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Modeling the mechanisms of the functioning of the logistics distribution system

Currently, the use of the concept of logistics in inventory management is considered by enterprises as one of the reserves to achieve a competitive advantage. In theory, inventory control deficit arises due to insufficient supply, unreliable source of supply, and because of inaccurate information provided by customers to suppliers. The solution to this problem consists in finding a compromise between the cost of creation of material stockpiles and storage costs, and the creation of the mechanisms of management of active systems, elements of which are suppliers and customers. The implementation of the control mechanisms of the two-level system supplier-consumer, we have considered the example of the game-theoretic model. For the consistency of the idea considered in the article, it should be emphasized that in the supply chain-each customer-consumer is also a supplier in an orderly sequence of suppliers and consumers, as long as the product does not reach the end user. In this article, the simulation game tool in the context of hierarchical games is used to simulate the simplest scheme of the logistics distribution system. In the process of realization of finished products the model of distribution logistics between the supplier and the consumer enterprises is considered. The case of deficit is simulated when the total volume of customers ‘ orders for early delivery exceeds the production capacity of the supplier. The main purpose of the article is to give a clear idea of the functioning mechanisms used in the management of the distribution system of logistics, as well as to provide distribution logistics specialists with the possibility of effective solutions in the process of distribution of finished products in a deficit.

Key words: distribution logistics, functioning mechanisms, game-theoretic model, supplier, consumer.

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Логистикалық тарату жүйесінің жұмыс істеу механизмдерін моделдеу

Қазіргі уақытта қорларды басқаруда логистика тұжырымдамасын пайдалану кәсіпорындар бәсекелестік артықшылыққа қол жеткізу бойынша резервтердің бірі ретінде қарастырылуда. Қорларды басқару теориясында дефицит қордың жеткіліксіздігі мен жабдықтаудың сенімсіз көзінің, сондай-ақ тапсырыс берушілер жеткізушілерге ұсынатын жалған ақпараттың салдарынан де туындайды, бұл проблеманы шешу материалдық қорларды құруға арналған шығындар мен оларды сақтауға арналған шығындар арасындағы компромисті табудан, сондай-ақ элементтері жеткізушілер мен тұтынушылар болып табылатын белсенді жүйелерді басқару механизмдерін құрудан тұрады. Екі деңгейлі жеткізуші-тұтынушы жүйені басқару механизмдерін жүзеге асыруды біз теориялық-ойын моделінің мысалында қарастырдық. Мақалада талқыланатын идеяның дәлелді болуы үшін, логистикалық тізбекте – әрбір тапсырыс беруші өнім соңғы пайдаланушыға келіп түскенше жеткізушілер мен тұтынушылардың реттелген бірізділігінде жеткізуші болып табылатынын атап өту қажет. Бұл мақалада логистикалық тарату жүйесінің қарапайым сызбасын модельдеу үшін иерархиялық ойындар контекстінде имитациялық ойын құралы қолданылады. Дайын өнімді өткізу барысында жеткізуші кәсіпорын мен тұтынушы кәсіпорын арасындағы тарату логистикасының моделі қарастырылды. Тапсырыс берушілердің мерзімінен бұрын жеткізуге тапсырыстарының жалпы көлемі өнім берушінің өндірістік қуатынан асып кеткенде дефицит жағдайындағы моделдеу. Мақаланың негізгі мақсаты – логистиканың тарату жүйесін басқару процесінде пайдаланылатын жұмыс істеу механизмдері туралы нақты түсінік беру, сондай-ақ, бөлу логистикасы бойынша мамандарға тапшылық жағдайында дайын өнімді бөлу процесінде тиімді шешімдер қабылдау мүмкіндігін ұсыну.

Түйін сөздер: тарату логистикасы, жұмыс істеу механизмдері, теориялық-ойын моделі, жеткізуші, тұтынушы

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Моделирование механизмов функционирования логистической распределительной системы

В настоящее время использование концепции логистики в управлении запасами рассматривается предприятиями в качестве одного из резервов по достижению конкурентного преимущества. В теории управления запасами дефицит возникает как из-за недостаточного запаса и ненадежного источника снабжения, так и из-за недостоверной информации, предоставляемой заказчиками поставщикам. Решение данной проблемы состоит в нахождении компромисса между затратами на создание материальных запасов и затратами на их хранение, так и построением механизмов управления активными системами, элементами которых являются поставщики и потребители. Реализацию механизмов управления двухуровневой системы поставщик-потребитель мы и рассмотрели на примере теоретико-игровой модели. Для состоятельноти идеи рассматириваемой в статье, необходимо подчеркнуть,что в логистической цепи – каждый заказчик-потребитель также является поставщиком в упорядоченной последовательность поставщиков и потребителей, до тех пор, пока продукт не поступит к конечному пользователю. В данной статье для моделирования простейшей схемы логистической системы распределения используется инструмент имитационной игры в контексте иерархических игр. В процессе реализации готовой продукции рассмотрена модель распределительной логистики между предприятием-поставщиком и предприятиями-потребителями. Моделируется случай дефицита, когда общий объем заказов клиентов на досрочную поставку превышает производственные мощности поставщика. Основная цель статьи – дать четкое представление о механизмах функционирования, используемых в процессе управления распределительной системой логистики, а также представить специалистам по распределительной логистике возможность эффективных решений в процессе распределения готовой продукции в условиях дефицита.

Ключевые слова: логистика распределения, механизмы функционирования, теоретико-игровая модель, поставщик, потребители.

Introduction. Managing the supply of raw materials, materials, ready products significantly affects the results of the operation of distribution logistics. An integrated view of the distribution system was developed in the 60s-in the early 70s. During this period, it was realized that the combination of different functions that belong to the distribution of the manufactured product into a single management system, will have a large reserve of efficiency (Bowersox 2001:128; Christopher 1986:85).

The tasks of distribution logistics at the micro and macro levels are different (Nikolaychuk 2001:78; Zalmanova 1992:75; Akhmetkaliyeva 2017:115). At the enterprise level, i.at the micro-level, the logistics poses and solves the following tasks:

– planning the processes of distribution of product design, production and sale;

– organization of receiving and processing orders;

– organization of distribution in the through goods through production;

– selection of the type of packaging, making a decision on the completion, as well as organizing the execution of other operations immediately preceding the shipment in the volume of distribution functions;

– realization of distribution functions in the shipment of products;

– the organization of post-sales service in the volumes of the distribution function.

At the macro level, the tasks of distribution logistics are:

– selection of flow distribution schemes and modeling of their characteristics;

– determination of the optimal number of distribution centers (warehouses) in the serviced territory;

– determination of the optimal place location of distribution centers (warehouses) in the service area, as well as a number of other tasks associated with managing the flow of the district, region, country, continent or around the globe.

As the domestic and foreign experience of improving the supply management system shows, the idea is based on the idea of coordinated interaction between all elements of the system "Supplier-consumers".

Literature reviuew. A large number of works in which the coordination is performed by selecting the Cele features elements or fine functions or enabling functions or data of formation procedures (Ashimov 1986:48; Burkov 2000:67; Burkov 1994:272 ; Burkov 1971:165).

However, in real logistical distribution systems, such as "consumers Supplier" is often the formation of orders procedures for delivery, performance criteria elements and the system as a whole are determined and are fixed, but some parameters such as contract prices, the volume of orders for the supply of ready products and other , can be purposefully changed in a given area, for example, depending on the efficiency of production. Functioning of distribution logistics in the set-theoretic language as two-level active systems (Burkov 1977:117; Burkov 2015: 225).

Let's consider the multiple description of the model of the organizational mechanism of distribution logistics. The status of supply processes is described depending on the status of the supplier enterprise acting as the sender of goods, and from consumers of ready products, which is demonstrated in Figure 1.

Denote by y_S the state of the enterprise-supplier, which is determined from the set of its states Y_S -the power of the supplier,

$$y_S \in Y_S,$$

through y_{Cj} – the state of the j – th consumer, which is determined from the set of its states Y_{Cj} , i.e.

$y_{Cj} \in Y_{Cj}$, $j \in J_C$, where J_C – a lot of consumers of ready products (Fig. 1):

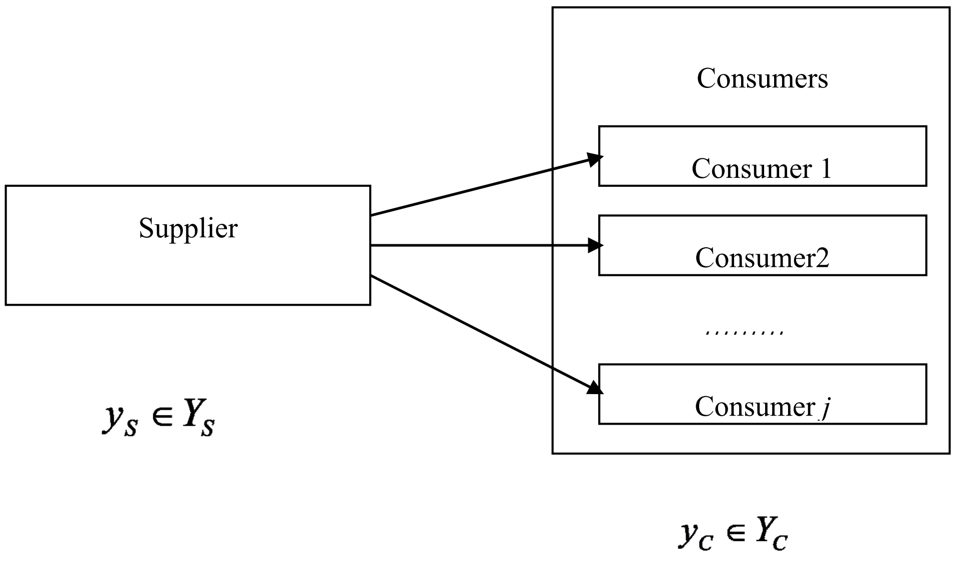

Figure 1 – Diagram of interaction of distribution logistics elements
*Note: developed by the author

The state of all consumers is described in the form $y_C = \{y_{Cj}\}$, where $j \in J_C$, and is determined from the set of their states Y_C , i.e.

$$y_C = \{y_{Cj}\} \in Y_C,$$
$$Y_C = \prod_j Y_{Cj},\ j \in J_C.$$

Then the state y of the distribution process is determined from the set Y of possible states of distributions, i.e. $y \in Y$, where

$$y = (y_S, y_C),$$
$$Y = Y_S \bigcap Y_C.$$

The general state of the distribution logistics system can be described as

$$y^D = (y_S, y_C) \in Y^D = Y_S \times Y_C .$$

The following assumptions are made:

– Enterprises (supplier and consumers) belong to the same industry (Ashimov 1978:29);

– The volume of prematurely delivered ready products to consumers does not exceed the volume of additional output by the supplier;

– for each consumer the volume of products delivered to him ahead of schedule does not exceed the volume of his order;

– the supplier does not know the volumes of necessary products for each consumer and the values of the coefficients of their losses from the shortage of raw materials, he knows only the boundaries within which these quantities can vary.

Material and Methods. According to the methodology of the imitation game (Burkov 2000:32; Shepkin 1999:138) the supplier's task is to distribute the required order among consumers in such a way as to achieve minimum costs (losses) in the distributive subsystem "supplier-consumers" related to the deficit of production. This is achieved by rational satisfaction of requests from consumers. The plan for the distribution of the order between consumers is compiled on the basis of data on the loss factors of consumers in the case of shortages.

The game situation arises because the supplier lacks reliable information about the loss factors of each consumer and the possibility of providing consumers with unreliable information to the supplier at the planning stage.

As a compensating influence, which stimulates the provision of reliable information, mechanisms are in place with the use of fines (criterion management) (Kulzhabaev 1997:216 ; Germeier 1986: 255; Gubanov 2010: 138; Novikov 2013:26; Novikov 2014:127).

The task of each consumer is to minimize their own costs in the conditions of the chosen economic mechanism.

Two classes of management mechanisms are considered: the principle of rigid centralization and the principle of coordinated management without penalty, and the same management mechanisms with penalties. This case reflects the real situation, when consumers and the supplier, in accordance with contractual contracts, can establish control over losses from shortage of products.

Results and Discussion. Description of the model of the simulation game

We introduce the following notation:

x_i – the volume of prematurely delivered readyproducts to my consumer;

R_i – the volume of the order of the consumer;

B – additional release of readyproducts by the supplier;

μ_i – the coefficient of consumer losses from the shortage of raw materials (specific losses);

λ – premium to the price for early delivery of products;

d_i – coefficient of user's penalty for unreliable information;

The task of the supplier is to determine such volumes of readyproducts x_i that ensure the minimization of total losses

$$F = \sum_{i=1}^{n} \mu_i (R_i - x_i) \to \min \qquad (1)$$

under constraints

$$\sum_{i=1}^{n} x_i \le B \qquad (2)$$

$$x_i \le R_i \ , \ i = 1 \div n \qquad (3)$$

The target function of the i-th consumer is:

$$f_i = \lambda x_i + \mu_i (R_i - x_i) \to \min , \quad i = 1 \div n \qquad (4)$$

If control laws with penalties are applied, then

$$f_i = \lambda x_i + \mu_i (R_i - x_i) + d_i |\mu_i - \mu 1_i| R_i \to \min \quad (5),$$

where $\mu 1_i$ is the estimate of the value μ_i reported to the supplier by the i-th consumer; , $\underline{M}_i \le \mu 1_i \le \overline{M}_i$, $\underline{M}_i, \overline{M}_i$ respectively, the lower and upper limits of the change in the quantity μ_i , $i = 1 \div n$.

The supplier collects information about the urgency of deliveries from consumers. Information comes in the form of estimates. After that, the supplier solves the problem of optimal supply planning, applying various control mechanisms.

The mechanisms of control

Stages of the game. The supplier collects information about the urgency of deliveries from consumers. Information comes in the $\{\mu_i\}$ form of estimates. After that, the supplier solves the problem of optimal supply planning, applying various control mechanisms.

a) The principle of rigid centralization (Burkov 1977:38). In this case, the premium to the price for the urgency of delivery is a known constant value for the urgency λ of delivery is a known constant in advance. The supplier solves the problem:

$$F = \sum_{i=1}^{n} \mu 1_i (R_i - x_i) \to \min \qquad (6)$$

under the conditions (1 – 3).

b) The principle of coordinated control (Ashimov 1986:103). In this case, it is determined in the course of solving the problem (1, 2, 6), taking into account the following additional conditions

$$(\lambda - \mu_i) x_i = \min_{0 \le x_i \le R_i} (\lambda - \mu_i) x_i ,$$
$$i = 1 \div n \qquad (7)$$

Conditions (7) require the harmonization of the interests of the supplier with the interests of consumers.

Preliminary analysis

According to the described model, we believe that on the basis of contracts-contracts for this supplier, consumers and the volume of the shipped order are determined to the consumer ($i = 1 \div n$). In this case, three cases are possible: 1) $\sum_{i=1}^{n} R_i < B$, 2) $\sum_{i=1}^{n} R_i > B$, 3) $\sum_{i=1}^{n} R_i = B$.

The supplier must draw up a schedule for the shipment x_i of ready products on the basis of customer requests taking into account their production capacities.

We assume that each consumer informs the supplier: the order in the required quantity of a certain volume of ready products R_i ; can also report information about the "urgency" of deliveries, for example, in the form of loss factors from the shortage of products β_i or the costs of its storage α_i .

It is natural to assume that for each consumer x_i , if the real shipment schedule R_i is rejected, the consumer bears losses in the event $x_i > R_i$ that it may be the cost of storing the surplus product, but with $x_i < R_i$ the loss from the shortage of raw materials.

We will consider the simplest case of a piecewise linear dependence of losses on the magnitude of the deficit $\Delta_i = R_i - x_i$, namely

$$f_i = \begin{cases} -\alpha_i \Delta_i & , \text{ если } \quad \Delta_i \le 0, \\ \beta_i \Delta_i & , \text{ если } \quad \Delta_i > 0, \end{cases}$$

where α_i and β_i are the coefficients of losses from the deficit and from storage, respectively.

Total losses $\sum_{i=1}^{n} f_i$ will be taken as a criterion for the effectiveness of the functioning of the relationship between the supplier and consumers in the process of selling ready products.

Consider the following system of relationships between the supplier and consumers. The consumer pays for the products at a price c_0, if the shipment is made at all. As a rule, the earlier the shipment is made, the more expensive the price, since early deliveries, beneficial to consumers, require the supplier to additional costs to increase their production capacity and temporary mobilization of production reserves. At the same time c_0, it can correspond to the wholesale price of products, and the difference $c_i - c_0 = \lambda_i$ determines the "premium for urgency". The supplier, in turn, is fined for disrupting the delivery time of products (non-fulfillment of consumer applications, ie, when shipping schedules deviate from those declared R_i by consumers). These penalties can partially or completely go to compensate for losses to consumers. Assuming a piecewise-linear form of the penalty function, we write the target function of the vendor in the form

$$F = \sum_{i=1}^{n} \left[c_0 x_i - \begin{cases} \gamma_i (x_i - R_i) \\ \mu_i (R_i - x_i) \end{cases} \right] \quad (8)$$

where γ_i, μ_i are the coefficients of penalties.

Comment. In (8), the components of the vendor's target function that do not depend on the schedule of shipment of products are not included, and the time of the document circulation corresponding to the time gap between the sale of ready products and its shipment is not taken into account.

The target function of the consumer includes a product fee and a loss when the actual shipping schedule deviates from the desired

$$f_i = c_i x_i + \begin{cases} \alpha_i (x_i - R_i) \\ \beta_i (R_i - x_i) \end{cases}, \quad i = 1 \div n \quad (9)$$

It does not take into account the costs of consumers on overheads and transportation of products, because they are weakly dependent on the dynamics of supply.

Finally, we write down the restrictions that determine the allowable shipping schedules:

$$\sum_{i=1}^{n} x_i \le B, \quad (10)$$

$$x_i \le R_i, \quad (11)$$

$$x_i \ge 0, \ i = 1 \div n$$

The schedule of shipment x_i of each consumer i does not coincide with the declared schedule of shipment R_i. In this case, the consumer i suffers losses due to a shortage of products or because of the costs of its storage, which forces him to insure himself against shortages or excessive deliveries in the next period, changing the order R_i.

Thus, there is a game situation between consumers, each of which tries to get a sufficient number of products at the right time; while taking into account only their own interests and showing maximum activity, consumers are going to minimize their costs. This can lead to a distortion of information about the real needs reported by the consumers to the supplier. The supplier, in turn, ships the products to consumers in accordance with their interests. As can be seen, the supplier-consumer system is a typical active system.

We perform a game-theoretic analysis of the functioning of the distribution subsystem: the supplier-consumer.

Let the formation of the initial data occur in a counter-way. Consumers can tell the supplier either the desired shipment schedule, or information about the loss factors, or both.

Suppose that the supplier and the consumer take into account the costs only from the short supply of products, accounting only for this production characteristic is justified by the fact that the losses from the deficit are much greater than other losses associated with storage, transportation and overhead costs; Moreover, early delivery in many cases is beneficial to consumers.

We will assume that the losses of consumers from shortages of products significantly exceed the costs of storing excess products. Neglecting the latter, we write down the consumer's objective function in the form

$$f_i = c_i x_i + \beta_i \, (R_i - x_i) 1[R_i - x_i], \quad (12)$$

where 1[θ] = 1 for θ ≥ 0 and 1[θ] = 0 for θ < 1.

We assume that the supplier does not ship the products beyond the ordered quantity R_i, i.e. $x_i \leq R_i$ for all consumers. Then you can discard the component of the target function of the supplier as independent of the plan for shipment of ready products

$$\sum_{i=1}^{n} c_i x_i = c_i \sum_{i=1}^{n} R_i \quad (13)$$

The system functions as follows. At the stage of data generation, each consumer informs the supplier (order) R_i and possibly an estimate of the loss factor β_i. Assume that the penalty coefficient μ_i is equal (or directly proportional) to this evaluation. At the planning stage, the supplier determines the schedule for the shipment of products. At the same stage, prices $c = (c_t)$ are determined (or adjustments).

Various procedures for the formation of shipment plans and prices are possible depending on the management mechanisms (principles of strict centralization and coordinated management. In the law of rigid centralization of prices $\{c_t\}$ fixed (in particular $c_t = c_0$ – the wholesale price of products), and the shipment plan is defined as the optimal solution of the maximization problem (12) with conditions (10-11).

We pose the problem of determining x_i ($i = 1 \div n$), so that the costs (1) are minimal under constraints (2-3). The solution of this problem can be considered in two ways: by ordering the loss coefficients or the simplex method.

1) Let consumers be numbered in descending order of loss factors, that is,

$$\mu_1 \geq \mu_2 \geq \mu_3 \geq ..... \geq \mu_m$$

Define consumers as follows:

$$\sum_{j=1}^{k-1} x_j < B \leq \sum_{j=1}^{k} x_j \quad (14),$$

where the first $k-1$ consumers receive the maximum order, the k -th consumer receives the balance, and the remaining consumers do not receive the order. The problem, however, is that the Supplier does not have complete and reliable information about the loss factors μ_i. This information is communicated to the Supplier by the consumers themselves. Here we are faced with the problem of the reliability of the data presented or the problem of manipulating information. Moreover, there are cases of both an overestimation of estimates of the coefficients of losses, and their understatement. The overestimation of estimates of loss factors probably aims to minimize the costs of the Supplier and the system as a whole, that is, the total costs determined on the basis of the reported (planned) estimates of the loss factors, and thus it is possible to increase own costs depending on the $\lambda \, (< \;\; > \mu_i)$ - surcharge to the price for the early delivery of products, which is established by the Supplier.

2) Simplex method. Underestimation of estimates of loss factors is intended not to receive an order even at the expense of increasing own losses. We will conduct an analysis of various mechanisms of order distribution from the perspective of possible manipulation of information. The results of the experiments performed for the case of rigid centralization are given and for the case of coordinated control.

From this it is clear, что при $\lambda > \mu_i$ it is profitable for consumers to underestimate, т.е. $\mu 1_i < \mu_i$. that it is advantageous for consumers to underestimate the estimates. And when $\lambda < \mu_i$, on the contrary, there is a tendency to overestimate the estimates $\mu 1_i > \mu_i$

Conclusions

`Thus, depending on the values λ and μ_i some consumers greatly underestimate the collected estimates, while others, on the contrary, report an estimate much larger than the true value of their own μ_i.

As can be seen from the example, the value of the vendor's target function under these conditions is far from the optimal value.

The case of coordinated control, $d_i = 0$

Suppose that consumers do not take into account the impact of their reported estimates $\{\mu 1_i\}$ on the value λ. Then, under the conditions of perfect coordination (7), which can be written in the form: if $\mu 1_i < \lambda$, then $x_i = 0$, if $\mu 1_i > \lambda$, then follows that $x_i = R_i$ for $i = 1 \div n$ the following conditions are fulfilled: if $\mu_i < \lambda$, then $x_i = 0$, if $\mu_i > \lambda$, then $x_i = R_i$, $i = 1 \div n$, that describe the equilibrium state of the system. To get into equilibrium, the i-th consumer should tell the supplier the estimate $\mu 1_i = \mu_i$, $i = 1 \div n$. This means that the equilibrium strategy of the i consumer who wants to get into an equilibrium state is $\mu 1_i^* = \mu_i$, $i = 1 \div n$.

The plan received by the supplier in solving the problem (8,9,12,13) on the basis of estimates $\{\mu 1_i^*\}$ is the optimal agreed plan.

Case of the game with a fine, $d_i > 0$.

With strict centralization, $\lambda = const$ and the application of weak penalties $0 < d_i < 1$, $i = 1 \div n$ it is difficult to obtain reliable information and consumers can not get into an equilibrium state. Only with strong penalties, when, $d_i \geq 1$, $i = 1 \div n$, consumers report reliable information $\mu 1_i^* = \mu_i$, $i = 1 \div n$ and the system comes to an equilibrium state, preferable for all. In the case of coordinated management, there is a weak enough penalty $0 < d_i < 1$,, $i = 1 \div n$ to ensure that the system is in an equilibrium state and consumers would report $\mu 1_i^* = \mu_i$, $i = 1 \div n$.

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