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MODELS AND APPLIED INFORMATION TECHNOLOGY FOR SUPPLY LOGISTICS IN THE CONTEXT OF DEMAND SWINGS

The **subject matter** of the study is the processes of planning supply logistics taking into account swings in demand and prices for products. The **goal** is to develop models and applied information technology for managing enterprise supplies taking into consideration the unforeseen demand swings. The following **tasks** were solved: a process model of supply logistics was developed, a model for forecasting demand for products was developed, a model for calculating the optimal volume of orders for various demand options was developed, the structure and modules of the applied information technology for supply logistics management was developed. The following **methods** were used: structural process models, methods for regression analysis and time series forecasting, inventory management models, STATISTICA software package, object-oriented programming methods. The following **results** were obtained: the generalized pattern of supply logistics was developed; the supplement of the first block of this pattern with the processes of marketing research of demand for products and planning supply volumes according to the forecasted demand and the probability of a shortage or surplus of products due to unforeseen swings in demand was substantiated; the application of the methods of regression analysis and forecasting of time series to assess the market factors of supply logistics was considered; the model for determining the optimal stock size was studied taking into account storage costs and probable shortages; the architecture of the applied information technology for planning supply logistics was developed; the proposed IT enables analyzing and predicting changes in the main market factors and, in accordance with the results obtained, solving inventory management tasks efficiently. In this case, the deficit and back-ordered demand can be taken into account. The operation of IT modules was illustrated by a test case. **Conclusions**. The use of IT is efficient in making decisions on logistics planning of business processes, as well as in analyzing the efficiency of logistics for a certain period of time. Further, the specified technology is going to be supplemented with the capabilities of solving inventory logistics problems.

Keywords: supply logistics; demand forecasting; parameter optimization; time series; applied information technology.

Introduction

Any enterprise, both manufacturing and trading, which processes the material flows, includes the service that purchases, sells and temporarily stores products (raw materials, semi-finished products, consumer goods). All functions of the logistic service should ensure the efficient execution of orders. Management tasks based on the logistic approach are to coordinate the need for operations on the cross-functional basis to achieve the global goal of an enterprise. Logistics management enables combining into a single system the task of managing the internal business processes of the enterprise with the business processes of partners and consumers.

Literature review and problem statement

M. Gordon, E. Kogan and others study the issues of supply management. E. Krykavsky, A. Gadzhynsky, B. Anikin, M. Oklander and others conduct model studies of logistic laws. Methodological approaches to the management of supplies are considered in the works written by such foreign scientists as J. Riggs, O. White, J. Johnson, J. Shapiro and others.

However, the issue of supply logistics is not thoroughly studied in the theory of domestic management. For example, the monograph [1] analyzes the system factors of the efficiency of the supply logistics at enterprises. Theoretical, methodological and applied aspects of the category "supply logistics" are generalized. The peculiarities of the implementation of integrational cooperation in the system "supplier – processing plant" are studied and organizational, strategic and information factors of the supply system optimization are substantiated.

Paper [2] considers the grounds of the material and technical support and the ways of its improvement. The basic requirements for operational inventory accounting were developed to provide the supply department with timely information for inventory management and optimization. The universal structure of the logistics department was developed and the main functions of this department were determined.

The main point of logistics is to reduce the cost of product delivery due to too frequent requests to a supplier and freezing money in excess stocks [3, 4]. Both of these extreme options are the consequence of the non-optimal volume of goods ordered from the product supplier. That is why attention should be paid to the fact how purchases are calculated, planned and carried out, including the way the volume of the purchased consignment of goods is determined.

Factors and efficiency of integration of marketing and logistics are considered in paper [5]. Conditions of such integration at the stages of strategic planning are studied. The idea of integration should also be used to manage supply logistics.

Most of the work is devoted to the analysis of logistic processes for industrial enterprises [6, 7]. The procurement activity of a manufacturing enterprise affects the operation of all sections of the enterprise: from production to sales of finished products. Modern trends of procurement logistics development are analyzed in paper [6], the paper also deals with practical recommendations to select a system for planning material resource needs optimizing, optimizing expenses for the order execution and maintaining the volume of stocks of the industrial enterprise. But for universal enterprises, such as small businesses, trade or intermediary firms, whose work focuses on a wide range of products and highly depends on demand, the problem of supply is not studied thoroughly.

To plan logistics, forecast models are used, in particular, ones based on regression equations. Paper [8] considers the issues of practical application of formalized methods of forecasting in the process of tactical and strategic planning at the industrial enterprise. The examples of using product life cycle models, regression equations and graphical analysis apparatus during scheduled calculations are given.

Heuristic methods of project management are also used [9]. Paper [10] proposes a choice of an integrated strategy for inventory management on the basis of key nomenclature groups that determine the profitability of the enterprise and on the analysis of the forecastability of goods sales. The methods of ABC/XYZ-analysis are used [11].

Issues of development of selective applied models of analysis, forecasting, quantitative assessment of supply parameters and decision-making tools for supply management according to the logistic concept remain topical.

Under the current conditions of competition and constant update of the range of market products, it is very difficult to predict the demand for a short period of time. In cases where the demand for separate items of the product line temporarily deviates from the predicted value, urgent decisions should be made on the supply of certain volumes of products. To make such decisions, special models for calculating the volume of stocks should be applied. Under these conditions, the applied software should be used. Under these conditions, the use of modern applied software technologies and tools will useful [12].

Therefore, the goal of the article is to develop models and applied information technology to manage the supplies of the enterprise taking into account unforeseen demand swings. The following tasks are to be solved:

1. To develop the process model of supply logistics.
2. To form demand forecasting models and product prices.
3. To form models for calculating the optimal volume of orders for different demand options.
4. To develop the structure and modules of applied information technology for managing the supply logistics.

Study materials and methods

1. Process models of supply logistics

Consider the basic logistics processes that support the activities of a small enterprise related to the purchase and sale of certain types of products [13].

Enterprise logistic processes are presented in the context chart as an IDEF0 model (fig. 1):

- supply of goods;
- acceptance of the order from the client;
- order picking;
- sending orders to the client;
- reporting.

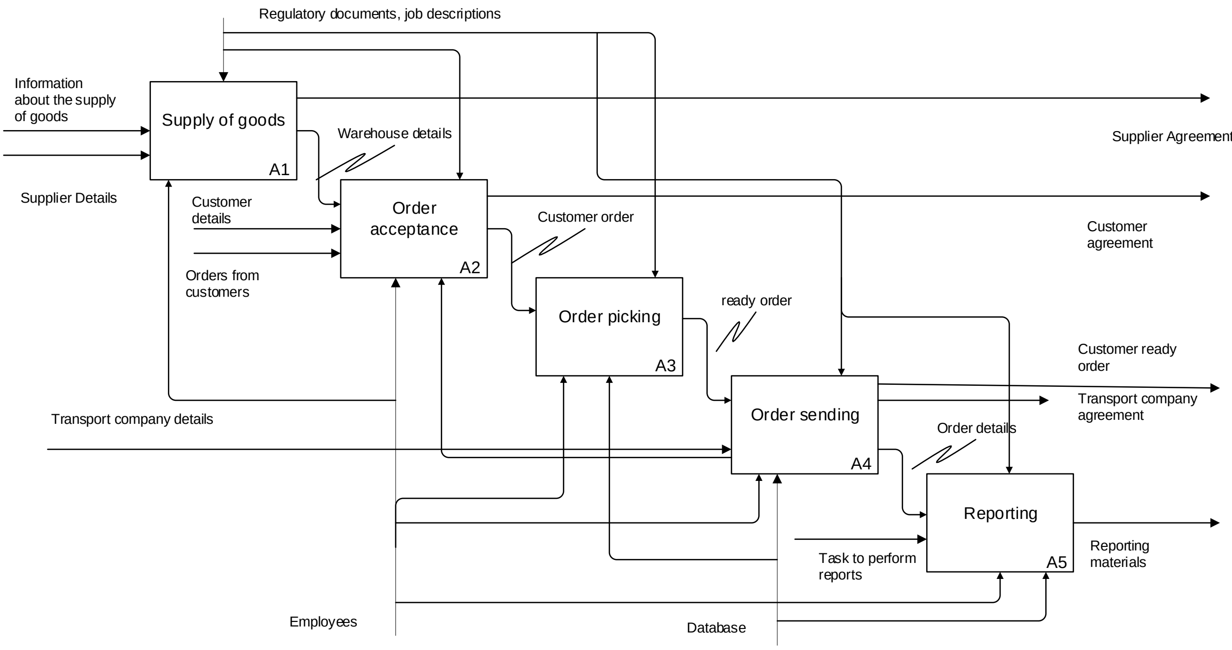

Fig. 1. The generalized chart of the enterprise logistic processes

In addition to the interrelation of processes, the chart reflects the input information, regulatory information, its sources and output documentation for each stage.

Employees will enter information in appropriate forms using the information system for supporting logistic processes. The final cost of the order is indicated by the company's responsible employee but a preliminary estimate of the value of the order is made in the information system. The details of the order and the customer are stored in the database. The information system automatically calculates the cost of consumables and a service agreement is formed in accordance with a template that can be changed if needed. The data on the contract will be obtained from the directory of customer data and the order form.

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However, the task of optimal calculation of a lot of goods should be solved in the first stage of the product supply [14]. The forecast of the demand assessment should be taken into account and a certain product should only be ordered when it is necessary and in the quantities in which the enterprise currently needs.

When implementing these processes, the situation can arise when orders do not correspond to the quantity or range of products kept at the warehouse. In this case, two opposite situations may arise:

- when the ordered products are not available or it will arrive shortly;
- when the products have already arrived but there are no orders for it.

Thus, the classical problem of balancing supply and demand [15] should be solved. This task is essential when making supply management decisions. Its solution is ensured by such components of logistic planning:

- forecasting demand;
- determining the optimal volume of supply orders;
- selecting a supplier with a reliable carrier to ensure supplies of certain volumes and range of products.

The main requirements for the procurement system are briefly described below.

1) while forecasting demand, a model should be used that takes into account trends, seasonality and the required level of meeting the demand with warehouse residues;

2) the order for the supplier should not be carried out until the residues of any product of this supplier have reached a critical level;

3) while determining the needs of the enterprise in any product, exactly such amount that is enough to provide the desired level of sales before entering the next product according to the current order should be ordered.

If these three conditions are fulfilled, the volume of the order, which is optimal in terms of the total costs of transportation and storage of products can be calculated. Determining the optimal amount of a lot of goods is possible only using the modelling of supplies with different variants of the volume and comparing the total costs of transportation and storage.

2. Models of demand forecasting.

To forecast demand for products, regression models that show a change in the resulting indicator when changing the values of factor characteristics are used. In this case, the factors affecting demand can be:

- the level of demand for the same product in past,
- advertising costs,
- the level of customers' paying capacity (or population as a whole),
- economic situation,
- the activity of competitors,
- the level of supply – is determined by substitutes that are available on the market, a number and position of competitors as well as the corresponding volumes of production.

Consider the forecasting variable *Y* (demand level) and a number of factors that have an impact – X_1, X_2, ..., X_m (independent variables). The values of the above factors should be presented in a formalized form (quantitatively).

The model of multiple regression in the general case is described by the expression

$$Y = F(X_1, X_2, \ldots, X_m) + \varepsilon . \quad (1)$$

In the case of a linear regression model, the dependence of the variable from the independent ones is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_m X_m + \varepsilon , \quad (2)$$

where $\beta_0, \beta_1, \beta_2 \ldots \beta_m$ are the assessed coefficients of regression, ε is the error component. It is assumed that all errors are independent and normally distributed.

To build regression models, the database of observations is needed. Using the table of values of past observations, regression coefficients can be determined (for example, by the method of least squares) thus building the model. The correctness and adequacy of the model are verified by several methods:

1) using the coefficient of determination, the strength of dependence can be determined

$$R^2 = 1 - \frac{D_\varepsilon}{D_y}, \quad (3)$$

where D_ε is the residual variability (error dispersion), D_y is the output dispersion.

2) the statistical significance of the linear model can be assessed basing on the *F*-criterion. If the connection between some variables is non-linear, they should be transformed (for example, their logarithm should be found).

3) the quality of the equation can be assessed using the *t*-criterion (Student) by checking the hypothesis that the absolute term of an equation β_0 is equal to zero;

4) to determine the problem of multicollinearity, which may arise if a lot of variables are analyzed, statistical indicators of redundancy (tolerance, etc.) should be used as well as ways to cope with redundancy (for example, the ridge regression method).

If the impact of external factors cannot be determined but there are statistics on the change in demand over a certain period of time, the method of time series analysis should be used, in particular, the Box-Jenkins method (ARIMA) [16, 17].

The method is based on the approximation of the stationary sequence by the sum of the autoregression sequence of the *p*-th order and the sequence of the average variable of the *q*-th order:

$$y_k = \sum_{j=1}^{p} \gamma_j y_{k-1} + \varepsilon_k - \sum_{l=1}^{q} a_l \varepsilon_{k-l} , \quad (4)$$

where γ_j is the autoregression parameters; al is the parameters of the average variable; ε_k is the sequence of independent random values.

When there is a monotonous trend, the initial sequence can be numerically differentiated. The result of

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such a transformation is checked for the stationary state by analyzing the coefficients of autocorrelation.

The Box-Jenkins method involves the following stages:

1) selecting the model structure, determining the order of autoregression p, the order of the average variable q, the multiplicity d of the numerical differentiation;

2) assessing the parameters γ_j (j = 1, 2, ... p), a_l (l = 1, 2, ... q);

3) forecasting the stationary sequence;

4) the numerical integration of the d-th order to renew the character of the process taking into account the trend;

5) assessing the accuracy of the forecast by comparing the forecasted values and real data when testing the method, assessing the statistical characteristics of the residuals, checking if they correspond to the white Gaussian noise.

The model of the demand dynamics is more accurate if it is the sum of two main components – the polynomial and the autoregressive ones.

The polynomial component μ_k characterizes long-term trends in the context of the changes in the demand for products due to the period of the product life cycle. The autoregression random correlated component $\overset{\circ}{y}_k$ characterizes changes caused by external factors. Therefore, the demand variable can be approximated by the sum of polynomial component (of the p-th order) and autoregression component (of the m-th order)

$$y_k = \mu_k + \overset{\circ}{y}_k \,;\; k = 1, 2, \ldots n, \qquad (5)$$

where $\mu_k = \sum_{i=0}^{p} \beta_i \varphi_{ki}$, $\overset{\circ}{y}_k = \sum_{j=1}^{m} \gamma_j \overset{\circ}{y}_{k-j} + \varepsilon_k$, γ_j $(j = 1, 2, \ldots, m)$ are the autoregressive parameters, $\langle \varepsilon_k \rangle = 0;$ $\langle \varepsilon_k^2 \rangle = \sigma_\varepsilon^2 = \gamma_0$.

The stationary autoregression sequence is characterized by normalized autocorrelation coefficients

$$\rho_l = \frac{R_l}{\sigma^2_{\overset{\circ}{y}}} = \frac{R_l}{R_0}, \qquad (6)$$

where $R_l = \left\langle \overset{\circ}{y}_k \overset{\circ}{y}_{k+l} \right\rangle = \sigma^2_{\overset{\circ}{y}} \rho_l$ are unnormalized autocorrelation coefficients (l = 0,1, ..., m-1); $\sigma^2_{\overset{\circ}{\lambda}}$ is the dispersion of the autoregression component.

The parametric adaptation of the model components of the polynomial and autoregression sequence provides for the assessment and iterative refinement of the coefficients of the polynomial $\beta_0, \beta_1, \ldots, \beta_p$ as well as the parameters of the autoregression $(\gamma_1, \gamma_2, \ldots, \gamma_m;\ \sigma_\varepsilon^2 = \gamma_0)$ by the data being observed. That will enable solving the task of determining the two components of the sequence based on the difference in their correlation properties.

3. Models of stock formation in the context of stochastic demand

The economic volume of the order is equal to the volume of the order for replenishment of stocks, which minimizes the total cost of the stock of inventory. The basis for the order is to reach the renewal point of the inventory level. The economic volume of the order is calculated to minimize the combined value of inventories including costs for buying, storing, placing the order and so on. The task of determining the order volume is related to the optimization of the reserve stock. At the same time, an optimal threshold value that acts as the basis for placing an order should be found.

The most famous formula for calculating an economic volume of an order is the Wilson formula, that is based on the following assumptions [18]:

- the cost of placing an order is constant;
- the rate of demand is known;
- the time of order execution is constant;
- the purchase price of a unit of goods is constant.

Let us introduce the following variables:

- Y is the volume of demand for a certain period of time;
- C_z is the fixed cost of placing one order;
- C_x is the cost of stock storage.

According to the above assumptions, the optimal volume of order is equal to

$$q = \sqrt{\frac{2YC_z}{C_x}}\,. \qquad (7)$$

But this formula cannot be used in modern logistic systems where the cost of placing an order is the only key factor and does not take into account changes in demand and price swings which are important when ordering a large number of goods.

Consider the case when a real demand is somewhat lower than a forecasted one. Then, the model of the stock formation with the final delivery rate without any deficit should be applied.

Let the ordered lot of goods of the q volume be supplied with the rate of λ units a period of time. The supply system can operate without deficit if the rate of supply λ is greater than the rate of consumption Y'.

The stock is both obtained and consumed during the period of time τ_1. The stock is only consumed during the period of time τ_2. Then, the cycle length is $\tau = \tau_1 + \tau_2$.

Let us designate the volume of demand for a certain period of time as Y. Taking into account that the minimal available stock is

$$l_m = q\left(1 - \frac{Y}{\lambda}\right), \qquad (8)$$

the system costs for a unit of time are:

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$$C = \frac{C_z Y}{q} + \frac{C_x q}{2}\left(1 - \frac{Y'}{\lambda}\right). \tag{9}$$

The volume of the optimal lot is:

$$q^* = \sqrt{\frac{2C_z Y}{C_x\left(1 - \frac{Y'}{\lambda}\right)}}. \tag{10}$$

The optimal period of the order renewal is:

$$\tau^* = \sqrt{\frac{2C_z}{C_x Y'\left(1 - \frac{Y'}{\lambda}\right)}}. \tag{11}$$

The minimal cost in a unit of time is:

$$C^* = \sqrt{2C_z C_x Y'\left(1 - \frac{Y'}{\lambda}\right)}. \tag{12}$$

Consider the case when real demand is higher than the forecasted one. Then the model of stock formation should be used in the context of a deficit taking into account the unsatisfied requirements. When the losses due to the deficit are comparable to the cost of saving, the deficit is allowed.

Fines related to the stock unit deficit per a unit of time are designated as d, the maximal value of the back-ordered demand is designated as yd. The cost of storing products is proportional to the average value of the stock $\frac{q - y_d}{2}$ and the time of its existence $\frac{q - y_d}{Y}$; in the same way, the deficit losses are proportional to the average value of deficit $\frac{y_d}{2}$ and the time of its existence $\frac{y_d}{Y}$. The average cost of the system operation within a cycle including the cost of placing an order, maintaining stock and losses due to the deficit is as follows:

$$C = C_z + \frac{C_x\left(q - y_d\right)^2 + d y_d^{\,2}}{2Y}. \tag{13}$$

Let us divide the cycle costs by its value $\tau = \frac{q}{Y'}$, system operation costs per unit of time are obtained:

$$C = \frac{C_z Y'}{C_x} + \frac{C_x (q - y_d)^2 + d y_d^{\,2}}{2q}.$$

Therefore

$$q^* = \sqrt{\frac{2C_z Y'}{C_x}\left(1 + \frac{C_x}{d}\right)}, \tag{14}$$

$$y^* = \frac{1}{d}\sqrt{\frac{2C_z Y' C_x}{1 + \frac{C_x}{d}}}, \tag{15}$$

$$C^* = \sqrt{\frac{2C_z C_x Y'}{1 + \frac{C_x}{d}}}. \tag{16}$$

Substituting values q^* and y^* into corresponding equations, other optimal supply parameters can be calculated:

$$Y^* = q^* - y_d^{\,*} = \sqrt{\frac{2C_z Y'}{1 + \frac{C_x}{d}}}, \tag{17}$$

$$\tau_1^* = \frac{Y^*}{Y} = \sqrt{\frac{2C_z}{C_x Y\left(1 + \frac{C_x}{d}\right)}}, \tag{18}$$

$$\tau_2^* = \frac{y_d^{\,*}}{Y} = \frac{1}{d}\sqrt{\frac{2C_z C_x}{Y\left(1 + \frac{C_x}{d}\right)}}. \tag{19}$$

Results and discussion

The proposed applied IT for supply management consists of modules of the developed software, the Statistica standard system and the database. The architecture of the applied IT is given in fig. 2 [19].

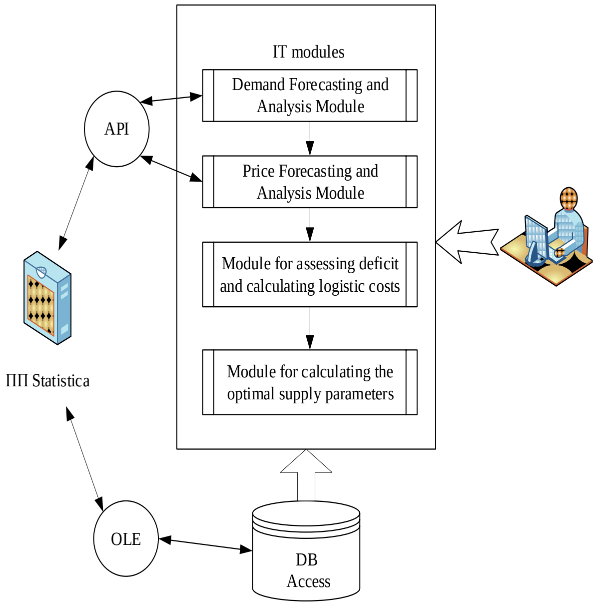

Fig. 2. The architecture of the applied IT of supply logistics

Information technology contains four calculation modules [20, 21]:

- demand forecasting and analysis module;
- price forecasting and analysis module;
- module for assessing deficit and calculating logistic costs;
- module for calculating the optimal supply parameters.

First two modules are linked to the Statistica system by ActiveX connection. The other two modules receive

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data from the database in the MS Access format and make calculations basing on the built-in algorithms. The Statistica system is integrated with the data based on the OLE technology.

The approbation of the applied IT operation was carried out using the example of procurement of materials for construction companies by an intermediary firm. Demand forecasting is carried out by the method of multiple regression. The following steps are performed:

- a base of observations is formed;
- significant independent variables (factors) are singled out;
- variables are transformed in the case of nonlinear dependence;
- a regression equation is built;
- the quality of the equation and forecast is assessed based on a number of criteria;
- the forecast is assessed by the diagram of predicted values and errors;
- the predicted value of demand is determined.

The forecasted variable denoted as Y is the time series of changes in demand for a month. The normalized values of the variables are chosen as independent variables: X_1 is the change in income of construction companies, X_2 is the cost of advertising, X_3 is the impact of competitors, X_4 is the change of price. The results of the regression are presented in table 1.

Table 1. *Multiple regression results*

Regression summary for dependent variable Y R = 0,898 R^2 = 0,806 Adjusted R^2 = 0,801 $F(4,177)$=183,76 p<0,000						
	β	Std.err. of β	b	Std.err. of b	t(177)	p-value
Intercept			111324,6	100412,8	1,108	0,269
X_1	0,023	0,034	11203,8	16198,5	0,691	0,490
X_2	**1,698**	**0,095**	**0,3**	**0,0**	**17,702**	**0,000**
X_3	**-0,499**	**0,088**	**-0,3**	**0,1**	**-5,646**	**0,000**
X_4	**-0,609**	**0,049**	**-3,3**	**0,3**	**-12,248**	**0,000**

The table shows that the first variable is not statistically significant, that means that it can be neglected in the equation. In this case, the regression equation is as follows:

$$Y = 111324,6 + 0,3\, X_2 - 0,3\, X_3 - 3,3\, X_4.$$

Thus, the conclusion can be made that the price change has the greatest impact on the value of demand. However, the advertising cost factor is the most statistically significant (β_2 is maximal).

The built model reflects a significant dependence of demand on these factors since the coefficient of determination is high (0,8). F-criterion proves the model linearity. However, the absolute term of the equation is not determined exactly enough (the error is about 25%).

Let us analyze the errors of this model. Fig. 3 shows the normal probability curve of residuals (errors). It shows that the residues are not distributed normally. Let us build the diagram of the residue dispersion with respect to the magnitude of the forecasted variable (fig. 4). It is evident that the dispersion of residues is random for large and average demand values. But for small values, this distribution is not random. That is, the built model is more adequate for large demand values.

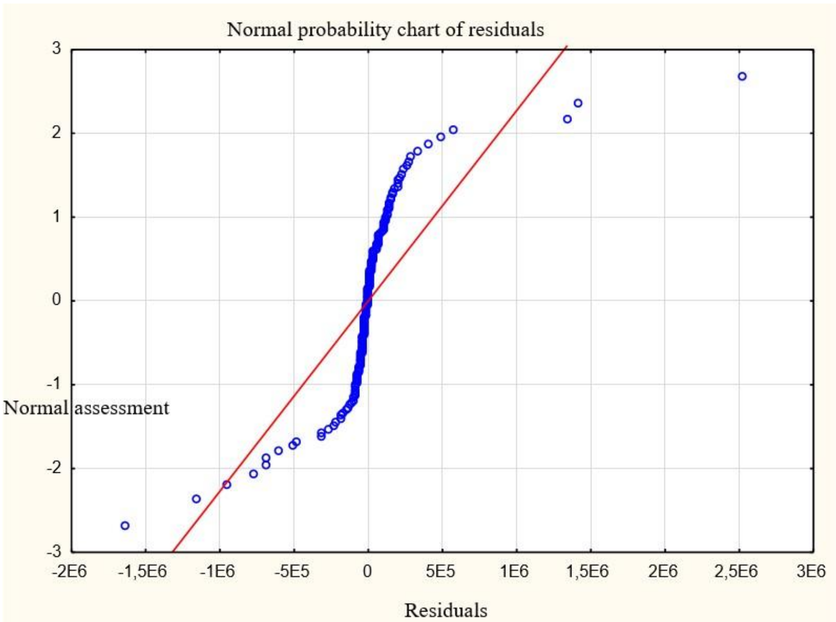

Fig. 3. The normal probability graph of regression residuals

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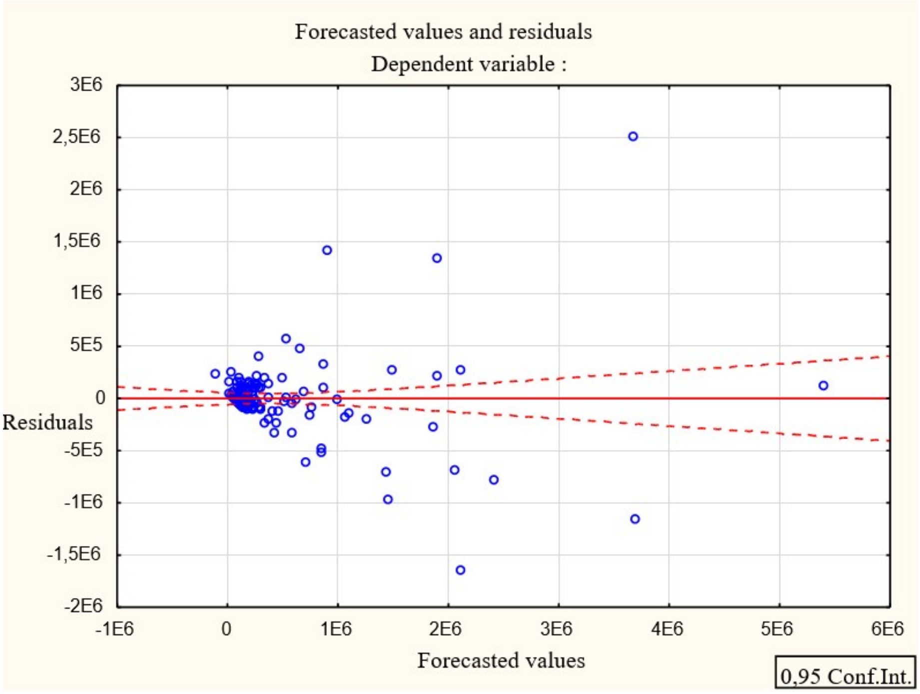

Fig. 4. The diagram of residual scatter relative to the forecasting variable value

Let us analyze the change in the price of products. The linear graph of price changes during a year is given in fig. 5. It is seen that the given time series is not stationary.

To use the Box-Jenkins method, a number of transformations should be done: three-point, moving, average, and logarithmic ones.

While assessing the model parameters, several sets were analyzed. The best parameters are $p = 0$, $P = 0$, $q = 1$, $Q = 1$ (table 2).

The built graph of the autocorrelation function also evidences the quality of the model (fig. 6). Thus, the built model of the autoregression can be used for forecasting product price.

Fig. 5. Source time series

Table 2. *The results of model parameter assessment*

Output: Price: Transformations:3 pts mov. aver., ln(x) Model: (0,0,1)(0,0,1) MS residual = 0,089						
	Paramet.	Asympt.std.err.	Asympt. t(394)	p	lower - 95% conf.	upper - 95% conf.
q(1)	**-0,973**	**0,008**	**-113,993**	**0,00**	**-0,989**	**-0,956**
Q(1)	**-0,857**	**0,018**	**-46,690**	**0,00**	**-0,893**	**-0,820**

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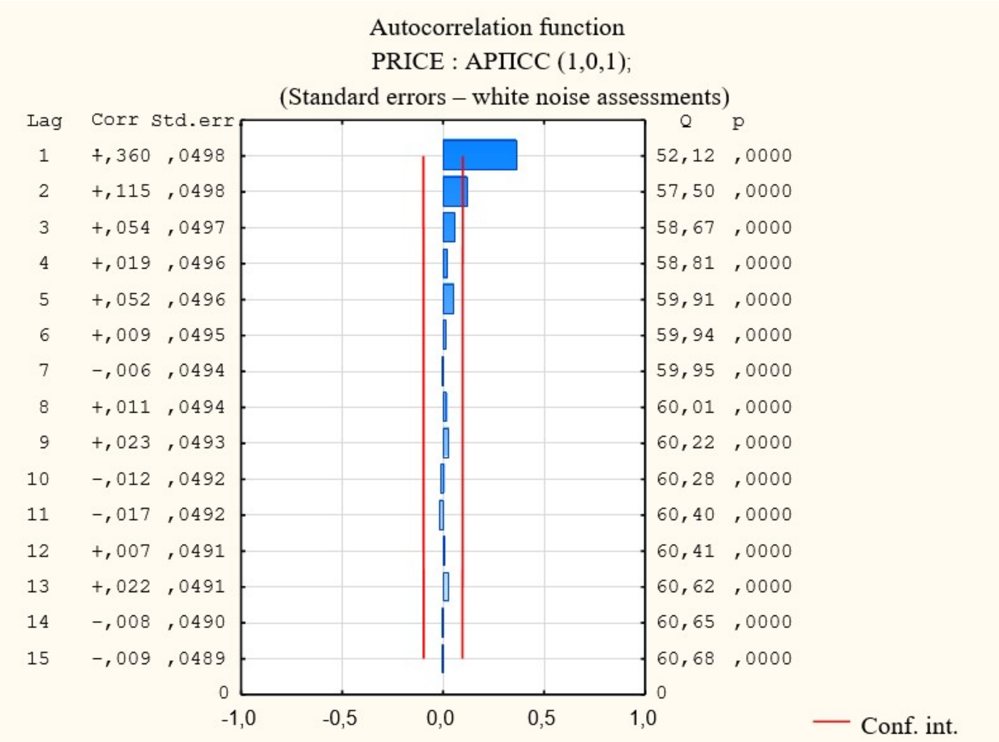

Fig. 6. Autocorrelation function

The next stage of logistics analysis is the assessment of the potential deficit or filling of the warehouse. In this case, costs and optimal supply parameters are calculated. Among the costs, the costs for the supply cycle and per unit of time are calculated.

In the model for calculating the optimal supply parameters, the following parameters are calculated (fig. 7):

- the optimal amount of a supply lot;
- the optimal amount of back-ordered demand;
- the optimum value of the stock;
- the optimal value of the order renewal period;
- optimal logistics costs.

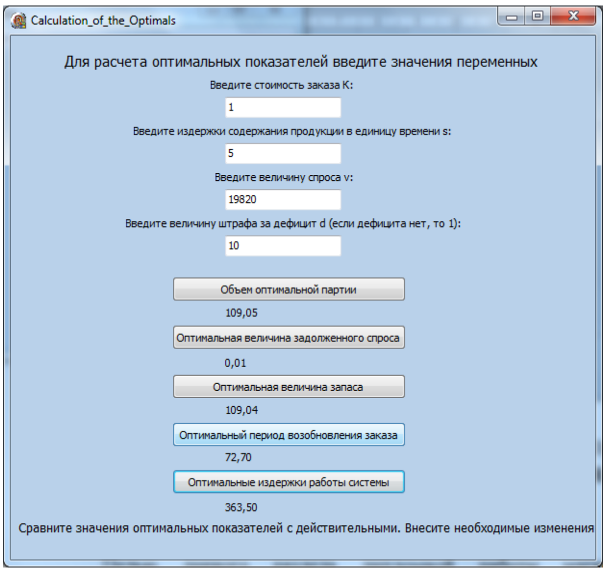

Fig. 7. The results of the calculation of the optimal parameters of supply logistics

Conclusions

The generalized logistics chart of supply was developed. The supplement of the first block of the above chart is substantiated by the processes of market research of demand for products and planning of volumes of supply in accordance with forecasted demand and possibilities of a deficit (or surplus) of products as a result of unforeseen swings of demand.

The use of methods of regression analysis and forecasting of time series for assessing market factors of supply logistics is considered.

The models for determining the optimal volume of the stock are considered taking into account storage costs and possible deficit.

The architecture of the applied information technology of supply logistic planning is developed. The proposed IT enables analyzing and forecasting the change in key market factors and, in accordance with the results obtained, efficiently solves the tasks of stock management. In this case, it is possible to take into account the deficit and back-ordered demand. The operation of IT modules is illustrated by a testing example.

The use of IT is efficient when making decisions on logistic planning of business processes as well as when analyzing the efficiency of logistics over a certain period of time. In the future, it is supposed to supplement the mentioned technology with capabilities for solving tasks of warehouse logistics.

References

1. Moroz, O. V., Muzika, O. V., Bezsmertna, O. V. (2007), System factors of the efficiency of the logistic concept of supply at the enterprises : Monograph [Systemni faktory efektyvnosti lohistychnoyi kontseptsiyi postachannya na pidpryyemstvakh : Monohrafiya], Vinnytsya : UNIVERSUM Vinnytsia, 165 p.
2. Zhulvsky, A. Yu., Sidorenko, N. V. (2011), "Organization of material and technical support of the enterprise as an object of logistic decisions" ["Orhanizatsiya materialʹno-tekhnichnoho zabezpechennya pidpryyemstva yak ob'yekt lohistychnykh rishenʺ"], *Visnyk Sumy State University, Series Economics*, No. 2, P. 51–58.
3. Iastremska, O. (2018), "Logistics at an enterprise the peculiarities of procurement activities", *Innovative Technologies and Scientific Solutions for Industries*, No. 3 (5), P. 141–148. DOI: https://doi.org/10.30837/2522-9818.2018.5.141.
4. Sumets, O. M. (2011), "Recommendations on introduction of synthetic accounting of logistics costs at the enterprise" ["Rekomendatsiyi shchodo zaprovadzhennya syntetychnoho obliku lohistychnykh vytrat na pidpryyemstvi"], *Logistics: Problems and Solutions*, No. 4 (35), P. 42–47.
5. Krykavsʹkyy, Ye. V. (2001), "Integration of marketing and logistics in the management system" ["Intehratsiya marketynhu i lohistyky v systemi menedzhmentu"], *Bulletin of Lviv Polytechnic National University*, No. 416: Logistics, P. 52–61.
6. Rosumna, N. V. (2011), "Actual questions of procurement marketing, planning of the needs of the material resources of the industrial enterprise" ["Aktualʹni pytannya marketynhu zakupivelʹ, planuvannya potreby materialʹnykh resursiv promyslovoho pidpryyemstva"], *Marketing and Innovation Management*, No. 2, P. 131–138.
7. Priyamak, O. Yu. (2007), "Methodical procedures of managerial accounting of inventory in logistics and enterprise management" ["Metodychni protsedury upravlinsʹkoho obliku vyrobnychykh zapasiv v lohistytsi ta upravlinni pidpryyemstvom"], *Bulletin of Lviv Polytechnic National University*, No. 594: Logistics, P. 141–148.
8. Yankovoi, A. G., Gura, O. L. (2009), "Improving enterprise planning with the help of math-statistical forecasting methods" ["Sovershenstvovaniye planirovaniya na predpriyatii s pomoshch'yu matematiko-statisticheskikh metodov prognozirovaniya"], *Actual problems economics*, No. 1 (91), P. 229–238.
9. Kosenko, V. (2018), "Decision support in planning investment projects", *Innovative Technologies and Scientific Solutions for Industries*, No. 4 (6), P. 113–119. DOI: https://doi.org/10.30837/2522-9818.2018.6.113.
10. Kunitskaya, O. M., Merzhievskaya, Ye. V. (2009), "Stock management using modern logistics and marketing approaches" ["Upravlinnya zapasamy z vykorystannyam suchasnykh pidkhodiv lohistyky ta marketynhu"], *Bulletin of Lviv Polytechnic National University*, No. 649: Logistics, P. 193–197.
11. Improving inventory management with ABC and XYZ analysis, available at : http://upravlenie-zapasami.ru/.
12. Filatov, V., Doskalenko, S. (2018), "On the approach to searching for functional dependences of data in relational systems", *Innovative Technologies and Scientific Solutions for Industries*, No. 1 (3), P. 54–58. DOI: https://doi.org/10.30837/2522-9818.2018.3.054.
13. Description of the business processes of the warehouse network [Opisaniye biznes-protsessov sklada torgovoy seti], available at : www.Ser-pavilion.narod.ru.
14. Ryzhikov, Yu. I. (2001), *Queue theory and inventory management* [*Teoriya ocheredey i upravleniye zapasami*], SPb. : Peter, 384 p.
15. Description of methods for optimizing inventory management [Opisaniye metodov optimizatsii upravleniya zapasami], available at : http://upravlenie-zapasami.ru/.
16. Algorithm of the monthly forecast of the demand for the year ahead, taking into account the trend and seasonality [Algoritm pomesyachnogo prognoza sprosa na god vpered s uchetom trenda i sezonnosti], available at : http://upravlenie-zapasami.ru/
17. Kosenko, V. V., Ginevsky, M. I., Sidorenko, M. F. (2007), "Modeling of non-stationary random processes" ["Modelyuvannya nestatsionarnykh vypadkovykh protsesiv"], *Information processing systems*, No. 7 (47), P. 199–202.
18. The optimal period between shipments [Optimal'nyy period mezhdu postavkami], available at : http://upravlenie-zapasami.ru/.
19. Malyeyeva, O. V., Elizeva, A. V. (2013), "System model and architecture of information technology supporting the procurement management of a manufacturing enterprise" ["Sistemnaya model' i arkhitektura informatsionnoy tekhnologii podderzhki protsessov upravleniya zakupkami proizvodstvennogo predpriyatiya"], *Processing Systems Information*, No. 2, P. 286–289.
20. Malyeyeva, O., Yelizyeva, A., Kosenko, N., Nevlyudova, V. (2018), "Information technologies of supporting decision-making on managing the procurement of a manufacturing enterprise", *Innovative Technologies and Scientific Solutions for Industries*, No. 3 (5), P. 57-66. DOI: https://doi.org/10.30837/2522-9818.2018.5.057.
21. Malyeyeva O.V., Elizeva A.V. (2013), "Information technology of logistics procurement management taking into account the product life cycle" ["Informatsionnaya tekhnologiya logisticheskogo upravleniya zakupkami s uchetom zhiznennogo tsikla produktsii"], *Radio and Computer Systems*, No. 1, P. 119–126.

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МОДЕЛІ ТА ПРИКЛАДНА ІНФОРМАЦІЙНА ТЕХНОЛОГІЯ ЛОГІСТИКИ ПОСТАЧАННЯ В УМОВАХ КОЛИВАНЬ ПОПИТУ

Предметом дослідження є процеси планування логістики постачання з урахуванням коливань попиту і цін на продукцію. **Мета** роботи – розробка моделей та прикладної інформаційної технології для управління поставками підприємства з урахуванням непередбачених коливань попиту. При цьому вирішуються такі **завдання**: розробка процесної моделі логістики постачань, формування моделей прогнозування попиту на продукцію, формування моделей розрахунку оптимального обсягу замовлень при різних варіантах попиту, розробка структури та модулів прикладної інформаційної технології з управління логістикою постачання. **Методи** дослідження: структурні процесні моделі, методи регресійного аналізу та прогнозування часових рядів, моделі управління запасами, програмний пакет STATISTICA, методи об’єктно-орієнтованого програмування. **Результати**: Розроблено узагальнену схему логістики постачання. Обгрунтовано доповнення першого блоку вказаної схеми процесами маркетингового дослідження попиту на продукцію та планування обсягів постачання згідно з прогнозованим попитом та можливістю дефіциту або надлишку продукції внаслідок непередбачуваних коливань попиту. Розглянуто застосування методів регресійного аналізу та прогнозування часових рядів для оцінки ринкових факторів логістики постачання. Досліджено моделі визначення оптимального розміру запасу з урахуванням витрат зберігання і можливого дефіциту. Розроблено архітектуру прикладної інформаційної технології (ІТ) планування логістики постачання. Запропонована ІТ дозволяє аналізувати і прогнозувати зміну основних ринкових факторів і відповідно до отриманих результатів ефективно вирішувати завдання управління запасами. При цьому з'являється можливість враховувати наявність дефіциту і заборгований попит. Робота модулів ІТ проілюстрована тестовим прикладом. **Висновки**: використання ІТ ефективно при прийнятті рішень логістичного планування бізнес-процесів, а також в аналізі ефективності логістики за певний період часу. Надалі передбачається доповнити зазначену технологію можливостями вирішення завдань складської логістики.

Ключові слова: логістика постачання; прогнозування попиту; оптимізація параметрів; часові ряди; прикладна інформаційна технологія.

МОДЕЛИ И ПРИКЛАДНАЯ ИНФОРМАЦИОННАЯ ТЕХНОЛОГИЯ ЛОГИСТИКИ СНАБЖЕНИЯ В УСЛОВИЯХ КОЛЕБАНИЙ СПРОСА

Предметом исследования являются процессы планирования логистики снабжения с учетом колебаний спроса и цен на продукцию. **Цель** работы – разработка моделей и прикладной информационной технологии для управления поставками предприятия с учетом непредвиденных колебаний спроса. При этом решаются следующие **задачи**: разработка процессной модели логистики поставок, формирование моделей прогнозирования спроса на продукцию, формирование моделей расчета оптимального объема заказов при различных вариантах спроса, разработка структуры и модулей прикладной информационной технологии управления логистикой поставок. **Методы** исследования: структурные процессные модели, методы регрессионного анализа и прогнозирования временных рядов, модели управления запасами, программный пакет STATISTICA, методы объектно-ориентированного программирования. **Результаты**: Разработана обобщенная схема логистики снабжения. Обоснованно дополнение первого блока указанной схемы процессами маркетингового исследования спроса на продукцию и планирования объемов поставок согласно прогнозируемым спросом и возможности дефицита или избытка продукции вследствие непредсказуемых колебаний спроса. Рассмотрено применение методов регрессионного анализа и прогнозирования временных рядов для оценки рыночных факторов логистики поставок. Исследована модель определения оптимального размера запаса с учетом издержек хранения и возможного дефицита. Разработана архитектура прикладной информационной технологии планирования логистики поставок. Предложенная ИТ позволяет анализировать и прогнозировать изменение основных рыночных факторов и в соответствии с полученными результатами эффективно решать задачи управления запасами. При этом появляется возможность учитывать наличие дефицита и задолженный спрос. Работа модулей ИТ проиллюстрирована тестовым примером. **Выводы**: использование ИТ эффективно при принятии решений логистического планирования бизнес-процессов, а также в анализе эффективности логистики за определенный период времени. В дальнейшем предполагается дополнить указанную технологию возможностями решения задач складской логистики.

Ключевые слова: логистика снабжения; прогнозирования спроса; оптимизация параметров; временные ряды; прикладная информационная технология.