Modeling inventory management: Considering application and construction issues separately

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Abstract:

The inventory management model for forestry businesses is presented in the article. We may use it to calculate the effectiveness of our inventory use, lower the cost of shipping and storage, and prevent fines for running out of stock when there is a demand. The suggested model accounts for the price of the received reserves' dependence, warehousing expenses, the price of holding stocks, the quantity of storage costs, and fines for promptly unloading client goods. We can identify the quantity of the inventory, guarantee proper inventory levels, and prevent supply delays thanks to the model. It has been demonstrated that rational inventory management allows businesses to determine the ideal level of reserve ordering and the interval between such orders. By using this model, one may manage logistics and warehouse expenses, assess the likelihood of not getting an order or lowering corporate earnings owing to excess inventory costs, and comprehend the effectiveness of inventory turnover. Purpose. The study's objective is to build a mathematical and economic model of the enterprise's inventory management, taking into consideration the varying costs of storing stocks, transportation from the supplier to the warehouse, storage space requirements, and fines for unshipped goods. Methodology. The application package Statistica and the use of the module MARSPline, a crucial component of technology Data Mining Outcomes, were used to validate theoretical advancements. The contribution to theory. On the basis of this, the primary dependencies influencing the formation of the value of stocks were identified, and a regression model of the ideal size of stocks was built with a fairly accurate approximation. Calculations of the effectiveness of the use of inventories were also made, aiming to minimise the total costs related to delivery, storage, and fines for the absence of stocks at the time when demand was available. Impact on daily life. We have built, researched, and tested an economic and mathematical model of the ideal stock size that accounts for the varying costs of storing inventories, transportation from the supplier to the warehouse, the amount of storage charges, and penalties for non-shipped goods.

Key words: Trade Enterprises Methods, Modelling, Inventory Economic and Mathematical Models, Optimization, Spline Surfaces, Random and Independent Values, Data Mining Results, MARSPline, Statistica package.

1. Introduction

India's forestry businesses work in an environment of intense competitiveness, risk, and uncertainty. This is because tax law is unstable and the state faces political risk. ence, managing forestry operations well is crucial for the long-term sustainability of these businesses.. In order to make effective management decisions, modern scientific approaches and practice- tested techniques, namely: forecasting, econometric and mathematical modeling of economic objects, production processes and individual economic situations, should be utilized. In the process of modeling the economic situations associated with the use of reserves, in practice, a number of tasks should be solved (Table 1).

Table 1. The content of solving particular tasks of inventory management optimization problems.

No	Tasks	Content
1	The task of distribution of stocks	Arises when a certain set of economic activities (work) that should be implemented by the small amount of resources
2.	The task of inventory management	They are in search of the best values of reserve levels and order sizes to meet the permanent production process
3.	The task of forecasting placing re-serves	Associated with the definition of the optimal number and location of new objects, taking into account their interaction with existing objects and interactions among themselves

Modeling of inventory management makes it possible to design a rational scheme of continuous and effective provision of material resources. For its implementation, the following tasks are required:

- study of accounting of the current level of inventories based on information flows of data;
- inventory analysis to determine the current level of stocks that will ensure continuity of activities;
- analysis of current programs in order to calculate the size of reserves;
- determining the intervals of time necessary to carry out the production process.

Sectoral and technological features of forestry enterprises have a great influence on the management system. This is explained by the organization of activities and complex logistics. It relies on production processes, product sales, commodity flow and cash flows. Forestry companies hold in question the optimal batch of ordering stocks of raw materials or goods. This is because the supply of a considerably large quantity of stocks or a surplus, greatly increases the cost of their logistics and storage, and may reduce their commodity value, and hence reduce the sale price. Otherwise, when the supply of reserves is less than the optimal demand or orders available, there will be a deficit of sales, that is, the enterprise will not be able to fulfill the contractual obligations in time, and will not receive a profit and may be punished by penal sanctions. At the same time, it should also be taken into account that a significant part of the logistical, warehouse and conservation costs are constant, do not vary depending on the volumes of work, and therefore affect the financial performance of the activity.

Think about the solution to the inventory management issue in woodworking businesses. We can reduce the overall costs of their supply, as well as storage and fines in the absence of stocks when there is a need for them, with the aid of a mathematical model that calculates the efficiency of the use of inventories. We suggest the following hypotheses or assumptions in response to the premise of our study, which will be tested empirically in order to provide a potential fix. First, there is a link between the quantity of transportation expenses, storage costs, and fines that are incurred when there is insufficient wood available when it is needed. Secondly, during certain periods, wood-processing companies can reimburse the cost of storing inventory to avoid imposing penalties for non-grassland timber products.

2. Literature review

Questions that are subject to research within the framework of this article have been the subject of many scientific investigations, depending on the content of the optimization tasks of inventory management. An increasing interest is emerging towards optimization modeling of stock management processes, it is recognized as an effective apparatus for formalizing scientific and technical problems in various fields of knowledge.

Paying tribute to many scholars who have made a significant contribution to solving theoretical and practical problems in the specified range of issues, in the framework of this study, pay attention only to those that, in our opinion, have a direct impact on the subject of research.

Shygun (2008) conducted an analysis of the content of scientific articles and reports on economic modeling in Ukraine, presented in professional editions and scientific conferences with the use of the bibliometric method, systematization of articles and reports on the issues of open issues, and the tendencies of economic modeling development were revealed.

Atamanchuk and Pasenchenko (2016) investigated the problem of choosing the optimal inventory management policy. They developed an algorithm for optimizing the parameters of the inventory management system, disclosed the features of efficient inventory management by the receipt of such (optimal) stock size, at which costs for their maintenance and maintenance would be minimal, and the number of stocks − sufficient for the stable operation of the business entity.

An economical and mathematical model that allows us to choose the optimal policy for inventory management in an unstable economy is presented in the paper, as well as numerical calculations have been carried out demonstrating the application of this model at the garment industry enterprise (Andrushkiv et al., 2012; Bukan & Kenigsberg, 2007; Kaplan & Norton, 2006; Kovács & Kot, 2017; Popovic et al., 2017; Robert, 1992).

The time point at which the delivery of the order should be designated, which allows maintaining stocks at the optimal level, while simultaneously reducing the cost of storing the stock and the loss from the shortage of goods, is determined. Demand for goods in the presented model is considered as a random variable with a normal probability distribution.

Isonin and Lagotsky (2012) studied the problem of ensuring the optimal balance between minimizing investment in stocks on the one hand and maximizing the level of service users of the enterprise for a continuous production process – on the other. It is indicated that many theoretical and methodological aspects of inventory management, taking into account the stochastic nature of demand, remain little studied and poorly covered in the economic literature.

Kushnirenko and Ralle (2015) reviewed the main approaches to the analysis of commodity and material inventory in the field of production and warehouse services and explored the methods of modeling the processes of material inventory management and their impact on the operation of the enterprise. They proposed the rationing of commodity inventories proposed by various methods such as: experimental and statistical method, method of technical and economic calculations, economic and mathematical modeling, etc.

Pasenchenko and Trubnikova (2011) reviewed inventory management issues at a trading enterprise. They define the main indicators of the activity of a trading enterprise within the framework of the concept of balanced development of the company, analyze their classification and the main factors that influence their change and can be called managers and used to improve the work of the enterprise.

Inventories stocks are related to objects according to A DAN DZO (2015) at the enterprise level that require significant investment. So, therefore, they are one of the factors that determine the policy of an enterprise and affect its level of liquidity, and for trading companies for profit.

Shraybfeder (2005) noted that efficient inventory management allows you to: serve the buyer well, to ensure return on investment and to eliminate dead stocks and surpluses. According to Takha (2005) classical inventory management models and their level control are based on the fact that inventory management is a complex set of measures aimed at providing the highest possible level of service to customers with minimum current costs associated with holding stocks. In practice, inventory management is limited to two main questions: when to replenish stock and in what quantity? The classic model of stock management is the Wilson model, which allows you to calculate the optimal amount of the lot and the time period of ordering.

Min and Zhou (2002) pointed out that over the years, most firms have focused on the overall effectiveness and efficiency of individual business functions. However, as a new way of doing business, businesses began to realize the strategic importance of planning, controlling and designing the supply chain as a whole. In an effort to help firms capture the synergy between inter-functional and inter-organizational integration and supply chain coordination and subsequently make better decisions on the supply chain, they drew attention to the synthesis of previous efforts to model supply chains.

Franca, Jones, Richards and Carlson (2010) drew attention to elements of fuzzy logic for optimizing, monitoring and controlling the process of executing orders in the supply chain of the global retail firm. They introduced a model for optimizing order fulfillment, which improves the integration of the supply chain and cooperation between supply chain partners through effective monitoring and control of supply chain variables. This model examines the critical requirements of the customer at the stage of supply chain development, making it a useful model by differentiating customers and separating supply channels.

Melo, Nickel and Da Gama (2006) and Takha (2005) focused on strategic planning of supply networks based on mathematical modelling, which simultaneously covers many practical aspects of network design problems: dynamic planning horizon, overall supply chain network, external material supply, opportunities of product inventory, product distribution, object configuration, capital availability for investments and storage restrictions.

Seuring (2013) summarized the research of quantitative models of forward chain supply. He drew attention to the social and environmental problems of the supply chain and noted that on the modeling side there are three dominant approaches: the equilibrium model, the multicriteria process of decision making and the analytical hierarchical process. Only limited empirical studies were conducted by this time.

Beamon (1998) has proven that over the years, theorists and practitioners have primarily studied various processes in the supply chain of production individually. At the same time, the development and analysis of the supply chain as a whole has been neglected. This focus is largely due to rising production costs, resource base reductions in production bases, shortening the product life cycle, leveling the playing field in production, and the globalization of market economies.

Biswas and Narahari (2004) investigated the possibility of stochastic models, models of mathematical programming, heuristic methods and modeling in the supply chain simulation. Because different problems for making decisions in supply networks require different approaches to modeling and solving problems, there is a need for a unified approach to supply chain modeling so that any necessary solution can be created in a fast and flexible way. In this paper, they have developed a decision support system for DESSCOM (support for solutions for supply chains using object simulation), which enables strategic, tactical and operational making decision in supply chains.

Scientific investigations of issues related to the management of material inventories and their distribution on the basis of the application of economic and mathematical modeling remain the requirements of time.

Taking into account the above and sectoral features of woodworking enterprises, one can conclude that research is incomplete in this direction and the need to find a model that would allow them to manage their inventories in order to minimize unproductive costs.

3. Research methods

The modelling of inventory management is closely linked with such components of the theory of management of economic systems as the information theory of hierarchical systems; target and oriented planning; the theory of project management; the theory of contracts that investigate problems in an uncertain environment.

Through the system analysis, we analyzed the activities of woodworking enterprises, identified the main areas that require further research. Since the main task of these companies is profit, we used software packages Statistica, and the module MARSPline with module Data Mining Results. This enabled to calculate regression model in multidimensional space and build a spline surface-planned dependencies through the basic functions. The obtained regression model established the relationships between variables with a rather precise approximation.

4. Research results

The development of a mathematical model of enterprise inventory management will contribute to increasing the efficiency of inventory turnover. Let's assume that there is a stock of wood (t) of time periods in the warehouse. Indicate the amount of wood stock (z_0) meters cubic at the beginning of the period.

Demand (v_y) on timber forms the amount of their delivery from the warehouse in (y) - period. In each separate period demand (v_y) is a random and independent value with probability density $f_y(v_y)$.

Price of shipment volume (m^3) ordered at the beginning of the wood period from the supplier to the warehouse until the end $(y)^{th}$ of the period is (q_y). The cost of maintaining a certain amount of timber in the (y) – period is (g_y), and the price of placing the stock is proportional to its volume at the end of the period is equal ($g_y z$). The amount of expenses for delivery, storage, and penalties related to the lack of wood, if necessary, depends on the proper receipt of the timber for the warehouse business entity.

Let's notice (k_y) the volume of (m^3) of the ordered wood at (y) – period. Hence, the stock (z_y) of timber for the end (y)-th of the period will be (1):

$$z_y = z_0 + \sum_{i=1}^{y} k_y - \sum_{i=1}^{y} v_y \qquad (1)$$

The number of undisturbed w_y of wood to maintain optimum functioning of the composition $z_y \geq 0$ due to its absence at warehouses until the end of the y-th period will have the form (2):

$$w_y = \left(\sum_{i=1}^{y} v_y - \sum_{i=1}^{y} k_y - z_0\right), \; w_y \geq 0 \qquad (2)$$

Thus, if during a certain (y-th) period a wood processing enterprise will reimburse the cost of storing inventory ($z_y \geq 0$), there will be no penalties for non-donation ($w_y = 0$) and vice versa. This situation can be represented as follows (3):

$$x_y\left(z_0 + \sum_{i=1}^{y} k_y - \sum_{i=1}^{y} v_y\right) = \begin{cases} g_y z_y \; when \; z_y \geq 0 \\ r_y w_y \; when \; w_y > 0 \end{cases} \qquad (3)$$

The total cost of the warehouse (C) of woodworking enterprise for (t) periods can be written down as:

$$C = \sum_{y=1}^{t} g_y k_y + \sum_{y=1}^{t} x_y\left(z_0 + \sum_{i=1}^{y} k_y - \sum_{i=1}^{y} v_y\right) \qquad (4)$$

This formula (4) is a function of random and independent values vy. It is necessary to calculate the volume of timber that has already been delivered and the demand for it to substantiate the volume (m^3) of the order of wood at the beginning of the next period. Thus, it is not possible to set all values of t for k_y at the same time.

Summarizing the above, we note that in the conditions of dynamic development of computer technologies, management decisions regarding orders in the planning period are taken on the basis of the results of the reporting period. This implies the following: for any (n)-th period we have $k_n^* = k_n^*(z_n)$. We will follow the use of this model at the wood processing enterprise LTD "Hansakom-West".

Let's calculate Z_{theor} by the data on the remnants of wood in warehouses and storerooms at the beginning of the reporting period, the volume of timber products that left the period, and their volume, which passes from the warehouses in the y-th period, which is determined by V_y demand for goods (the initial data is given in Table 2).

In Figure 1, we show the quadratic surface on the basis of data in Table 2:

$$Z_{theor} = -39771.4135 + 7.5882 \cdot v - 3.1036 \cdot k + 0.0005v^2 + 0.0005vk - 0.0001k^2 \qquad (5)$$

Table 2. Stock of wood at the end of the y-th period, thousand UAH.

Period, month	Demand, v	Received, k	Value, Z_{theor}
1.	18256	16890	2156
2.	18749	17450	1759
3.	17256	18652	1632
4.	18413	18509	2587
5.	19785	21687	2374
6.	21059	21059	1960
7.	19760	19760	3658
8.	17694	16751	2520
9.	18340	17996	2136
10.	19761	19761	1825
11.	19800	19800	957
12.	16543	15266	1653

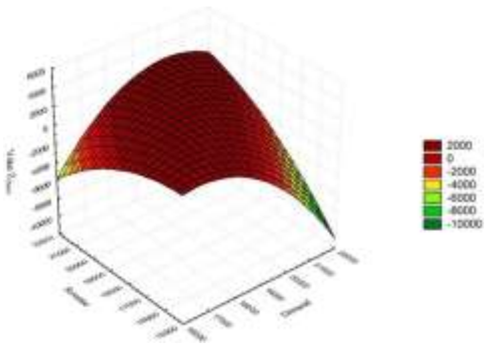

Figure 1. The quadratic surface of the theoretical stock (Z_{theor}) according to the Table 2.

As a result, we obtain the estimated values of theoretical data volumes (m^3) of inventories, comparing with which real volumes we will find variants of immobilization of funds invested in production reserves.

Hansakom-West Ltd (Ukraine) uses the method of paying for the storage of reserve stocks of wood in warehouses in the amount of five-day volume of use of timber (0.03% from the cost of materials). Now, it is necessary to calculate the cost of storing the reserve volume of the raw forest (Table 3) and to construct the surface of the smallest squares (Figure 2).

Table 3. Amount of payments for storage of timber, thousand UAH.

Period, month	Value, Z_{theor}	Cost of storage, *g*	The amount of payment for storage, *x*
1.	3522	0.0598	210.96
2.	3056	0.0647	198.02
3.	3026	0.0408	123.47
4.	2683	0.0656	176.20
5.	4276	0.0627	268.11
6.	1965	0.0496	97.64
7.	2368	0.0591	140.17
8.	3463	0.0526	182.46
9.	2480	0.0437	108.45
10.	2652	0.0481	127.63
11.	1860	0.0463	86.21
12.	2930	0.0535	157.03

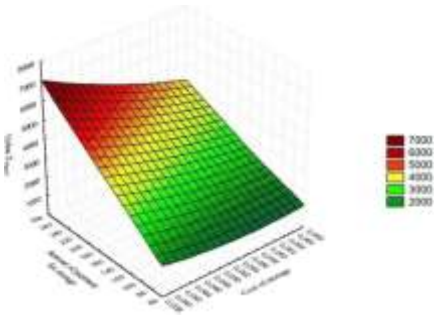

Figure 2. The surface of the smallest squares according to Table 3.

$$Z_{theor} = 2766.8 - 49620.8 \cdot g + 17.67 \cdot x \quad (6)$$

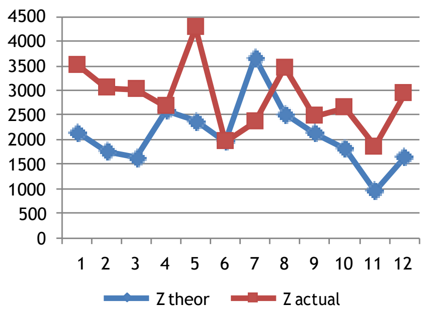

Figure 3. Dynamics of actual and theoretical data on the turnover of wood stocks, thousand UAH.

Source: it was formed by the author

Indicator R^2=0.988 indicates the adequacy and accuracy of the proposed model. Let's introduce the value of Z_{theor} and Z_{actual} graphically, which will help compare the results obtained during computations with the actual results in Figure 3.

Calculate the amount of payments for the theoretical volume (m^3) of the forest raw material for comparison with the real volume (m^3). Results of calculation of theoretical and actual costs borne by a woodworking enterprise in the process of keeping the timber will be reflected in Figure 4.

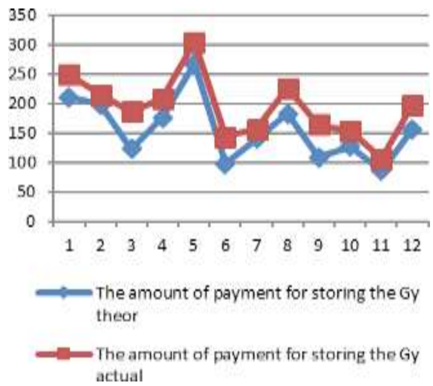

Figure 4. Dynamics of expenses for storage of the theoretical and actual volume of wood, thousand UAH.

Source: Authors

Table 4. Determination of the cost of warehouse for the storage of the actual volume of wood by periods, thousand UAH.

Period, month	Amount of payment for storage, *x*	Received, *k*	Cost of delivery, *Q*	Total cost of warehouse, *C*
1	210.96	16890	0. 1254	383.54
2	198.02	17450	0.1332	396.59
3	123.47	18652	0.1410	414.86
4	176.20	18509	0.1394	411.37
5	268.11	21687	0.2185	492.88
6	97.64	21059	0.2663	478.61
7	140.17	19760	0.1982	449.09
8	182.46	16751	0.1687	380.70
9	108.45	17996	0.1410	409.36
10	127.63	19782	0.1865	451.73
11	86.21	19800	0.1935	462.58
12	157.03	15266	0. 1478	346.95

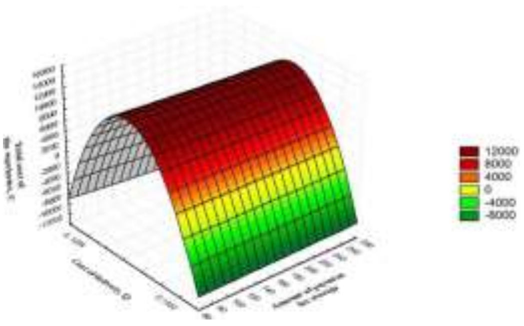

Figure 5. Quadratic surface according to Table 4.

$$C = 484.7 - 1.8 \$ x + 199.97 \$ Q + \\ +0.005x^2 - 0.083xQ - 4.77Q^2 \quad (7)$$

well as others, which are characterized by similar technological features of activity.

In addition, it should be noted that, in our opinion, the study conducted allowed to form new scientific problems of great theoretical and practical importance and could become the subject of further scientific research.

These, in the first place, should include:

- optimization of management of financial capital of economic entities of different forms of ownership;
- intensification of the use of blockade and artificial intelligence technologies in conditions of uncertainty of logistics of stocks and

Thus, the carried out calculations allow to makeoptimal managerial decisions regarding the volume and structure of production stocks, accordingly adjusting the work of warehouse areas.

5. Discussion of the results

The conducted research has made it possible to identify the main factors influencing the management of stocks of woodworking enterprises in order to minimize unproductive costs. The solution of the proposed model in the application package Statistica and the use of the module MARSPline – an integral element of the technology Data Mining Results and the resulting regression equations allow to determine the general dependencies. This enabled through the basic functions calculate regression model in multidimensional space and build a spline surface and planned dependencies. The obtained regression model established the relationships between variables with a rather precise approximation.

The constructed generalized economic and mathematical model of inventory management allows minimizing unproductive costs. The model can be adapted for woodworking enterprises, as management of them.

The possible direction of further research on this problem is also to take into account in this model the future value of money and the effect on it of the inflationary effect of the depreciation of money. In our opinion, this requires additional substantiation and changes in the individual components of the calculations.

6. Conclusions

In order to avoid unproductive costs, the management of stocks under uncertainty should be as much as possible shielded from risk operations. Thus, it takes time to ensure data transparency. In this situation, it becomes especially crucial to evaluate how to manage additional finances for inventory management in an effective and thoughtful manner.

Also, a variety of more specialised and relevant scientific and theoretical applied challenges relating to the creation of models of business entities can be resolved using the developed organisational, methodological, and methodical tools.

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