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DEVELOPMENT OF THE ALGORITHM FOR DETERMINING THE OPTIMIZING CONSIGNMENT SIZE IN INTERNATIONAL ROAD TRANSPORT

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There is considered the dynamics of the index of business activity PMI (Purchasing Managers Index) across regions and countries. This index is used to measure changes in inventory, supplier performance, employment level, output volume, and the number of new orders in production. A decrease of the inventories level increases the trade intensity. Thus, the transition to more frequent deliveries in small batches is necessary. This leads to increased transport costs. The influence tendencies of such external factors as consumer demand for goods, refinancing rate, national currency rate are considered.

Purpose. *To determine the consignment size and its delivery frequency using the minimizing total logistics costs criterion.*

Methodology / Methods. *In the article mathematical statistics method, regression analysis were used.*

Conclusion. *The algorithm for solving the optimizing consignment size task is proposed. Dependences of components of total costs on the delivery frequency are obtained.*

Keywords: *small-shipments; logistics costs; inventory management; consumer demand; automobile transport.*

РАЗРАБОТКА АЛГОРИТМА ОПРЕДЕЛЕНИЯ ОПТИМАЛЬНОГО РАЗМЕРА ПАРТИИ ГРУЗА ПРИ МЕЖДУНАРОДНЫХ АВТОМОБИЛЬНЫХ ПЕРЕВОЗКАХ

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Рассмотрена динамика индекса деловой активности PMI (Purchasing Managers Index) по регионам и странам. Этот индекс

используется для определения изменений товарных запасов, производительности поставщиков, уровня занятости, объемов выпуска продукции и количества новых заказов в производстве. Снижение уровня товарных запасов увеличивает интенсивность товарооборота. Таким образом, необходим переход на более частые поставки мелкими партиями. Это приводит к увеличению транспортных расходов на транспортировку. Рассмотрены тенденции влияния таких внешних факторов, как потребительский спрос на товары, ставка рефинансирования, курс национальной валюты.

Цель. *Определить размер партии грузов и периодичность их поставок по критерию минимизации суммарных логистических затрат.*

Методология / Методы. *В статье используются методы математической статистики, регрессионного анализа.*

Результаты. *Предложен алгоритм решения задачи оптимизации размера партии грузов. Получены зависимости составляющих суммарных затрат от частоты поставок.*

Ключевые слова: *мелкие отправки; логистические издержки; управление запасами; потребительский спрос; автомобильный транспорт.*

Introduction

The article deals with the relevant topic of reducing stocks of finished products [1, 2]. This leads to an increase in the small shipments turnover and an increase in logistics costs consequently. To address this topic, it is necessary to consider the impact of external factors on the rise of logistics costs.

In order to maintain the truck transport productivity using modern technologies there is necessary to get reliable information about the prospective cargo transportation volumes. One of the most significant economic indicators of the demand forecast is the PMI (Purchasing Managers' Index) or purchasing managers' expectations index [3]. It is possible to identify active business areas, cargo flows directions and their characteristics using the dynamics of changes in this indicator (PMI) in a number of countries and regions.

Currently, the principles of evaluating macroeconomic indicators of the originally developed in the United States business activity index are used in various economy sectors. The forecast of changes, growth or decline, in the purchases and deliveries activity in industry, trade allows transport companies to make all necessary preparations for the upcoming work or freeze assets.

The method of assessing business activity [4] consists of selecting the main indicators; determining its weight values; regular conducting of industry senior employees survey under study on the selected indicators.

The greatest impact on the overall value of the PMI index is accounted for by such indicators as new orders, output volumes (Table 1).

Table 1.

The importance of business activity indicators

No	Indicator	Weight value, %
1.	Inventory indicator	10
2.	Supplier activities	15
3.	Employment rate	20
4.	Production volumes	25
5.	Number of new orders in the production segment	30
	Total:	100

The range of the business activity index changes varies from 1 to 100. The index value of 50 means that half of the surveyed specialists assess the prospect positively, and the other half mark negative prospect. That means that they expect production and purchases decrease. This can also be characterized as a stable situation in the economy or industry. In practice the index deviates from 50 slightly. A value above 52 points indicates a marked growth in the economy while a value below 48 points indicates a large decline (Table 2).

The analysis of world values shows the positive dynamics of the index. At the same time, Europe has been showing the index decline for 9 months (up to and including January 2020). That is worth marking that South-East Asia (in comparison with Europe) is close to stabilizing business activity. Despite the slight deviation of the PMI value from

the normal 50 in the South-East Asia region some countries bordering this region (for example, China) have been holding positive indicator dynamics for a long time.

Table 2.

Dynamics of the manufacturing activity index PMI by countries and regions (fragment)

Country / region	PMI value	Trend	Period for which the maximum or minimum value was reached (based on the PMI trend)
World	50.4	↑	10 months
Europe	47.9	↑	9 months
Southeast Asia	49.8	↑	1 month
Russia	47.9	↑	5 months
China	51.1	↓	4 months
Japan	48.8	↑	2 months

In different countries (groups of countries), there is used the PMI or its analog taking into account specific to a particular country additional indicators. Each country that uses business activity data has its own research organization to collect and publish indicator data with its own publication frequency that can be differed from other countries. In Russia, the PMI index is published by the PMI research organization Markit Economics. According to this organization, Figure 1 shows the manufacturing activity index dynamics for 2019. As you can see, in the first half of the year there was mainly positive dynamics, in the second half of the year there is a negative dynamics. In late 2019 – early 2020, there is a tendency to stabilize business activity, in January 2020 the PMI index value was 47.9 points (Table 2) that still means a production volumes and new orders reduction.

The "inventory level" indicator [5, 6] is of particular interest for transport companies. The actual inventory levels are determined as the difference between the respondents percentage marked "improvement" and "deterioration" of the indicator compared to the previous period. The dynamics of the surveys results of the actual inventory level according to Rosstat data indicates an inventory decrease (Figure 2).

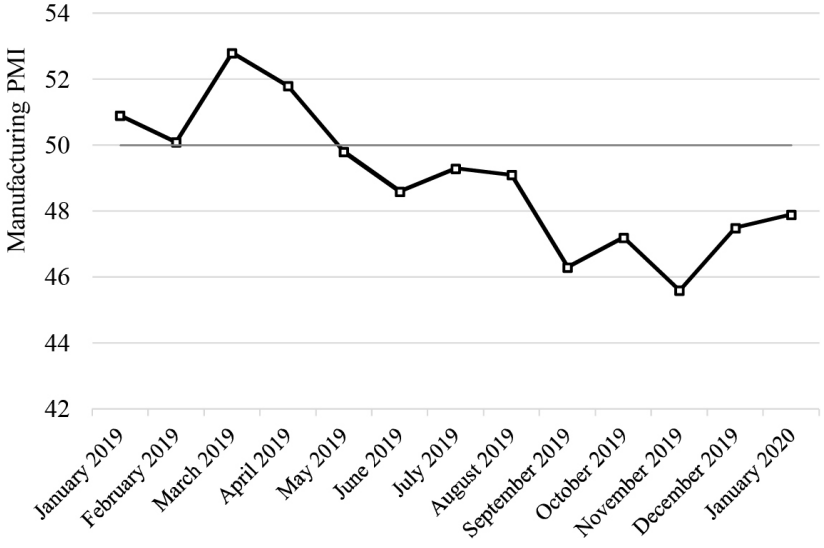


Fig. 1. Manufacturing PMI dynamics (Russia)

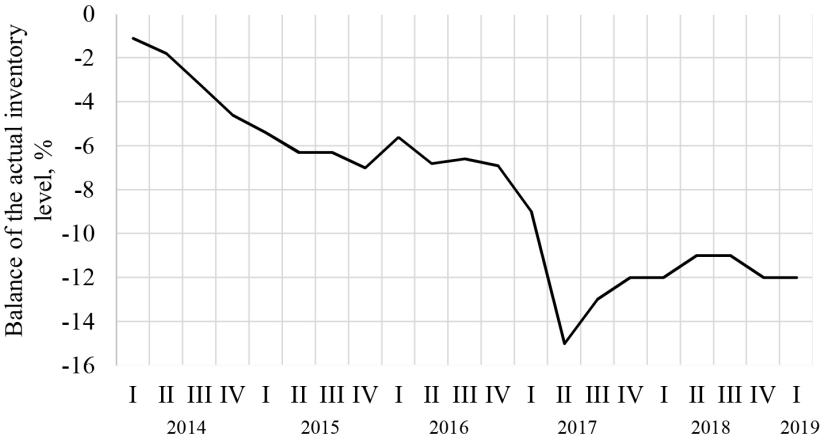


Fig. 2. Dynamics of the surveys results of the actual inventory level (Rosstat)

Comparison of the dynamics of the PMI index (Figure 1) and the inventory level (Figure 2) shows similar changes movements, there is a stabilization of values in May–August 2019. Thus, the business

activity weakening in the production sector (production volumes and new orders reduction) and the decrease in the inventory level suggest attenuation of consumer demand for goods.

When stocks are reduced the trade intensity increases meaning deliveries need to be made more often but in small consignments. However, increase in trade turnover in small-shipments leads to transport costs growth [7], so it is necessary to consider the factors that influence them. The trends of these factors are set in Table 3.

Table 3.

Influence of external factors on logistics costs

Factor	Trend	Logistics costs
Consumer demand for goods	↑	↓
Refinancing rate	↓	↓
National currency rate	↑	↓

The demand for logistics services can be characterized by such indicators as: the cargo traffic volume, the directions of transportations, etc.

1) cargo traffic volume, as a key demand characteristic, is the amount of cargo transported or planned for transportation between the points of departure and destination for a certain period of time. The traffic volume depends on the product demand. To determine the demand, we use forecasting methods, effectiveness of the implementation of the logistics concept-delivery "just in time" depends on accuracy and reliability of these methods;

2) the directions of transportations are determined by the location of product suppliers [8]. Supplies from European countries are gradually being replaced by manufacturers from the Asian region, while the process of import substitution is taking place. Increasing the distance of transport from suppliers leads to an increase in transport costs. In addition to reviving trade with China, the share of imports from Asia-Pacific economic cooperation countries is also increasing. This is facilitated by [9]:

– igning of free trade zone Agreements between the EEU (Eurasian economic Union) and Vietnam in 2015, Iran – in 2017, and Singapore – in 2019 [10];

– establishment of the business Council for cooperation with Malaysia (under the auspices of the Russian Chamber for Trade and Commerce) in March 2016;
– acceptance of the roadmap for monitoring strategic programs of Russian-Indonesian cooperation – in May 2016;
– creation of bilateral agreement on international road transport between Russia and China in 2019. The signing of the new agreement made it possible to transport goods not only to the regions of China, but also in transit [11, 12].

Any business requires borrowing to purchase raw materials, equipment, or finished products. The cost of borrowed funds is an important competitive advantage. The refinancing rate is the annual interest rate of the Central Bank of Russia lending to credit institutions. At the end of 2019, the loan rates are 7.9% in Russia (Table 4), that is significantly higher than the level of European countries and, consequently, has a negative impact on the purchase and updating of vehicles. However, the reduction of the refinancing rate continues, in December 2019 its value decreased by 1.5% (compared to the value in December 2018), and in February 2020 – by 6% per annum (according to the Central Bank of the Russian Federation). Declining the rate reduces the cost of borrowed funds and creates favorable credit conditions for doing business.

Table 4.

Loan rate in the countries of the world (fragment)

№	Country	Loan rate, %
1.	United Kingdom	1.75
2.	The Euro area	1.88
3.	India	9.4
4.	Russia	7.9
5.	Ukraine	15.04
6.	Japan	0.95

Exchange rate fluctuations of the national currency affect the ratio of the expected profit to the initially planned cost for production and goods promotion, and the loan rate [13]. In turn, the weakening of the

ruble has a negative impact on goods and services imports and leads to a reduction in freight turnover. At the same time, this has a positive effect on exports, and national transport companies receive certain advantages.

The strengthening of the ruble (at the real exchange rate) in December 2019 against the dollar by 7.6% and against the Euro – by 11.7% (compared to December 2018) can be considered as another positive factor for business lending, along with a refinancing rate decreasing.

Transport companies do not have the ability to influence the above factors directly. At the same time, the positive effect of external factors helps to strengthen the company's position, increase its competitiveness and profitability.

Internal factors are defined as the process of performing work that the company can influence. In particular, these factors include the vehicle fleet structure, the direction of transportations, the efficiency of vehicle usage and the applied technological transportation schemes.

The main characteristics of a motor transport enterprise are its specialization and characteristics of the vehicle fleet. The specialization of road transport companies engaged in cargo transportation depends on the range of transported goods, the type of transportation (interurban, international), the availability of specialized automobile fleet, as well as the providing additional services (storage, warehouse processing).

Increased competition forces trading and manufacturing companies to look for reserves to reduce costs. One direction is to reduce inventory. Decreasing inventory levels and transition to just-in-time technologies leads to declining purchased and transported cargo consignment size.

To describe and set the task, there is necessary to analyze the following terms: "dispatch", "consignment of cargoes", "logistics costs".

In road transport:

1) *carload dispatch* is a dispatch required for transportation by one consignor to one consignee on one bill of lading, for this transportation a separate vehicle is provided. This term is given in the document that is no longer valid ("General rules of cargo transportation by the road

transport" (with amendment of 21.05.2007)), this definition is not given in the current document;

2) *small consignment* is a consignment of cargoes weighing up to 5 t inclusive, issued by one bill of lading, for this transportation a separate vehicle is not required. This definition is given in the expired document (Government Decree of the Russian Federation of 15.04.2011 N 272 (ed. by 12.12.2017) "On approval of Rules of transportation of goods by road"); in the current document, this definition is not given. This definition of small consignment does not specify how many types of cargoes can be transported in a single shipment;

3) *consignment of cargoes* is one or more names of cargoes transported by one bill of lading (Government Decree of the Russian Federation of 15.04.2011 N 272 (ed. by 31.01.2020) "On approval of Rules of transportation of goods by road").

In railway transport (the Order of the Ministry of Railways of the Russian Federation of 18.06.2003 N 33 "On approval of Rules of transportation of goods in small shipments by rail"): *small dispatch* is a consignment of cargoes presented by one transport railway bill, for this transportation a separate wagon or container is not required. The total weight of small dispatch of cargoes should be from 20 kg to 20 tons.

In water transport ("Rules of transportation of goods. Part 1" (approved by the Ministry of transport of the Russian Federation) (as of 01.01.1994)): *small consignment* is a consignment of cargoes less than 20 tons. This definition is given in an invalid document, in the current document (Rosstat Order of 28.03.2018 N 138 "On approval of statistical tools for the organization of Federal statistical monitoring of transportation activities by the Federal Agency for sea and river transport on sea and inland water transport") the definition of this term is not given.

There can be noticed that the availability of several types of cargoes in one consignment is specified only in road transport.

After analyzing the terms discussed above, the concepts of dispatch and consignment of cargoes can be considered equivalent. The concept of consignment of cargoes is inextricably linked with dispatch frequen-

cy that shows the number of delivered batches for a certain period to meet the needs of demand.

Logistics costs are costs for delivering of the purchased products from the supplier's warehouse to the buyer's warehouse, namely: the costs for transportation; the costs for inventory in transit; the costs for storage and warehouse processing.

Task statement:

The buyer X purchases the quantity of products Q from the seller Y at a time (Figure 3) or in parts $q_1, ..., q_n$ (Figure 4) during the certain time period T. It is necessary to determine the optimizing consignment size that provides the minimum costs.

$$\sum_{i=1}^{n}\sum_{j=1}^{3} C_j * q_i \rightarrow \min.$$

Criterion: minimization of logistics costs for purchased goods transportation from the supplier's warehouse to the buyer's warehouse.

Limitations:

$$\sum_{i=1}^{n} q_i = Q,$$

q_i – the quantity of transported cargoes in batch i; Q – the quantity of purchased goods; C_j – the logistics costs, taking into account the costs of inventory in transit:

$$C_j = C_1 + C_2 + C_3,$$

C_1 – the costs for transportation; C_2 – the costs for inventory in transit; C_3 – the costs for storage and warehouse processing.

Options for solving the task:

1) *the base* (Figure 3): all purchased batch Q is delivered at a time;

2) *proposed* (Figure 4): all purchased batch Q is delivered in parts $q_1, ..., q_n$ (from 2 deliveries per month).

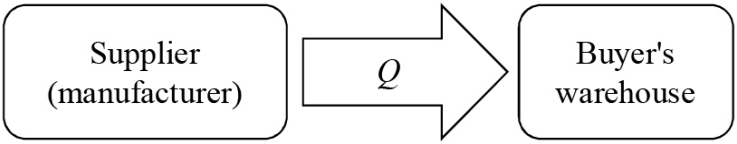


Fig. 3. Basic option: one-time delivery of a batch of goods Q

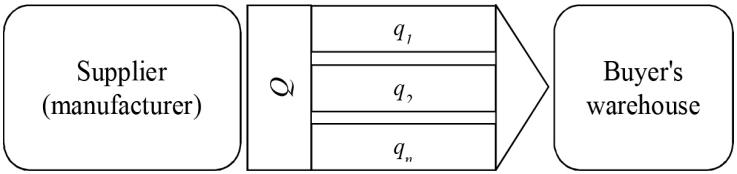


Fig. 4. Proposed option of cargo delivery in parts $q_1, \ldots, q_n$

Source data:

Q = 1000 units (33 pallets with cargo (hereinafter – pallets)) – the size of the purchased batch of goods;

Cm = 200000 USD – the cost of the purchased batch Q;

$q_1, q_2, \ldots, q_n$ – batch sizes depending on the frequency of deliveries;

T = 30 days – the period of delivery of the purchased batch of goods from the manufacturer to the buyer's warehouse;

L = 2000 km – distance of transportation between points;

$C_{тр.}$ = 2000 USD – costs for transportation (average market price for transportation);

$C_{обр.}^{1пал./мес.}$ = 10 USD – storage and warehouse processing costs of 1 pallet per month (average value on the Russian market);

r = 20% – the average market value of the lending rate (according to the Central Bank of the Russian Federation);

$N \leq 5$ – maximum number of deliveries per month.

To determine the optimizing consignment size

Decision

Minimum total costs:

$$C = C_{тр.} + C_{пут.} + C_{хр.} + C_{обр.}, \text{ USD},$$

C – total costs, USD; $C_{тр.}$ – costs for transportation, USD; $C_{пут.}$ – costs for inventory in transit, USD:

$$C_{пут.} = \frac{r * Cm * Д_{дост.}}{100 * Д_{к.}}.$$

r – the annual interest rate on the loan, %; Cm – the cost of purchased goods, USD; $Д_{дост.}$ – number of days for transportation, days; $Д_{к.}$ – number of calendar days in a year, days; $C_{хр.}$ – storage costs, USD:

$$C_{хр.} = C_{хр.}^{1пал.} * N_{пал.} * Д_{хр.}, \text{ USD};$$

$N_{пал.}$ – number of transported pallets (in batch), pal.; $C_{хр.}^{1пал.}$ – storage costs of one pallet per day, USD; $Д_{хр.}$ – number of storage days, days; $C_{обр.}$ – costs of processing goods in the warehouse, USD:

$$C_{обр.} = N_{пал.} * C_{обр.}^{1пал.}, \text{ USD};$$

$C_{обр.}^{1пал.}$ – costs for warehouse processing of one pallet, USD.

The algorithm for solving this task is shown in Fig. 5.

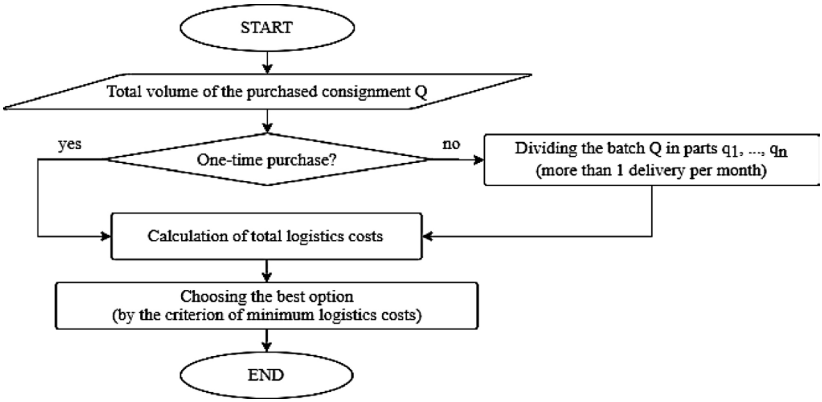


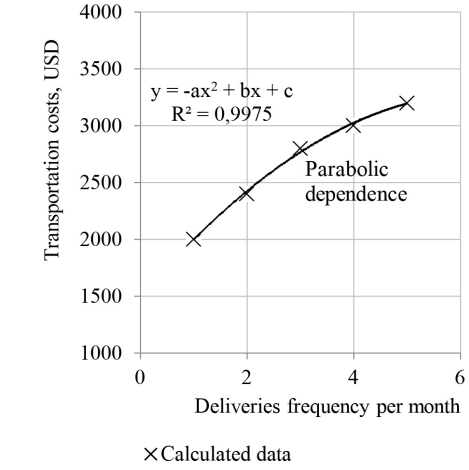
Fig. 5. Algorithm for determining the task of optimization

Based on the source data, the regularities of the impact of the size of the consignment on logistics costs are obtained.

Regularities are defined between the dependent variable *y* (transportation costs; inventory costs in transit; storage and warehouse processing costs) and the independent variable *x* (frequency of deliveries per month). After constructing the dependencies based on the calculated data, a general view of the functional dependencies of the trend lines *y=f(x)* was obtained by smoothing, where *a*, *b*, and *c* are the smoothing coefficients. Along with the definition of the functional dependence type, the quality coefficient of the line construction R^2 is also determined.

The trend of transportation costs changes with the shipments frequency increasing (Figure 6) can be described by the dependence of the parabolic and power type of function, respectively. The accuracy

of the constructed trend line was evaluated by determining the corresponding coefficient value R^2. The coefficient value in both cases is in the range of more than 0.7 that indicates a close relationship between the transportation costs and the frequency of deliveries. Therefore, both options are suitable for describing the dependency, with high accuracy.



a) b)

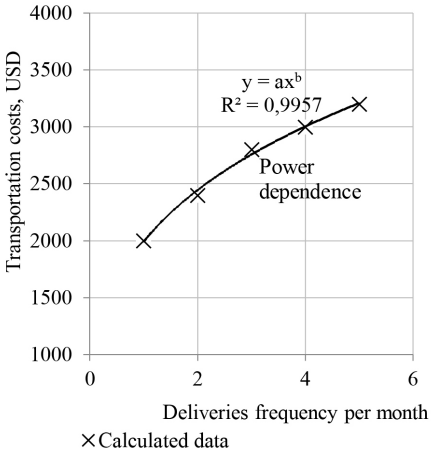


Fig. 6. Parabolic (a) and power (b) dependences "transportation costs – deliveries frequency"

Fig. 7 shows the dependence between the cost of maintaining inventory in transit and deliveries frequency. After evaluating the accuracy of the trend line, a power type of dependence (a kind of hyperbolic) was determined. Fig. 8 shows the relationship between storage costs and deliveries frequency that also corresponds to a power model of function. As you can see in Fig. 7 and 8, increasing of deliveries frequency reduces the costs for maintaining inventory in transit and storage.

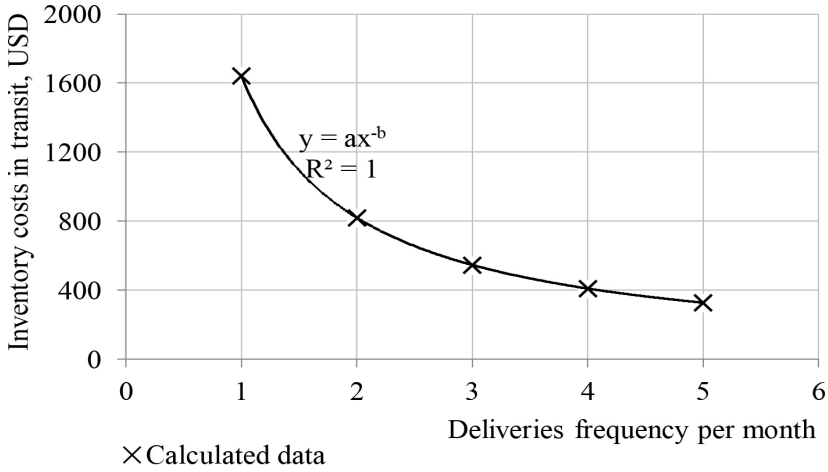


Fig. 7. Power type of function "inventory costs in transit – deliveries frequency"

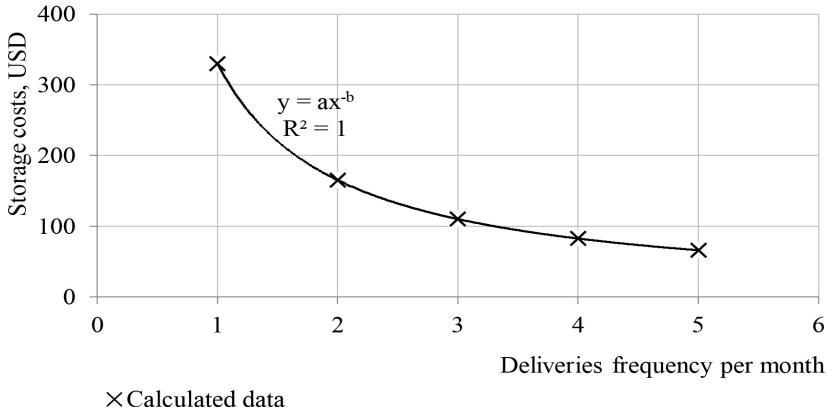


Fig. 8. Power type of function "storage costs – deliveries frequency"

From the obtained dependencies (Figures 6–8), it can be seen that batch size reduction entails an increase in transportation costs and, accordingly, a decrease in the costs of maintaining stocks in transit and its storage. Reducing the costs of maintaining inventory in transit is due to decreasing the amount of borrowed funds for the goods purchase. The reduction of storage costs is due to the use of a smaller warehouse space to accommodate the batch and the duration of goods storage.

Fig. 9 shows the dependence of total costs on the deliveries frequency [14]. The minimum total costs are achieved at the point of optimal ratio of each costs component separately. The minimum calculated total costs value is reached at a point with a delivery frequency of two per month. The graphical representation of the smoothing trend line (based on the calculated data) indicates that the minimum total costs are achieved when the delivery frequency is equal to three.

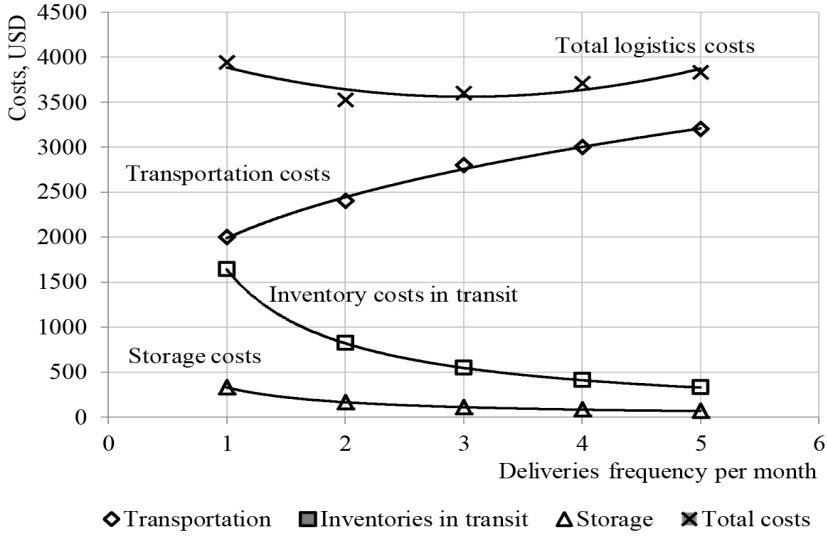


Fig. 9. Dependence between total costs and deliveries frequency

Conclusion

The development of an algorithm for studying the impact of the frequency of deliveries, and therefore determining the batch size, on

logistics costs allowed us to determine the degree of influence of each logistics costs component on their total value. The solution of this task led to the following conclusion: the total costs (with increasing the deliveries frequency per month) decrease at first, reaching 2–3 deliveries per month, and then increase. The reduction is due to declining costs for maintaining inventory in transit and also storage and warehouse processing costs. The further increase in total logistics costs at a delivery frequency of three per month depends on the costs of transportation. It is important to note that the costs of maintaining inventory in transit and storage, which are less than 50% of the total logistics costs, could affect the constantly growing transportation costs and contribute to reducing logistics costs at a delivery frequency of 2–3 per month. Thus, there is always an optimal consignment size (depending on the size of the purchased batch), in which the total logistics costs for purchased goods delivery from the supplier's warehouse to the buyer's warehouse will be minimal.

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