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Optimization of Interaction of Industrial Enterprises and Marketing Network

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Abstract

The article is devoted to the economic and mathematical optimization of the inter-action of industry and trade and supply chains. The main optimization criteria are the minimization of costs goods-movement, minimizing the time of delivery of goods, maximizing boot storage and transport facilities. Formed by the interaction of an optimization algorithm, which allows to determine the appropriate scope of supply and the optimal size of the order, to find the optimal supply chain and calculate the parameters of the supply and movement of goods.

Keywords: trade and distribution networks, industry, economic and mathematical modeling, optimization of interaction

1. Introduction

Background research is determined by the fact that the weight of the world-headquarters is an integration of multinational and corporate companies. Plenty of shopping and retail companies are entering the Russian market. Increasing the number of participants leads to a loss of competitiveness of regional production and trade enterprises, and the crisis could further aggravate the situation of domestic companies. In addition, under current conditions the expectations and requirements of customers are constantly changing. Therefore, manufacturers and members of the product distribution should guide efforts to optimize the supply chain to adapt to the changing market conditions. Accumulated experience of enterprises in market conditions requires a constant search for more perfect product distribution. Supplies for retail chains from producers are horizontally integrated interaction. Analysis of existing models and methods of supply chain management and merchandising in the horizontal-integrated structures suggests the imperfection of the currently existing formal models. Basically, they cover only one criterion (usually cost savings) and not taken into account the specific features of the supplies for retail chains, such as delivery time and utilization of warehouse equipment and vehicles. In addition, there is the problem of reliable calculation of the parameters of the supply chain and product distribution. Known modeling techniques and tools for calculating the parameters of the supply chain and product distribution (methods of game theory, methods of inventory management methods for selecting storage networks, CASE-tools, structured and object-oriented tools, means of cost analysis, simulation tools) have the ability to provide for settlement only individual parts of the business processes. A significant drawback of currently used equipment is fragmented, that is, there are no means to carry out a full calculation of the basic characteristics of the flow of products. Many studies have not paid much attention to the formation of the optimal supply of the complex, and the choice of optimal variants of individual components of the flow of products in the framework of standard models. Development of models and algorithms for optimization of the supply chain and product distribution will coordinate the actions of the participants.

2. Theory

Consider the formal statement of the problem. Production companies $i \in N$ can produce goods in bulk $0 \le w_i \le W_i$. In addition, any company $i \in N$ can sell the product to any consumer, dealer or distribution network $j \in N, j \ne i$ in the volume $0 \le v_{ij} \le V_{ij}$. Trade network has retrospective information about the values of the market demand for the previous periods v_t. On the basis of information about the volume of market trading network determines the required volume of supply v_s, which will be realized in the future. We denote: v_t – sales volume for the previous period; v_t^{pr} – projected volume of sales in the same period; the required amount of supplies; v_s – the required amount of supplies. Function of demand for products can be described by the following dependence:

$$v_t^{pr} = f(P_{ai}, b_0, b),$$

where b_0 – the turnover in the initial period ($b = 0$), pc.; b – annual increase, pc..

Products from manufacturers comes in several batches over certain periods. Order for delivery of another batch of goods is supplied with a minimum balance of the reserve at the sales company. The price of products from different manufacturers may vary. We denote: Q_a – the number of items assortment group a, who bought business structure for the delivery of one (batch size order), pc.; P_{ai} – the purchase price of one unit of output at the i-th manufacturer, rub.; $Z_{ai}^{пр}$ – costs per unit of product commodity group a at the i-th manufacturer, rub.; T^r – the number of working days per year, days.; $R_{торг}$ – margin of trading structure,%. The transfer of goods costs arise: $c^d{}_{i,j}$ – the cost of shipping one lot of the product from the i-th element to the j-th, rub.; $c^h{}_{i,j}$ – costs of storage of one batch, rub.; $C_{об}$ – the total cost of inventory management, rub.

For definiteness, we assume that the function of batch size order is as follows:

$$Q_a = f(c^d{}_{i,j}, c^h{}_{i,j}, v_s).$$

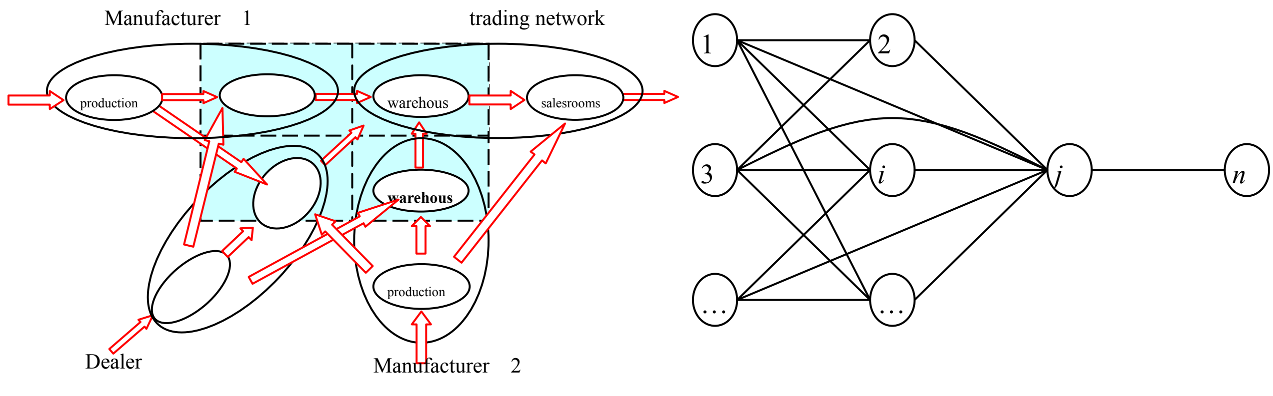
Business network can consider several possible supply schemes. When selecting the supply chain is necessary to calculate the gain, which occurs at the optimum scheme and compare it with a win, which is obtained when a non-optimal merchandise. Thus, $V(\{S_n\})$ – winning of the n-th element at a non-optimal supply pattern.

$V(I) = П_{ОБ}$ – cumulative winning of companies with an optimal supply chain. $\sum_{i \in I} V(\{S_n\}) = П'_{ОБ}$ – cumulative winning of companies with sub-optimal supply chain. $V(I) > \sum_{i \in I} V(\{S_n\})$ – condition of materiality, ie the feasibility of optimization. $\Delta C_{об} = V(I) - \sum_{n \in I} V(\{S_n\}) > 0$ – additional winning. $H^k = (h^k{}_1, h^k{}_2, ..., h^k{}_n)$ – allocation vector of winning.

3. Results

Supply chain and product distribution can be represented as a directed graph, consisting of N elements (see Figure 1).

The elements of the system are producers (factories, shops), con-sumers (agents, dealers, distributors, etc.), as well as storage space products - warehouses. Between the elements of the system passes the flow of goods from producer to consumer. Edges of the graph represent the flow of material, and the vertices of the graph are the economic entities.



Real system of supply and commodity *Formal system of supply and commodity*

Figure 1. Graphical representation of supply and commodity

The main task of the model can be summarized as follows. Required to build the supply chain and product distribution for optimal movement of goods from producers to consumers X , provided that the well-known: the agreed scope of supply v_s , the purchase price of one unit of product from the manufacturer P_n , the number of items that must be ordered and trading structure for one delivery Q , the number of working days year T^r . It is also necessary to take into account and allocate an additional prize if it occurs as a result of optimization.

We represent the model as a constant matrix of costs $C = \left\{ c_{i,j}, i = \overline{1,N}; j = \overline{1,N} \right\}$, time limits delivery of the product from the manufacturer to the consumer based on one production batch $T = \left\{ t_{i,j}, i = \overline{1,N}; j = \overline{1,N} \right\}$ and load factors $K = \left\{ k_{i,j}, i = \overline{1,N}; j = \overline{1,N} \right\}$. Costs include transport - procurement costs $C = \left\{ c_{i,j}, i = \overline{1,N}; j = \overline{1,N}; i \neq j \right\}$, and the costs of storage $C = \left\{ c_{i,j}, i = \overline{1,N}; j = \overline{1,N}; i = j \right\}$.

Matrix of variables in the model is the incidence matrix and defines the structure of the interaction of elements of the system by moving a lot of the product:

$$X = \left\{ x_{i,j}, i = \overline{1,N}; j = \overline{1,N} \right\},$$

where N - the number of indices of the matrix.

The elements of the matrix are defined as follows:

$$x_{i,j} = \begin{cases} 1, \text{ if the vertex } x_j \text{ adjacent to the vertex } x_i \\ 0, \text{ otherwise;} \end{cases}$$

and characterize the flow of material, which moves from *i*-th element of the system to *j*-th element. The incidence matrix is a reflection of the graph supply schemes.

Interaction is directed to perform tasks that are defined criteria: minimization of costs of goods movement $F_1(X) = \sum_{i-1}^{N} \sum_{j=1}^{N} c_{i,j} \cdot x_{i,j} \longrightarrow \min$, minimize the time of delivery of goods $F_2(X) = \sum_{i-1}^{N} \sum_{j=1}^{N} t_{i,j} \cdot x_{i,j} \longrightarrow \min$, maximizing load storage and transport facilities $F_3(X) = \sum_{i-1}^{N} \sum_{j=1}^{N} k_{i,j} \cdot x_{i,j} \longrightarrow \max$.

These optimization criteria are essentially eco-logarithmic-contradiction, because of the reduction of delivery of the goods from the producer to the consumer increases transport - procurement costs and costs of the organization associated with the storage. Furthermore, each element of the system is interested in improving load factors. However, with increasing load factors increase the delivery time of products to the consumer.

In operation, the system raises a number of limitations:

$$\sum_{i-1}^{N} \sum_{j=1}^{N} c_{i,j} \cdot x_{i,j} < v_s \cdot P_a .$$

Economic interpretation of the limitations is that the elements of the system begin to interact with each other only when the result of this interaction arises economic benefit to the producer, that is, its costs do not exceed revenues.

$$\sum_{i-1}^{N} \sum_{j=1}^{N} x_{i,j} > \frac{v_s}{Q_a} .$$

Limitation is the minimum number of links between elements of the system, ie for the whole period the total amount of supply elements of the adjacency matrix can not be less than the number of shipments.

$$\sum_{i-1}^{N} \sum_{j=1}^{N} t_{i,j} \cdot x_{i,j} < \frac{Q_a \cdot T^r}{v_s} .$$

Inequality imposes on the manufacturer's obligation to comply with the terms of supply of products.

$$\sum_{i=1}^{N}\sum_{j=1}^{N} k_{i,j} \cdot x_{i,j} < \frac{2v_s}{Q_a} + 1 .$$

Each element of the system tends to move $k_{i,j}$ to one (100% load on its power), where $k_{i,j} \in [0;1]$.

The total value of load factors cannot be greater than the sum of elements and the number of connections between them for the selected period. The maximum value of this criterion will be structured according to the minimal connected graph. If for the selected period of four deliveries performed, the programming load factors must not be more than nine.

Following constraint shows that deliveries should not exceed the total volume of demand:

$$\sum_{a=1}^{m} Q_a \le \sum_{r=0}^{q} \frac{b_r}{r!} \cdot P_a^{\ r} .$$

So the system of constraints is a raznonaprav-lennuyu system of inequalities.

Formulation of performance criteria and system constraints, provides an approach to the problem of the optimal supply chain and product distribution. Required to construct a matrix of a directed graph X representing the structure of supply, which contains in its structure n vertices and interconnected so that the selected performance criteria achieved optimal values within the constraints.

Search for the optimal supply chain and commodity produced with the help of the principles of the decisions that are based on the calculation of multiobjective optimization problems with non-uniform equivalent criteria. Criteria problems are not uniform, as part of the optimization criteria tends to the minimum value, and one - to maximal. Criteria are equivalent in the formation of an optimal supply chain and product distribution. Equivalence criteria due to the fact that each criterion has a significant impact on the supply chain and retail outlets.

Minimization of costs $F_1(X)$ associated with the movement of goods such economic indicators such as price and cost of goods sold. Minimizing the delivery time $F_2(X)$ is a key factor in modern concepts (JIT) and (QR). Maximizing load storage and transport $F_3(X)$ associated with increased use of local reserves.

With the objective functions and system limitations, we can begin to develop procedures and algorithms for solving the optimization problem.

Step 1: Determining the scope of supply and the optimal size of the order.

1: Determining the volume of deliveries v_s. The required volume of shipments is based on the forecast of demand or other known methods of forecasting.

2: Define the model of inventory management and the search for optimum th order size.

Step 2: Search for the optimal supply chain

1: Perform control system limitations and the formation of a set of matrices of supply (supply schemes of products from producers to consumers) X, the domain of acceptable values.

2: Define the matrix supplies corresponding to the optimal values of the objective functions $F_{1,2,3}(X)$.

Allocation of three types of supply schemes $\{X_1, X_2, X_3 \in X_k\}$, which corresponds to the minimum / maximum value of the corresponding criteria:

$X_1\{F_1^{\min}(X), F_2(X), F_3(X)\}$, $X_2\{F_1(X), F_2^{\min}(X), F_3(X)\}$, $X_3\{F_1(X), F_2(X), F_3^{\max}(X)\}$,

$F_1^{\min}(X) = \min\{F_1^k(X)\}$, $F_2^{\min}(X) = \min\{F_2^k(X)\}$, $F_3^{\max}(X) = \max\{F_3^k(X)\}$.

3: Normalization criteria. Because the optimization criteria $\{F_1^k(X), F_2^k(X), F_3^k(X)\}$ have different dimensions and economic sense, they need to be normalized by the following formula:

$$\overline{F_k(X)} = \begin{cases} \dfrac{F(X)_k^{\max} - F_k(X)}{F(X)_k^{\max} - F(X)_k^{\min}}, k = 1{,}2 \\ \dfrac{F_k(X) - F_k^{\min}}{F(X)_k^{\max} - F(X)_k^{\min}}, k = 3, \end{cases}$$

where $F_k(X)$ - the current value of the objective function of the k-th supply chain; $\overline{F_k(X)}$ - the value of the normalized k-th objective function; $F(X)_k^{\min}$ - the minimum value of the k-th objective function, which is obtained by solving a one-criterion optimization problem without taking into account all the other criteria; $F(X)_k^{\max}$ - maximum value of the k-th criterion is obtained by solving a one-criterion optimization problem without taking into account all the other criteria.

4: Determination of the parameter $g_k^{i,j}$:

$$g_k^{i,j} = \overline{F_k(X_j)} - \overline{F_k(X_i)}, i, j, k \in K \ ,$$

where $g_k^{i,j}$ - a parameter that reflects the share of loss (gain) k-th criterion for the transition from the supply chain of products i to the circuit output j.

5: Building a graph in which the vertices correspond to matrices supply X (optimal for each objective function). Edges of the graph - is the management, in which the transition from a supply circuit j to the supply chain i.

Further, the weight of graph edges should be determined as the sum relative increases (losses) of the target system functions during the transition from supply circuit i to the supply chain j:

$$D_k^{j,i} = \sum_{k=1}^{K} g_k^{j,i}, \ \text{i, j} \in 1..3 \ .$$

6: Finding the parameter Ψ_k , which values characterize the vertices of supply schemes:

$$\Psi_k = \sum_{k=1}^{3} D_k^{i,j}, \ \text{k} \in 1..3 \ .$$

Vertex represents the sum of relative increases (losses) criteria for the transition to the supply chain X_κ^* from other supply schemes. The parameter Ψ_k is a quantitative characteristic of the relative preference of the supply chain X_κ^* as compared to other schemes. Effective transition from one optimal scheme to another can be represented as a directed graph (see Figure 2) where X_κ - supply chain, the best according to the criteria K.

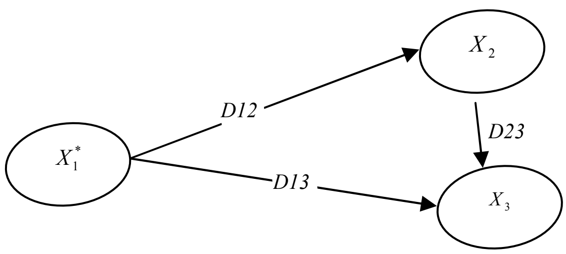


Figure 2. Graphical interpretation of multicriteria choice

7: Select the optimal scheme of supply of products from the condition:

$$X^{opt} = \max \Psi_k(X_k^*), k = 1,..., K \ .$$

Supply chain and commodity $X_k^* = \arg \max\limits_{k=1,2,3} \Psi_k$ is a compromise-optimal according to the criteria $\kappa=1,2,3$, because relative increase of criteria will exceed relative losses.

Step 3: Calculation of the supply and movement of goods

1: Calculation of the basic parameters of the supply and movement of goods under sub-optimal supply chain: $V(\{S_1\})$, $V(\{S_n\})$, $\sum\limits_{i \in I} V(\{S_n\})$.

2: Calculation of total return $V(I)$ with an optimal supply chain.

3: Select the vector percentage of profit distribution H^k .

4: Calculation of the basic parameters of the supply and movement of goods at an optimum supply chain: $V(\{S_1\})' = \Pi'_T$ $V(\{S_2\})' = \Pi'_{\Pi P}$.

4. Conclusions

In the formed criteria optimization of the supply chain and product distribution (based on a study of supply for retail chains) to quantify the costs of merchandising, delivery times and utilization of warehousing and transport.

Developed a multi-criteria optimization model of the supply chain and product distribution to retail chains formed on the basis of criteria that can simultaneously take into full account the costs of merchandising, delivery times and utilization of warehousing and transport.

The algorithms and methods of the optimal system-order delivery and product distribution to retail chains based on multicriteria evaluation methods on the graph of Pareto - optimal controls.

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