had no orders in that group during the year in question. For the remaining partners the variability index ranged from 67.39% to 132.91%.
Group G_4 has the greatest dispersion from the mean which results in high variability indices. In five cases (partners 4, 5, 10, 11, 12) there were no orders in group G_4. The least value of the variability index was 108.68%, the greatest exceeded 340%.
In the analysis of flow stream throughput it is important to determine the aggregated variability index for all product groups and for all twelve partners. Figure 8 presents the averaged value of V_i for all four products groups.

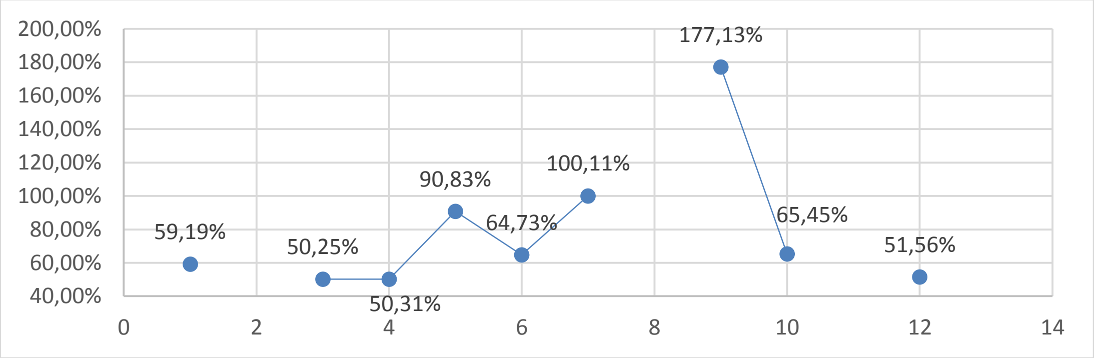

Fig. 4. Variability index for group G_1

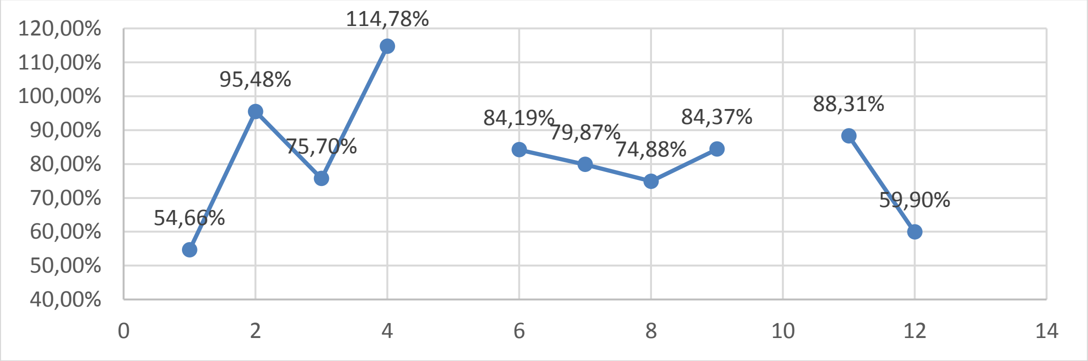

Fig. 5. Variability index for group G_2

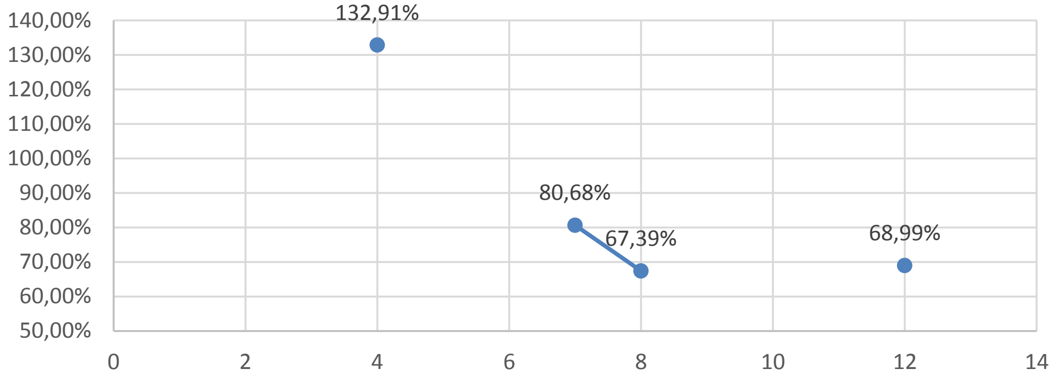

Fig. 6. Variability index for group G_3

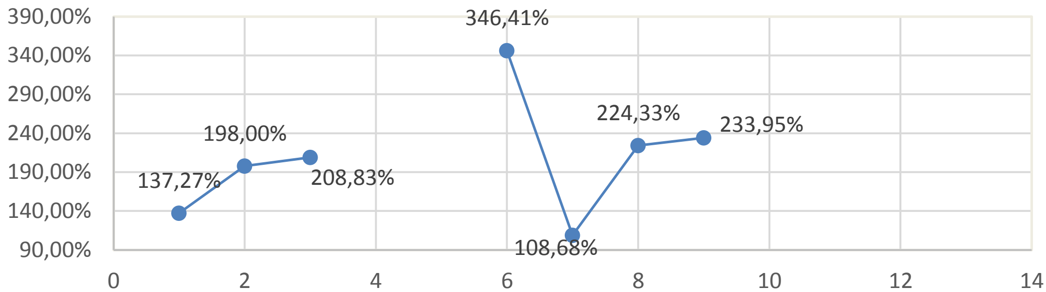

Fig. 7. Variability index for group G_4

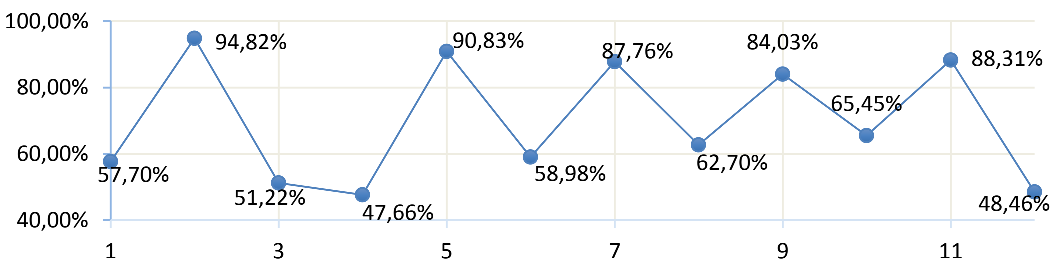

Fig. 8. Variability index for all products groups – G_1, G_2, G_3, G_4

The highest sales stability was achieved by partner 4 (V_i= 47.66%); partners 2, 5, 11, 7 and 9 had the lowest stability.

Lack of sales stability and the resulting large dispersion from the mean would suggest using the structure with a warehouse-distribution centre. However, the decision in this regard depends on the total costs of fulfilment of orders and on maintaining the distribution chain infrastructure.

3. Cost determinate model

Relatively high fluctuations of the variability index guarantee low probability values of a single random event in the space: Ω^{I} ,Ω^{II} and Ω^{III} . Denoted by:

N– random variable describing the number of purchases by ***i*** individual customers,

n – number of individual purchases which is finite but relatively very high (in 2015 there were over 27,000 purchase events).

$$N = N_1 + N_2 + N_3 + \ldots \quad \forall i : N_i \sim Bernoulli(p) \qquad (2)$$

All N_i are independent with the same low probability of success. In addition:

p – probability of individual purchase by the i^{th} customer; (p) is relatively low.

N_i – have the same Bernoulli distribution with the same probability.

Hence, N has a Poisson distribution with a certain value of λ. The λ parameter is estimated in a unit of time equal to a month.

X^I, X^{II}, X^{III} – random variables describing the costs at individual levels, where:

I – customer's level, probability space – Ω^I;

II – distributors level, probability space – Ω^{II};

III – partner's level, probability space – Ω_2^{III}

or distribution centre costs in variant one – Ω_1^{III}.

Then:

$X^I \mid N$ – random variable describing costs at level one (these are variable costs resulting from the changing number of events i).

$X^I \mid N + K^I_{opr}$ – random variable describing total costs at level one which are the sum of the variable and fixed costs, where: K^I_{opr} – operating costs which can include all types costs of servicing and maintenance of the nodal infrastructure in the logistics distribution system.

On the basis of historical data, we can adapt distribution $X^I \mid N$, in addition, also on the basis of data from the previous year, we can determine the average value of K^I_{opr}.

$X^I \mid N$ – has a continuous distribution with density function f, then:

$$P(X^I \in \langle t_1, t_2 \rangle | N = n) = \int_{t_1}^{t_2} f(x)\,dx \qquad (3)$$

where: $f(x)$ – is a probability density function of random variable $X^I \mid N$.

Then:

$$P\left(X^I \in \langle t_1, t_2 \rangle\right) = \sum_{n=0}^{\infty} P\left(X^I \in \langle t_1, t_2 \rangle \mid N = n\right) \cdot P(N = n) \qquad (4)$$

$$P\left(X^I \in \langle t_1, t_2 \rangle\right) = \sum_{n=0}^{\infty} \int_{t_1}^{t_2} f(x)\,dx \cdot \frac{e^{-\lambda} \cdot \lambda^n}{n!} \qquad (5)$$

Determination of costs for level two in probability space – Ω^{II}:

$X^{II} \mid X^I$ – random variable describing costs at level two, provided that at level one we achieved the costs in interval $<t_1, t_2>$.

$X^{II} \mid X^I + K^{II}_{opr}$ – variable describing total costs at level two, being the sum of operating costs at level two and costs resulting from demand at level one.

On the basis of historical data, we can determine average operating costs and adapt the probability distribution to random variable: $X^{II} \mid X^I$. Moreover, we know that variable: $X^{II} \mid X^I$ – has a continuous distribution g.

$$P(X^{II} \in \langle t_3, t_4 \rangle | X^I \in \langle t_1, t_2 \rangle) = \int_{t_3}^{t_4} g(y)\,dy \qquad (6)$$

where: $g(y)$ is a probability density function of random variable $X^{II} \mid X^I$.

Then:

$$P\left(X^{II} \in \langle t_3, t_4 \rangle\right) = \int_{-\infty}^{+\infty} \int_{t_3}^{t_4} \sum_{n=0}^{\infty} f(x)\,dx \cdot \frac{e^{-\lambda} \cdot \lambda^n}{n!} \cdot g(y)\,dy \quad (7)$$

where: $g(y)$ depends on the costs at level one (X^I), examining all possible cases (from $-\infty$ to $+\infty$).

In the case of distribution channel with a warehouse-distribution centre, all flows would be aggregated in one shipment point.

Finally, we determined the level three variables (in probability space Ω_1^{III}) – for variant one with a warehouse-distribution centre.:

$X_1^{III} \mid X^{II}$ – random variable describing costs at level three.

$X_1^{III} \mid X^{II} + K_1^{III}{}_{opr}$ – random variable describing total costs at level three.

$X_1^{III} \mid X^{II}$ – random variable has a continuous distribution h_1.

$$P(X_1^{III} \in \langle t_5, t_6 \rangle | X^{II} \in \langle t_3, t_4 \rangle) = \int_{t_5}^{t_6} h_1(z)\,dz \qquad (8)$$

where: $h_1(z)$ – is a probability density function of random variable $X_1^{III} | X^{II}$.

Hence:

$$P\left(X_1^{III} \in \left\langle t_5, t_6 \right\rangle\right) = \\ = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{t_5}^{t_6}\sum_{n=0}^{\infty} f(x)\,dx \cdot \frac{e^{-\lambda}\cdot\lambda^n}{n!} \cdot g(y)\,dy \cdot h_1(z)\,dz \tag{9}$$

Assuming that X^{II} has density $g_1(y)$, the formula (9) takes the form:

$$P\left(X_1^{III} \in \left\langle t_5, t_6 \right\rangle\right) = \int_{-\infty}^{+\infty}\int_{t_5}^{t_6} g_1(y)\,dy \cdot h_1(z)\,dz \tag{10}$$

where: $h_1(z)$ depends on the costs at level two (X^{II}) simultaneously examining all possible cases which can occur at levels one and two.

The calculations indicate that random variable X_1^{III} has a certain probability density $K_1(x)$. As this is a random variable with a continuous distribution, the expected value of the random variable X_1^{III} is given by the:

$$E\left(X_1^{III}\right) = \int_{-\infty}^{+\infty} x \cdot K_1(x)\,dx \tag{11}$$

In variant two where flows of materials are fragmented, one needs to account for costs which occur at the greater number of transport events directly dependent on the number of partners. For this purpose, we determined the variables which describe costs generated at level three in the variant without a warehouse-distribution centre.

$X_2^{III} \mid X^{II}$ – random variable describing costs at level three.

$X_2^{III} \mid X^{II} + K_{2\,opr}^{III}$ – random variable describing total costs at level three..

$X_2^{III} \mid X^{II}$ – random variable has a continuous distribution h_2 .

$$P(X_2^{III} \in \left\langle t_{5'}, t_{6'} \right\rangle | X^{II} \in \left\langle t_{3'}, t_{4'} \right\rangle) = \int_{t_{5'}}^{t_{6'}} h_2(z)\,dz \tag{12}$$

where: $h_2(z)$ –is a probability density function of random variable $X_2^{III}|X^{II}$.

Hence:

$$P\left(X_2^{III} \in \left\langle t_{5'}, t_{6'} \right\rangle\right) = \\ = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\int_{t_{5'}}^{t_{6'}}\sum_{n=0}^{\infty} f(x)\,dx \cdot \frac{e^{-\lambda}\cdot\lambda^n}{n!} \cdot g(y)\,dy \cdot h_2(z)\,dz \tag{13}$$

Assuming that X^{II} has density $g_1(y)$, the formula (13) takes the:

$$P\left(X_2^{III} \in \left\langle t_{5'}, t_{6'} \right\rangle\right) = \int_{-\infty}^{+\infty}\int_{t_{5'}}^{t_{6'}} g_1(y)\,dy \cdot h_2(z)\,dz \tag{14}$$

where: $h_2(z)$ depends on the costs at level two (X^{II}) examining all possible cases which can occur at levels one and two.

Similarly to variant one, where the inventory of distributed products was in the warehouse-distribution centre, we can determine the expected value of random variable X_2^{III} for the case where a part of the inventory is located at territorially scattered partners. From the calculations we know that random variable X_2^{III} has a probability density function $K_2(x)$ and that it is a variable with a continuous distribution. Then, the expected value will be calculated according to (15):

$$E\left(X_2^{III}\right) = \int_{-\infty}^{+\infty} x \cdot K_2(x)\,dx \tag{15}$$

Denoting Q – as the costs borne by the manufacturer at all three levels, we can calculate the cost-effectiveness of examined solutions:

$$Q = \frac{E\left(X_1^{III}\right)}{E\left(X_2^{III}\right)} = \frac{\int_{-\infty}^{+\infty} x \cdot K_1(x)\,dx}{\int_{-\infty}^{+\infty} x \cdot K_2(x)\,dx} \tag{16}$$

if $Q < 1$ – it is economically advisable to use the distribution strategy with a warehouse-distribution centre,

otherwise, when $Q > 1$ the financial expenditures on maintaining the warehouse-distribution space exceed the costs of distribution by partners.

4. Conclusion

The paper presents a model of two exemplary systems of physical distribution in the construction products sector. The statistics for one of the leading Polish manufacturers of construction products have been analysed. The considered data include the number and size of purchases generated by end customers. The first example is the distribution channel with a warehouse-distribution centre. In this case, the distribution centre performs the warehousing and shipping function, and its main task is to both manage and plan the deliveries and shipments. The second case is the distribution channel without a warehouse-distribution centre, where the warehousing and shipping functions are performed by the partners. The presented model is based on the number of shipments resulting from the number and size of orders and costs resulting from these orders. The model describing the costs generated at individual levels is examined from the bottom up i.e. from the level of the customer to the level of the manufacturer.

The paper presents a model representing the costs of two typical distribution structures in the construction sector. The analysed systems have a three-tier distribution structure. The choice of the structure depends on the company's outsourcing policy and total costs of all three major system components: the distribution network, transport network, and warehousing. Rationally built and implemented functioning models are a key element of business success in the marketplace. The choice of a suitable strategy is difficult, as it depends on many dynamically changing parameters which directly affect costs. In addition, the relations between the system elements are very complex and interdependent.

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