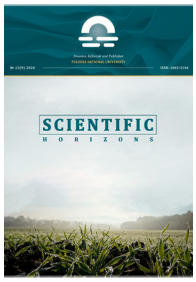
SCIENTIFIC HORIZONS

Journal homepage: https://sciencehorizon.com.ua
Scientific Horizons, 24(5), 81-91



UDC 338.984; 338.4; 519.233.2
DOI: 10.48077/scihor.24(5).2021.81-91

Inventory Management at the Enterprise in the Field of Probability Models

Anatolii Kulyk[1*], Kateryna Fokina-Mezentseva[2], Nataliya Boretska[3], Aleksii Bilousov[4], Svitlana Prokhorchuk[4]

[1]Kyiv National Economic University named after Vadym Hetman
03057, 54/1 Peremohy Ave., Kyiv, Ukraine

[2]Kyiv National University of Trade and Economics
02156, 19 Kyoto Str., Kyiv, Ukraine

[3]Kyiv National University of Technologies and Desion
01011, 2 Nemyrovych-Danchenko Str., Kyiv, Ukraine

[4]International University of Business and Law
73000, 37-41 49-i Hvardiiskoi Dyvizii Str., Kherson, Ukraine

Article's History:
Received: 20.08.2021
Revised: 15.09.2021
Accepted: 25.10.2021

Suggested Citation:
Kulyk, A., Fokina-Mezentseva, K., Boretska, N., Bilousov, A., & Prokhorchuk, S. (2021). Inventory management at the enterprise in the field of probability models. *Scientific Horizons*, 24(5), 81-91.

Abstract. The inventory management system is designed to continuously ensure the production activities of the enterprise with all necessary resources. The purpose of this study is to build a probabilistic model that can be proposed as a new inventory model, which establishes the relationship of period factors between the purchase of parts and the duration of their suitability, which affect inventory management. The research methods are based on a probabilistic approach using continuous distributions. Using the statistical method, point estimates were found for the studied parameters: mean and standard deviation. The histograms of relative frequencies between dates of two next purchases, volume of purchases of details and days of replacement of the fulfilled details are constructed. The critical areas for the studied parameters are illustrated. The values of the difference in days between the purchases of parts and the values of purchases of parts that meet the normal distribution of random variables with the appropriate parameters, as well as the critical values of the need for parts in the production process. The size of the part reserve, which corresponds to Erlang distribution, was found, depending on the established risk factor. For different values of this factor, the value of the difference in days between the purchases of parts, the size of purchases and the reserve of parts that correspond to the distributions of random variables, as well as the critical value of the need for parts in the production process to avoid downtime. Using the central limit theorem, it is shown that the purchase volume of parts and the volume of used parts are distributed according to the normal law. The study concludes that the probabilistic approach is the basis for forecasting inventory management in the enterprise, taking into account the risks associated with determining the optimal demand for raw materials in the enterprise

Keywords: stocks, costs, reserve, normal distribution, Erlang distribution

*Corresponding author

INTRODUCTION

One of the main tasks in market conditions is to increase the efficiency of the enterprise by optimizing the use of its resources, building a promising production program. The use of models allows to solve the issues of forming the optimal production program of the enterprise, investing in production, and also helps to carry out strategic planning of enterprise development. The successful development of the enterprise will largely depend not only the marketing strategy, but also on the purchase of the products it needs [1; 2].

The problem of inventory management today is relevant for enterprises, which is caused by the following reasons: inconsistency in the rhythm and continuity of production, as well as the rhythm of production of the supplier and consumer; discreteness of the supply process; random fluctuations in consumption intensity and different duration of intervals between deliveries relative to the design level. This leads to the creation and storage of production or inventories, which may consist of raw materials, semi-finished products, components, goods, waste, etc. In addition, capital can also be considered as a stock, the cost of storage of which is determined by inflation [3; 4].

When managing production or inventories, there are two main questions: when to replenish the stock and what should be its optimal size. Obviously, stocks require certain costs for their storage until they are sold. Moreover, due to the share of working capital that is invested in stocks, the company's losses increase. Therefore, in each case, it is important to find the optimal cost-benefit ratio of the selected level of stocks and determine which stocks are sufficient for each group of goods or raw materials. To do this, build a mathematical model that describes such a system. The value of inventory management models lies in their accuracy, which allows not only to reduce operating costs, but also the cost of stockpiling.

There are different ways to manage inventory with different business models of inventory management, as well as types of goods and services. Each company has a unique location, infrastructure and logistics. Therefore, you need to find mechanisms that meet the requirements of the enterprise, to choose special models of inventory management to coordinate business processes. Assume that there are expected annual raw material costs of an enterprise. During the year, raw materials are replenished n times in equal batches. Since the consumption of raw materials is a random variable, in order to have enough raw materials for each of the n time intervals, you need to create a certain additional stock, which is called a reserve stock. In this case, the company creates a reserve in a predetermined amount, and then makes regular purchases of raw materials. Thus, when the main stock is depleted, and the company did not have time to purchase a new batch of raw materials, unforeseen needs are covered from the reserve. Therefore, the main task is to determine the optimal size of the reserve. After all, it is clear that if the company creates a large reserve, it will cover all possible unforeseen costs of raw materials, but in this case, the cost of storing such a reserve will be quite large.

In practice, the calculations of the optimal size of the reserve stock are based on some, pre-established, probability that the demand for raw materials for a given period of time will not exceed the existing reserve. This probability is called the reliability factor. The risk factor is also defined as the probability that the reserve will be insufficient. If for some reason such a risk factor is set, then on the basis of statistics you can simulate this situation and determine the optimal size of the reserve. A natural question arises: what should be the risk and, accordingly, the reserve, so that the cost of its storage or possible shortage was minimal.

In the last few decades, interest in procurement and inventory theory has not diminished [5-7]. And despite the fact that scientists have developed many methods of inventory management and solved a large number of related practical problems, but the question of applying probabilistic models in conditions of uncertainty in inventory management in the enterprise is still relevant.

The purpose of this study is to find the optimal reserve stock, when the size of raw material needs is distributed at different time intervals and by different distributions.

The realization of this goal is achieved by solving the following tasks: accounting for the current level of stock in warehouses of different levels; determining the size of the order; determining the interval between orders.

The materials of the study will be useful for further study of the specifics of inventory management systems and can be used in planning production costs.

LITERATURE REVIEW

To minimize the costs associated with the acquisition and storage of stocks, determine the optimal size of the order to replenish stocks and the time of submission of the order to replenish stocks [8]. These problems are solved with the help of automated inventory management systems and with the use of economic and mathematical methods [9]. A large number of monographs are devoted to this topic, among which it is possible to note [10-12]. Here are some works that are devoted to the tasks of inventory management, related to the use of mathematical modeling.

In [13] calculated the efficiency of the use of inventory, which helps to minimize the cost of transportation and storage of products. The author in [14] on the example of a study of the company with two indications that inventory management should take measures to implement a strategy of inventory control to optimize the production process, inventory costs and thus increase efficiency. In [15] considered the problem of inventory management based on the model of mathematical programming. J. Madhuri [16] investigated how the introduction of neural networks can improve profitability by reducing capital for inventory, forecast orders and calculate the stock of products accordingly. In [17], a new business model was proposed for a multi-stage supply chain inventory management scheme. The aim was to investigate the potential reduction of the overall costs of the enterprise and, conversely, whether such an approach can significantly improve the level of service achievable through more efficient resource management.

In [18] five models for the problem of the number of economic orders are considered. These models are nonlinear functions with binary variables that are related to the procurement strategy and are also responsible for accepting or rejecting each strategy.

There is a number of scientific studies in the development of various models of inventory management, as well as their evaluation. All models are divided into two main types:

• Deterministic models (built on the assumption of the absence of uncertainty associated with demand and replenishment [19]).

• Probabilistic models (take into account the fact that there is always a certain degree of uncertainty associated with the structure of demand and the time of execution of stocks [20]).

Here are three of the most popular deterministic models of inventory management:

1. Economic order quantity (EOQ). This inventory model requires constant checking of inventory levels and is reduced to the formula EOQ=2·D·S/C, where D is the annual demand, C is the cost of delivery, S is the cost of the order. The EOQ model expects a consistent product request and offers the availability of items to be replenished [21-24].

2. Economic purchase quantity (EOQ). The model complements the EOQ and allows you to calculate the volume of inventory production. Inventories can be managed using the inventory turnover ratio, which establishes the relationship between average inventories and the value of inventories consumed or sold over a period of time [25].

3. ABC analysis. Often used with other inventory management models, such as Just in Time (JIT). Inventories are sorted by groups A, B, or C to determine the most stringent control requirements with the greatest degree of attention for the contribution of the inventory management model to the object of most interest. Thus, the company applies a selective approach to controlling investments in various types of stocks [26].

Deterministic calculation methods are used in the calculation of secondary demand for materials according to the known primary [27]. In the analytical method, the calculation is based on the product specification [28]. The synthetic method involves calculations for each group of parts based on the degree of their applicability at individual levels of the hierarchy [29-31].

The probabilistic model is based on the assumption that there is some uncertainty associated with demand. In this model, demand may fluctuate and may not always be predictable. The probabilistic approach allows to change demand and it is considered at stock management [32; 33].

Stochastic calculation methods allow to establish the expected need on the basis of numerical data that characterize its changes over a period of time [34]. For this purpose, the approximation of average values is used (used in conditions when the demand for materials varies by months at a stable average value), the method of smoothing (the coefficient that is selected to minimize the forecast error is calculated) and regression analysis (involves the approximation of known trends in the consumption of material resources using mathematical functions that can be extrapolated to the future) [35; 36].

Note that the warranty stock of raw materials at the enterprise is intended for use when [37]:

• demand exceeds the forecast;

• the relevant material is produced less than planned;

• the actual execution time of this order exceeds the usual term.

In [38], the optimal size of the reserve stock was found, which corresponds to the risk factor at which the costs associated with storage and scarcity are minimal. It should be noted that found in this work, such a coefficient in practice can be quite large. But there are cases when the risk factor will go to zero, despite the fact that there are certain costs for the storage of such stock.

At the same time, [39] considers the problem when the cost of raw materials in the main production is a random variable with some intensity per hour, when the systematic supply of raw materials to some extent creates a shortage of raw materials with constant demand in the main market. It is assumed that the value is the optimal value, which determines the absence of shortage and balance of raw materials, during which the total consumption of raw materials is equal to the volume of its supply has a gamma distribution with parameters: the volume of raw material supply in conventional units of value and the intensity of raw material costs per hour in conventional units of value. The flow of events with a constant intensity of raw material costs in conventional units of cost per hour is considered, the random variable is the time required for the occurrence of a given number (volume of raw material supply) of events. It is concluded that if market demand is constantly declining, it is necessary to consider the assortment component in terms of diversification of basic production.

MATERIALS AND METHODS

The study used a statistical method based on the systematization and processing of statistical data. Relative frequency histograms are constructed for the set of observed X objects. Variants (observations) from the smallest value x_{min} to the largest x_{max} are divided into several segments of equal length h. Then calculate the sum of the relative frequencies of the values of the variant of the X, which belong to each of the obtained segments. If in the k-th segment (k=1,2,…) the number of observed variants is equal to n_k, then construct a rectangle Π_k, the basis of which will be the k-th segment of length h, and the height will be n_k/n, where n is the number observations.

Next, using the results of the constructed sample, found point statistical estimates of the unknown parameters of the random variable X: mean and standard deviation.

From the form of the constructed histogram make assumptions about the law of distribution of general population. The hypothesis of the distribution of the general population according to some selected criterion is tested.

After selecting a certain agreement criterion, the set of all its possible values is divided into two subsets that do not intersect: one of them contains the values of the criterion in which the main hypothesis is rejected (critical region), and the second – in which it is accepted (hypothesis acceptance area). To find the critical area, you need to find the critical point K_{cr}, which separates the critical area from the area of acceptance of the hypothesis. To do this, set a fairly small probability – the level of significance of a, and then look for a critical point, taking into account the requirement.

The following continuous distributions and the central limit theoremwere used:

• normal distribution: The general form of its probability density function is:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} exp\left(-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right) \quad (1)$$

The parameter μ is the mean or expectation of the distribution, while the parameter σ is its standard deviation;

• uniform distribution: The probability density function of the continuous uniform distribution is:

$$f(x) = \begin{cases} \frac{1}{b-a} & \text{for } a \le x \le b, \\ 0 & \text{for } x < a \text{ or } x > b \end{cases} \quad (2)$$

$$\text{mean} = \frac{a+b}{2}, \ \text{standard deviation} = \frac{b-a}{2\sqrt{3}}$$

• erlang distribution: The probability density function of the Erlang distribution is:

$$f(x;k,\lambda) = \frac{\lambda^k x^{k-1} e^{-\lambda x}}{(k-1)!} \quad \text{for } x, \lambda \ge 0, \quad (3)$$

$$\text{mean} = \frac{k}{\lambda}, \ \text{standard deviation} = \frac{\sqrt{k}}{\lambda}$$

The central limit theorem (CLT) establishes a connection between the distribution of the sum of explosives and its limit form – the normal distribution. CLT states that with a sufficiently large number of equally distributed random variables that have the same mean μ and standard deviations σ, the sum of these quantities is approximately distributed over the normal distribution with the parameters:

$$\text{mean} = n\mu, \ \text{standard deviation} = \sqrt{n}\sigma$$

The calculations were performed using the **numpy** library for the **Python** programming language.

RESULTS AND DISCUSSION

Parameter distributions and critical regions

Determine the minimum size of the reserve required to ensure that the probability that the reserve will be insufficient does not exceed some value of p (usually p<0.1). Let's make a designation: V – the size of the demand for raw materials between two consecutive purchases of raw materials, S – the size of the purchasing party of raw materials, R – the reserve of raw materials. For a continuous production process, the values of V, S and R must meet the conditions:

$$P(V > S + R) = p$$

when probability p is the state of insufficient reserve.

The need for materials for products is calculated in detail according to the norms for each part that is part of the product, and for each type of material separately.

Consider the process of purchasing parts at the enterprise "Kyiv Central Design Bureau of Valves", where in the production process you need to periodically purchase more than 60 different parts. Without limiting the generalities, the analysis made the purchase of a single part, which is a necessary component in the production process, namely "Plate XNEX 080616TR-ME09 F40M (SECO 552)".

Using the statistics of purchases of parts for the period 2013-2021 [40], it is seen that the difference in dates between two consecutive purchases of the above part is distributed according to the normal distribution with a sample average value – 60 days and standard deviation – 14 days (Fig. 1). The differential function for this distribution has the form:

$$f(T; 60.14) = \frac{1}{14\sqrt{2\pi}} exp\left(-\frac{(T-60)^2}{392}\right) \quad (4)$$

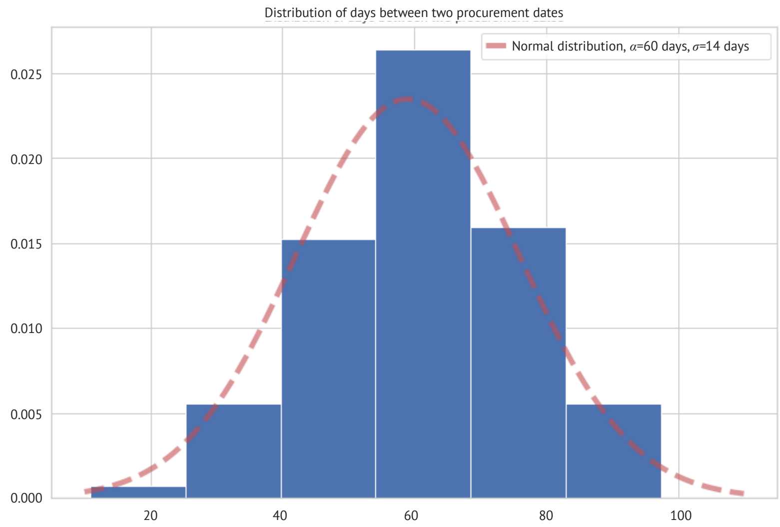


***Figure 1**. Histogram of relative frequencies between the dates of two consecutive purchases and the graph of the function of a normally distributed random variable V with parameters α=60, σ=14*

***Source**: authors' elaboration*

In Figure 2 shows the critical area for a normally distributed random variable with parametersa=60, σ=14 for α=0.05, which corresponds to the value of the random variable T_{α}=84 – the number of days between purchases. The area of the shaded area $T \in (T_{\alpha}; +\infty)$ is equal to the probability α=0.05 that characterizes the state of insufficient reserve (Fig. 2). For the production process, this will mean that if the number of days exceeds 84, then the probability of continuous production will be only 0.05.

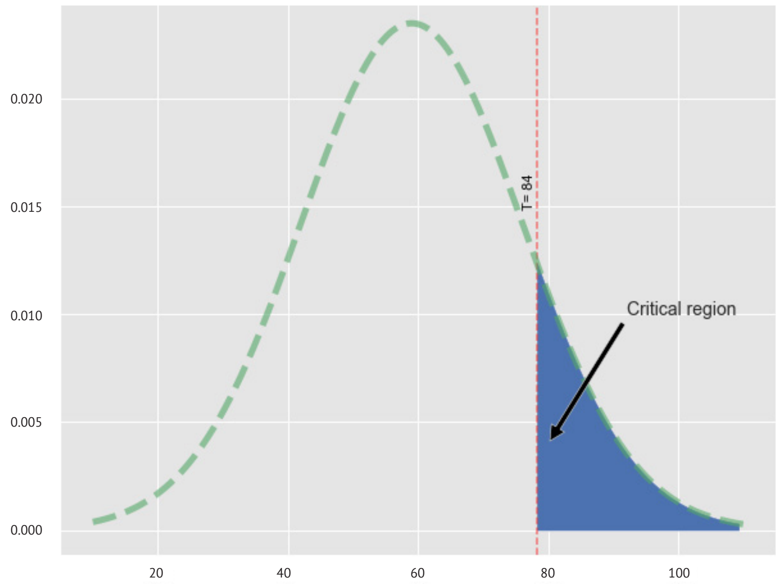


***Figure 2**. Critical region for a normally distributed random variable T with parameters a=60, σ=14 for α=0.05*

***Source**: authors' elaboration*

According to the statistics of procurement of parts for the period 2013-2021 [40], the amount of individual parts "Plate XNEX 080616TR-ME09 F40M (SECO 552)" during each purchase is described by a uniform distribution with parameters $a=10$, $b=40$ ($M(X)=25$, $\sigma(X)=5\sqrt{3}$). Purchases of parts take place on average every 2 places. Thus, the differential function of the uniform distribution has the form (Fig. 3):

$$f(x) = \frac{1}{25}, x \in [10; 40] \tag{5}$$

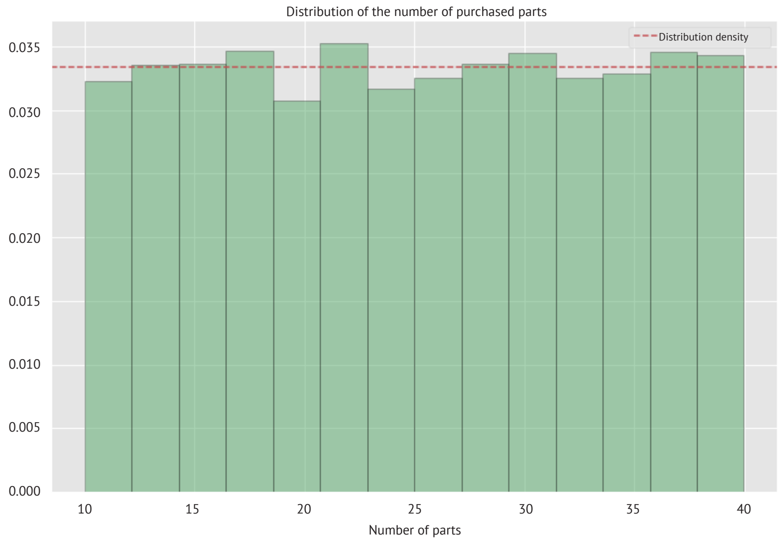


***Figure 3**. Histogram of relative frequencies of volume of purchases of details and density of uniform distribution with parameters a=10, b=40*

***Source**: authors' elaboration*

Using the central limit theorem, it can be stated that during the year the procurement volume of parts of the type "Plate XNEX 080616TR-ME09 F40M (SECO 552)", distributed according to the normal distribution with parameters, $a=6\cdot25=150$, $\sigma=\sqrt{6\cdot5\sqrt{3}}=15\sqrt{2}$ (On average, 6 purchases are made per year). The differential function of the normal distribution has the form (Fig. 4):

$$f(S;150.15\sqrt{2}) = \frac{1}{30\sqrt{\pi}} exp\left(-\frac{(S-150)^2}{900}\right) \quad (6)$$

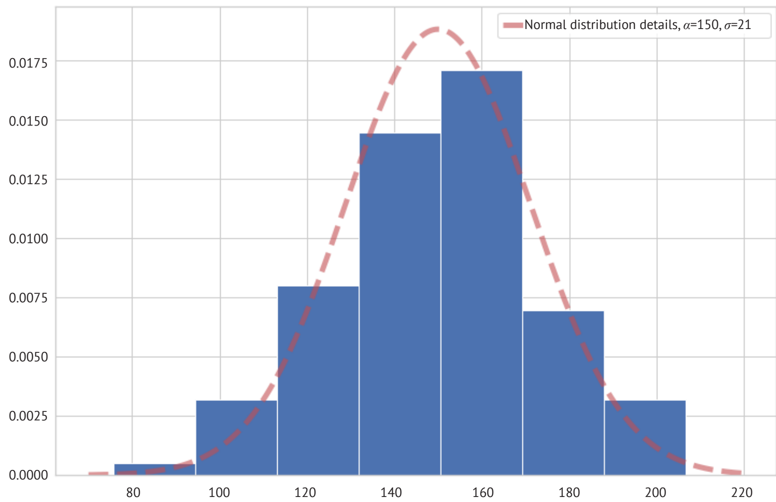


***Figure 3**. Histogram of relative frequencies of the volume of parts purchased for a calendar year and the graph of the function of the normally distributed random variable S with the parameters α=150, σ=15√2*

***Source**: authors' elaboration*

Figure 5 shows the Gaussian curve and the critical region for a normally distributed random variable with parameters a=150, σ=15√2 for p=0.05, which corresponds to the value of the random variable S=115 – the number of parts. The area of the shaded area for $S\in(0;S_p)$ should be equal to the probability p, which is calculated by the Laplace function and characterizes the state of insufficient reserve.

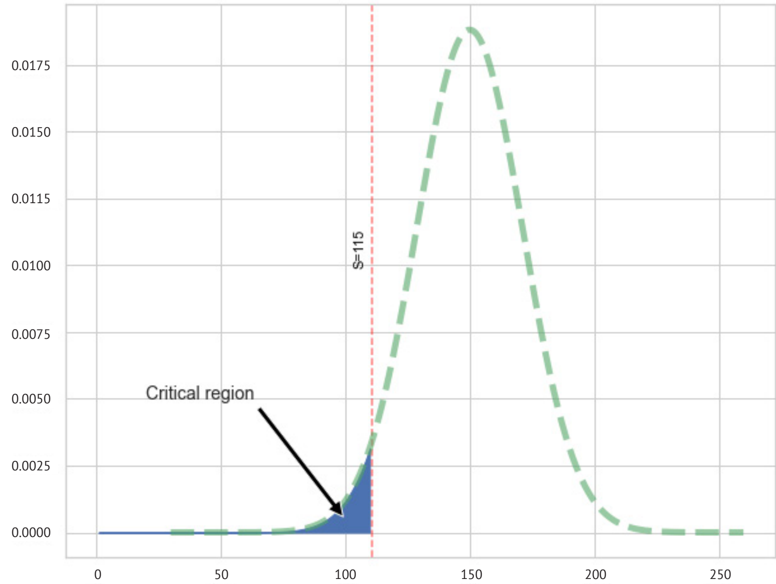


Figure 5. *Critical region for a normally distributed random variable S with parameters a=150, σ=15√2 for p=0.05*
Source*: authors' elaboration*

Replacement of used parts of the type "Plate XNEX 080616TR-ME09 F40M (SECO 552)" with new ones is described by Erlang distribution with parameters k=2, θ=5 (R~Γ(2;5)), which corresponds to the average number of days – 10, with a variance – 50. The differential Erlang distribution function has the form:

$$f(R; 2.5) = R \cdot exp\left(-\frac{R}{5}\right),\ \Gamma(2) = \int_0^{+\infty} R \cdot exp(-R)dR \quad (7)$$

Figure 6 shows a histogram of the relative frequencies of the days of replacement of used parts and a graph of the function distributed according to Erlang distribution random variable R with parameters k=2, θ=5.

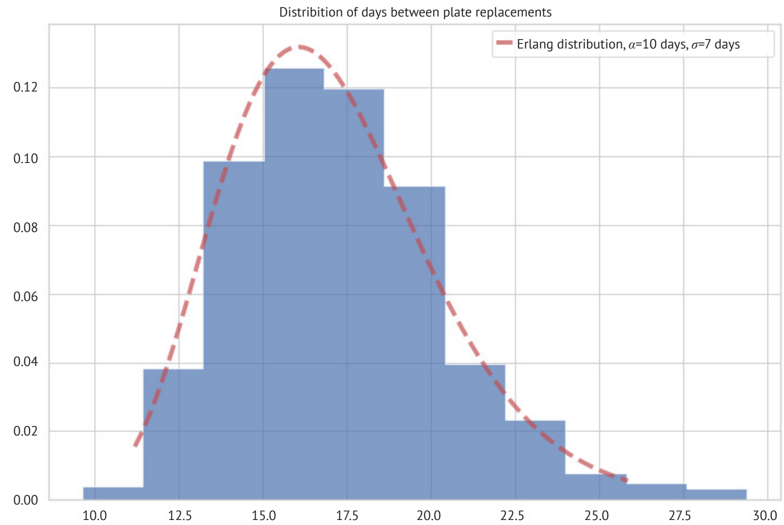


Figure 5. *Histogram of relative frequencies of days of replacement of used parts and graph of the function of random variable R distributed according to Erlang distribution with parameters k=2, θ=5*
Source*: authors' elaboration*

According to the central limit theorem, it is assumed that during the year the amount of spent parts of the type "Plate XNEX 080616TR-ME09 F40M (SECO 552)", distributed according to the normal distribution with parameters, $a=36\cdot10=360$, $\sigma=\sqrt{36}\cdot\sqrt{50}=30\sqrt{2}$ (36 replacement parts per year).

Figure 7 presents a histogram of the relative frequencies of the volume of replacement of parts during the calendar year and a graph of the function of the normally distributed random variable R with parameters $a=300$, $\sigma=30\sqrt{2}$.

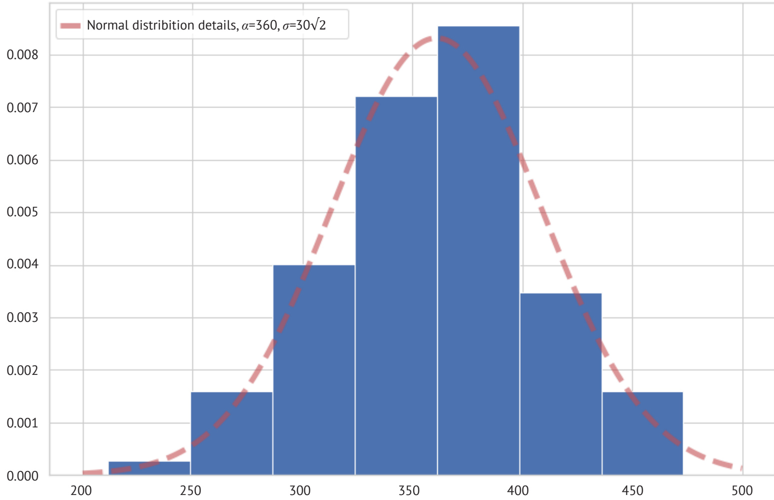


***Figure 7**. Histogram of relative frequencies of replacement volume during a calendar year and graph of the function of a normally distributed random variable R with parameters a=300, σ=30√2*

***Source**: authors' elaboration*

Calculate the size of the reserve of parts depending on the established risk factor. Table 1 for the different values of p shows the value of the difference in days between parts purchases, purchase values and parts reserves that meet the laws of distribution of random variables T, S and R with the corresponding parameters, as well as the critical value V_p of parts demand during production.

***Table 1**. Critical values days, sizes, reserves, demands (T, S_α, R_α, V_α)*

p	T	S_p	R_p	V_p
0.01	93	101	261	362
0.02	89	106	273	379
0.05	84	115	290	405
0.1	78	123	306	429

***Source**: authors' elaboration*

From Table 1 we can draw the following conclusion: the longer the period between purchases in days T, the smaller the value V_p that characterizes the process of continuous production (if there are less than *405* parts or the period between purchases exceeds *84* days, it means that the probability of continuous operation is *0.05*, or that with a probability of *1-0.05=0.95* it can be argued that there will be a simple production).

Inventories are the means of production that have arrived in the warehouses of the enterprise, and are waiting to enter the production process. These stocks allow to provide release of materials in shops and on workplaces according to requirements of technological process. It should be noted that the creation of stocks distracts a significant amount of material resources. Reducing inventories reduces the cost of their maintenance, reduces costs, accelerates the turnover of working capital, which ultimately increases profits and the feasibility of production. Therefore, according to the authors, optimizing the size of stocks is an important task. The reserve in case of violations in the supply or increase in output is characterized by a certain value and is restored after receiving the next batch of materials. The standard of insurance stock of materials is determined by the interval of backlog of deliveries or by actual data on replenishment of stocks. Finding the size of such a reserve is an urgent problem. The company should strive to minimize inventories, but stocks of raw materials should be close to optimal. The point of economically justified order is the equilibrium point of the cost of purchase and storage. For some stocks, purchase costs are negligible, and the main burden falls on storage costs. Costs can be minimized if low-cost parts are purchased in large batches at long intervals, and expensive ones more often, but in small batches. If the terms of placing the order satisfy the company, the smallest number of parts is ordered at the appointed time of submission of the request. Maintaining inventories at a predetermined level is one way to increase the company's profits.

Given the above research, it can be argued that one of the main tasks is to find the optimal value for each product, or to determine the minimum level of stocks for continuous production. The optimal amount of reserves should correspond to the economically optimal volume of the purchasing party plus some guarantee stock. The optimal volume of purchases should be equal to the volume of stocks used in the production process for production. When managing production or inventories, there are two main questions: the time of renewal of inventories and what should be its size. Obviously, stocks require certain costs for their storage until they are sold. Moreover, the company's losses increase due to the part of working capital that is invested in stocks. Therefore, it is important to build a mathematical model that describes the system under study, and on its basis to find the optimal ratio between costs and benefits of the selected level of stocks and determine what stocks for each group of goods or raw materials are sufficient.

CONCLUSIONS

Thus, taking into account the degree of uncertainty associated with the structure of demand and the time of use of stocks at the enterprise, the authors chose probabilistic models that allow flexible change of simulated demand and take this into account in forecasting. The process of purchasing parts at enterprise "Kyiv Central Design Bureau of Valves' for the period 2013-2021 is considered, while it is proved that the difference in dates between two regular purchases of one individual part is distributed according to the normal distribution, and the amount of individual parts at the time of each purchase is described by a uniform distribution.

Using the central limit theorem, it is shown that during the year the purchase volume of parts is distributed according to the normal distribution. It is also proved that the replacement of used parts with new ones is described by Erlang distribution. The histogram of relative frequencies of volume of replacement of details during a calendar year is presented. The value of the difference in days between the procurement of parts, the value of purchases and the reserve of parts that correspond to the distributions of random variables with the appropriate parameters, as well as the critical value of the need for parts in the production process. This made it possible to draw conclusions about the optimal values of the reserve for continuous operation of production, indicating the conditions under which downtime may occur. Therefore, the problem of finding the optimal reserve stock, when the random value of the size of raw material needs is distributed over different time intervals and according to different laws, including different from normal, may be the subject of further research.

REFERENCES

[1] Smith, V.L. (1961). *Investment and production: A study in the theory of the capital-using enterprise*. Cambridge: Harvard University Press.

[2] Carrilo, J.E., & Franza, R.M. (2006). Investing in product development and production capabilities: The crucial linkage between time-to-market and ramp-up time. *European Journal of Operational Research*, 171(2), 536-556. doi: 10.1016/j.ejor.2004.08.040.

[3] Gilbert, R.J. (1979). Optimal depletion of an uncertain stock. *The Review of Economic Studies*, 46(1), 47-57. doi: 10.2307/2297171.

[4] Ray, J., Goswami, A., & Chaudhuri, K.S. (1998). On an inventory model with two levels of storage and stock-dependent demand rate. *International Journal of Systems Science,* 29(3), 249-254. doi: 10.1080/00207729808929518.

[5] Seigworth, G.J., & Gregg, M. (2010). An inventory of shimmers. In *The affect theory reader* (pp. 1-26). New York: Duke University Press. doi: 10.1515/9780822393047-002.

[6] Wild, T. (2017). *Best practice in inventory management*. London: Routledge. doi: 10.4324/9781315231532.

[7] Muller, M. (2019). *Essentials of inventory management*. Nashville: Harper Collins Leadership.

[8] Schwartz, L.B. (Ed.). (1981). Multi-level production/inventory control systems: Theory and practice. In *Studies in the management sciences* (pp. 163-193). Amsterdam: North Holland.

[9] Raymond, F.E. (1931). *Quantity and economy in manufacture*. Chicago: McGraw-Hill.

[10] Kampf, R., Lorincová, S., Hitka, M., & Caha, Z. (2016). The application of ABC analysis to inventories in the automatic industry utilizing the cost saving effect. *Nase More*, 63(3), 120-125.

[11] Masse, P. (1959). *Le choix des investissements*. Paris: Dunod & Co.

[12] Taha, H.A. (2003). *Operations research – An introduction* (7th ed). New Jersey: Prentice Hall, Inc.

[13] Luchko, M.R., Lukanovska, I.R., & Ratynskyi, V. (2019). Modelling inventory management: Separate issues for construction and application. *International Journal of Production Management and Engineering,* 7(2), 117-124. doi: 10.4995/ijpme.2019.11435.

[14] Inegbedion, H., Eze, S., Asaleye, A., & Lawal, A. (2019). Inventory management and organisational effsciency. *The Journal of Social Sciences Research*, 5(3), 756-763 doi: 10.32861/jssr.53.756.763.

[15] Buschiazzo, M., Mula, J., & Campuzano-Bolarin, F. (2020). Simulation optimization for the inventory management of healthcare supplies. *International Journal of Simulation Modelling*, 19(2), 255-266. doi: 10.2507/IJSIMM19-2-514.

[16] Madhuri, J. (2020). Inventory management using machine learning. *International Journal of Engineering Research & Technology*, 9(6), 866-869.

[17] Cesarelli, G. (2020). An innovative business model for a multi-echelon supply chain inventory management pattern. *Journal of Physics: Conference Series*, 1828(2021), article number 012082. doi: 10.1018/1742-6596/1828/1/01/2082.
[18] Pereira, V., & Costa, H.G. (2017). A multiproduct economic order quantity model with simulated annealing application. *Journal of Modelling in Management*, 4, 119-142.
[19] Göçmen, E., & Erol, R. (2019). Transportation problems for intermodal networks: Mathematical models, exact and heuristic algorithms, and machine learning. *Expert Systems with Applications*, 135(6), 374-387. doi: 10.1016/j.eswa.2019.06.023.
[20] Engebrethsen, E., & Dauzère-Pérès, S. (2019). Transportation mode selection in inventory models: A literature review. *European Journal of Operational Research*, 279(1), 1-25. doi: 10.1016/j.ejor.2018.11.067.
[21] Chan, S.W., Tasmin, R., Nor Aziati, A.H., Rasi, R.Z., Ismail, F.B., & Yaw, L.P. (2017). Factors influencing the effectiveness of inventory management in manufacturing SMEs. *IOP Conference Series: Materials Science and Engineering*, 226(1), article number 012024. doi: 10.1088/1757-899X/226/1/012024.
[22] Chitsaz, M., Cordeau, J.F., & Jans, R. (2019). A unified decomposition matheuristic for assembly, production, and inventory routing. *Informs Journal on Computing*, 31, 134-152. doi: 10.11287/ijoc.2018.0817.
[23] Huang, Q., & Wu, P. (2020). A new economic order quatitty model. *Journal of Physics: Conference Series*, 1670, article number 012047. doi: 10.1088/1742-6596/1670/1/012047.
[24] Makoena, S., & Olufemi, A. (2019). Economic order quantity model for growing items with imperfect quality, perations. *Research Perspectives*, 6, article number 100088. doi: 10.1016/j.orp.2018.11.004.
[25] Beklari, A., Nikabadi, M.S., Farsijani, H., & Mohtashami, A. (2018). A hybrid algorithm for solving vendors managed inventory (VMI) model with the goal of maximizing inventory turnover in producer warehouse. *Industrial Engineering & Management Systems*, 17(3), 570-587. doi: 10.1016/j.peva.2018.07.003.
[26] De Kok, A.G., Grob, C., Laumanns, M., Minner, S., Rambau, J., & Schade, K. (2018). A typology and literature review on stochastic multi-echelon inventory models. *European Journal of Operational Research*, 269(3), 955-983. doi: 10.1016/j.ejor.2018.02.047.
[27] Jauhari, W.A., Sianipar, M., Rosyidi, C.N., & Dwicahyani, A.R. (2018). A vendor-buyer inventory model with imperfect production considering investment to reduce lead time variability. *Cogent Engineering,* 5(1), 1531455. doi: 10.1080/23311916.2018.1531455.
[28] Lin, F., & Jia, T., & Wu, F., & Yang, Z. (2019). Impacts of two-stage deterioration on an integrated inventory model under trade credit and variable capacity utilization. *European Journal of Operational Research*, 272(1), 219-234 doi: 10.1016/j.ejor.2018.06.022.
[29] Baek, J.W., Bae, Y.H., Lee, H.W., & Ahn, S. (2018). Continuous-type (s, Q)-inventory model with an attached M/M/1queue and lost sales. *Performance Evaluation*, 125(9), 68-79. doi: 10.7232/iems.2018.17.3.570.
[30] Park, J.H., Kim, J.S., & Shin, K.Y. (2018). Inventory control model for a supply chain system with multiple types of items and minimum order size requirements. *International Transactions in Operational Research*, 25(6), 1927-1946. doi: 10.1111/itor.12262.
[31] Zadjafar, M.A., & Gholamian, M.R. (2018). A sustainable inventory model by considering environmental ergonomics and environmental pollution, case study: Pulp and paper mills. *Journal of Cleaner Production,* 199(20), 444-458. doi: 10.1016/j.jclepro.2018.07.175.
[32] Duan, L., & Ventura, J.A. (2019). A dynamic supplier selection and inventory management model for a serial supply chain with a novel supplier price break scheme and flexible time periods. *European Journal of Operational Research*, 272(3), 979-998. doi: 10.1016/j.ejor.2018.07.031.
[33] Esteso, A., Alemany, M.M.E., Ortiz, A., & Peidro, D. (2018). A multi-objective model for inventory and planned production reassignment to committed orders with homogeneity requirements. *Computers & Indrustrial Engineering*, 124(7), 180-194. doi: 10.1016/j.cie.2018.07.025.
[34] Gabor, A.F., Van Vianen, L.A., Yang, G.Y., & Axsater, S. (2018). A base-stock inventory model with service differentiation and response time guarantees. *European Journal of Operational Research*, 269(3), 900-908. doi: 10.1016/j.ejor.2018.02.039.
[35] Cholodowicz, E., & Oelowski, P. (2018). Impact of control system structure and performance of inventory goods flow system with long-variable delay. *Elektronika ir Elektrotechnika*, 24(1), 11-16. doi: 10.5755/j01.eie.24.1.14244.
[36] Mnikas, A.S. (2017). Interdependence among inventory types and firm performance. *Operations and Supply Chain Manag*, 10(2), 63-80. doi: 10.31387/OSCM0270181.
[37] Karadag, H. (2018). Cash, receivables and inventory management practices in small enterprises: Their associations with financial performance and competitiveness. *Small Enterprise Research,* 25(1), 69-89, doi: 10.1080/13215906.2018.1428912.
[38] Poo, M.C.P., & Yip, T.L. (2019). An optimization model for container inventory management. *Annals of Operations Research*, 273, 433-453. doi: 10.1007/s10479-017-2708-8.

[39] Tarasova, E.V., Moskvicheva, N.V., & Nikulina, E.N. (2019). Simulation-based improvement in the models for tool-inventory management at manufacturing plants. *Russian Engineering Research*, 39(2), 160-166. doi: 10.3103/S1068798X19020102.
[40] Reports private joint stock company "Kyiv central design bureau of reinforcement construction". (n.d.). Retrieved from http://kckba.pat.ua/emitents/reports.

Управління запасами на підприємстві із застосуванням імовірнісних моделей

Анатолій Борисович Кулик[1], Катерина Володимирівна Фокіна-Мезенцева[2], Наталія Петрівна Борецька[3], Олексій Михайлович Білоусов[4], Світлана Володимирівна Прохорчук[4]

[1]Київський національний економічний університет імені Вадима Гетьмана
03057, просп. Перемоги, 54/1, м. Київ, Україна

[2]Київський національний торговельно-економічний університет
02156, вул. Кіото, 19, м. Київ, Україна

[3]Київський національний університет технологій та дизайну
01011, вул. Немировича-Данченка, 2, м. Київ, Україна

[4]Міжнародний університет бізнесу і права
73000, вул. 49-ї Гвардійської Дивізії, 37-41, м. Херсон, Україна

Анотація. З метою забезпечення неперервної виробничої діяльності підприємства усіма потрібними ресурсами будується система управління виробничими запасами. Метою цього дослідження є побудова ймовірносної моделі, яка може бути запропонована як нова модель інвентаризації, за допомогою якої встановлюються взаємозв'язки факторів періоду між закупівлею деталей та тривалістю їх придатності, що впливають на управління запасами. Методи дослідження засновані на ймовірнісному підході з використанням неперервних законів розподілу. Використовуючи статистичний метод, знайдені точкові оцінки для досліджуваних параметрів: середнього і середньоквадратичного відхилення. Побудовані гістограми відносних частот між датами двох чергових закупок, обсягу закупок деталей та днів заміни відпрацьованих деталей. Проілюстровані критичні області для досліджуваних параметрів. Розраховано значення різниці в днях між закупками деталей та величин закупок деталей, які відповідають нормальним законам розподілу випадкових величин з відповідними параметрами, а також критичні значення потреби в деталях в процесі виробництва. Знайдено розмір резерву деталей, який відповідає закону розподілу Ерланга, в залежності від встановленого коефіцієнту ризику. Для різних значень цього коефіцієнту наведено значення різниці в днях між закупками деталей, величин закупок і резерву деталей, які відповідають законам розподілу випадкових величин, а також критичне значення потреби в деталях в процесі виробництва для уникнення простою виробництва. Використовуючи центральну граничну теорему, показано, що закупівельний обсяг деталей та обсяг відпрацьованих деталей розподілені за нормальним законом. У дослідженні зроблено висновки, що ймовірнісний підхід є основою прогнозування управління запасами на підприємстві, що враховує ризики, пов'язані з визначенням оптимальної потреби в сировині на підприємстві

Ключові слова: запаси, витрати, резерв, нормальний розподіл, розподіл Ерланга