Economics

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ECONOMIC AND MATHEMATICAL MODELLING OF SUPPLY CHAIN

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The article highlighted the main problems of irrational wasting of material resources and money used during the transportation and in other industries. Also it deals with the criteria and ways to optimize flows in supply chains, presents options of software products for the rationalization of supply chains via using mathematical models.

The latest achievements in projecting the technology of supply chain have given a rise to useful optimization of the companies. Modern enterprises can manage the great amount of information for projecting, analysis and optimization the operation of the supply chain, starting with extensive rationalization of a whole net and ending with rationalization of product lines and analysis of transport flows. Being the part of continuing process of projecting a supply chain, expression 'modelling of production' can be used for designation the main enhancements: price, service, risks.

The main criteria of improving the effective functioning of supply chain are:

1) maximization of profit;
2) risk management;
3) minimization of costs.

The opportunities of approach, allowing to *maximize profit,* which is gained from completing requests by choosing the best option of their fulfilment, are shown in [1].

It's clear today that the *risk management* problem is relevant. The risk turns into an integral element of socio-economic relations and becomes a great part of socio-economic political strategy and tactic of enterprises.

Logistical risks include customs risks, risks of failure in supply, damages in the fulfilment of logistical operations for each element of supply chain etc. It is accepted to divide transport risk into auto-hull risks and cargo risks [2]. In the first case the risk source is a vehicle, in the second one – goods, which are moved by vehicle.

One of the planning and supply chain management goals is *minimizing logistical costs*, i.e. fulfilment of logistics operations costs. Total logistics costs consider the whole range of costs associated with logistics, which includes transport and warehousing costs, but also inventory carrying, administration and order processing costs (fig. 1).

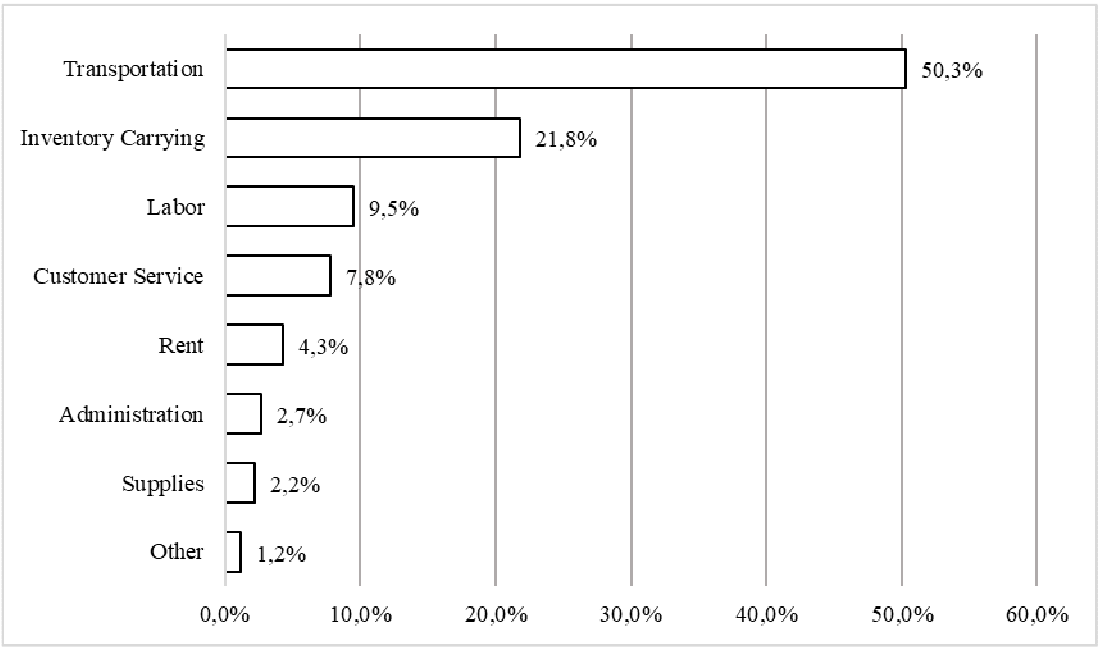

Fig. 1. The share of logistical costs

Every logistical activity leads to costs emergence, so in order to plan them, it's useful to merge them in accordance with the main logistical activities of supply chain (table 1) [3].

Table 1 – Logistical costs structured by basic logistical operations

Provision	Transport	Manufacturing	Stock	Distribution
Purchasing raw materials	Transportation rates	Order processing	Warehousing	Order processing
Processing the order	Cargo transshipment	Intra-company transportation	Operating the warehouses	Mission costs
Losses of stock shortages	Storage and freight forwarding	Storage of semi-finished products	Storage facilities rent	Warehousing functionalities
Correction of manufacturing defects	Loading and unloading of the goods	Workflows management	Stockpiles insurance	Invested capital

It would be more appropriate to talk about total logistical costs looking at supply chains. Total logistical cost is a set of costs, which are related to managing and moving material, information and financial flow through the whole supply chain.

For solving complex supply chain tasks, in which the aforementioned optimization criteria are combined in different ways, it's necessary to turn to computer modelling and numerical methods usage.

Linear programming models and their optimization methods play the main role in all types of supply chain management missions. Models and methods were originally conceived for optimization of limited resources distribution in maintaining the economic activity.

Formally, the task of production program optimization can be described by the following linear programming model:

$$\begin{cases} \sum_{j=1}^{n} c_j x_j \to max \\ \sum_{j=1}^{n} a_{ij} x_j \leq b_i, 1, \dots, m; \\ x_j \geq 0, \quad j = 1, \dots n. \end{cases} \quad (1)$$

where n – the number of products;

m – the use of production resources (i.e. production capacity, raw materials, labor);

a_{ij} – the share of resource i at the product j output;

c_j – the profit from the output and the sale of product j;

b_i – the number of available resource i;

x_j – the output amount of product j.

The model (1) is determined as a linear programming model in standard maximizing form. The examples of its solving and different variations of this task are described in [4].

To create a linear programming model correctly it's necessary to identify the dependences between variables. It requires correlation and regression costs analysis. Correlational analysis represents detecting the impact of independent values on dependent ones and on each other, while regression analysis represents model formulation and determination its statistical significance level.

As a result of correlation and regression analysis the most significant cost are found and dependence equations between such costs and efficiency indicators of the enterprise are built. These equations are used after in formulation the linear programming task.

For conducting complex statistical analysis, in particular correlation and regression analysis, advanced statistical programs like IBM SPSS Statistics should be used. SPSS Statistics is a software package used for logical batched and non-batched statistical analysis. SPSS provides a wide choice of statistical instruments beginning from determining standard sample indicators (mean, mode, median) and ending with complex researches (different types of t-tests, ANOVA). The software name originally stood for Statistical Package for the Social Science (SPSS), reflecting the original market, although the software is now popular in other fields as well, including the health sciences and marketing.

For solving both statistical tasks and linear programming models MS Excel is frequently used. For choosing MS Excel as a software there are built-in functions and some search for solution algorithms (MS Solver). Its disadvantage is related with the absence of opportunity to solve some categories of optimization

tasks, i.e. mixed integer programming using Boolean variables. Also as a disadvantage of MS Excel can be identified a limit on the number of variables (200 cells), that makes impossible to solve major problems.

There are a lot of software specializing at linear programming in the market, for example MATLAB and Mathcad, which are specially focused on solving mathematical tasks, or Business Studio, which is aimed to business process modelling. Also it is worth to highlight Statistica software – instruments for data analysis, visualization, prediction etc.

Optimization software package IBM ILOG CPLEX Optimization Studio (often informally referred to simply as CPLEX) deserves specific attention. CPLEX Optimizer was named for the simplex method as implemented in the C programming language, although today it also supports other types of mathematical optimization and offers interfaces other than C.

CPLEX Optimizer provides flexible, high-performance mathematical programming solvers for linear programming, mixed integer programming, quadratic programming, and quadratically constrained programming problems. These solvers include a distributed parallel algorithm for mixed integer programming to leverage multiple computers to solve difficult problems [5].

CPLEX enables to optimize all business decisions, develop and deploy optimization models quickly, and create real-world applications that can significantly improve business outcomes (it's possible to optimize the models with billions of constants and variables).

CPLEX Optimizer has flexible interfaces, that gives developers a variety of ways to interact with it during the development and deployment of their applications. CPLEX doesn't give a single-valued solution, it looks for different options. That's why the necessity to variables replacing excludes.

Presented options for solving task of costs, profit etc. optimizing can be used not only in supply chain engineering. Economical and mathematical methods of modelling play a crucial role in determining the optimal quantity of produced items, in building the product portfolio, organizing better product distribution at the end of delivery and so forth.

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