# Risk management models in operative planning at an industrial enterprise

Zaruba Viktor
Department of Economic Cybernetics and Marketing Management
National Technical University “Kharkiv Polytechnic Institute”
Kharkiv, Ukraine
vza.kpi.kharkov@gmail.com

Parfentenko Iryna
Department of Economic Cybernetics and Marketing Management
National Technical University
“Kharkiv Polytechnic Institute”
Kharkiv, Ukraine
parfentenko2408@gmail.com

***The subject of the study was the situation of operational planning of production of an industrial company in the face of random fluctuations in the current demand for its products. It is shown that in this situation there are loss risks that depend on the decisions made during operational planning. A model of the planning situation is developed for the case when the volume of orders for products for one period of time is described by a random variable with stationary statistical characteristics. The effectiveness of decisions made was estimated by the average economic effect per unit of time over an infinite time interval. The planning situation model was used to conduct a comparative analysis of the effectiveness of various operational planning policies.***

***Keywords: operational planning, operative planning, risk of loss, risk management***

## I. Introduction

One of the pressing problems of management is to ensure the balance of enterprise resources with the demand for their products. From the system-resource approach in management it follows that the tasks of resource management are distributed between three organizational levels. These levels ensure the achievement of the goals of the enterprise in the long, medium and short term. They are often called strategic, tactical, and operative levels. At the strategic level, a product policy, a program for the development of production units based on a long-term forecast of demand for enterprise products and the introduction of new technologies are being developed. In the course of tactical planning, the company develops a program for the production of products for a period of time that spans several periods of operative planning. The operative volume-nomenclature production plans reflect decisions regarding current production volumes based on orders received for manufacturing products, production capacities of the enterprise, and forecasts of future orders.

The concept of sales and operational planning (S&OP) is closely related to the system-resource approach. The long-term planning horizon for a typical process (S&OP) spans more than 18–36 months. As a medium-term goal of the company in terms of sales and supplies, the Annual Operations Plan acts. Short-term (monthly) sales and operations plans are a means of gradually achieving Annual Operations Plan goals. The purpose (S&OP) for short-term periods of time is to determine the general level of output (production plan) and other activities to achieve the goals of profitability, productivity, and competitive lead time. One of the tasks (S&OP) is to establish production paces that will achieve the goal of maintaining, increasing or decreasing reserves or accumulated reserves, while maintaining the relative stability of personnel [1-3]. The S&OP process enables efficient supply chain management. In recent years, many supply chain professionals have been tasked with improving the relationship between supply and demand; and concepts such as “demand-driven supply chains” and consumer-oriented supply chains are attracting attention [4].

The concept of ERP (Enterprise Resource Planning) for creating information systems providing complex automation of enterprise management is also based on a system-resource approach. [5-8]. The ERP concept embodies modern management methods aimed at improving the efficiency of the business as a whole. Therefore, in systems of the ERP class, it is considered necessary to implement a set of functional management technologies: presentation of production plans in the context of calendar periods (Master Planning Scheduling); planning requirements for materials and components (Material Requirement Planning); capacity requirements planning to ensure timely execution of orders (Capacity Resource Planning). The ERP system may also include modules for managing financial flows, customer relations (Customer Relationship Management), relations with suppliers and logistics management (Supply Chain Management) and others. As we can see, ERP-system technologies provide ample opportunities for solving production planning problems associated with calculations based on predetermined demand levels. However, they do not provide risk management, which involves taking into account subjective preferences regarding losses and benefits.

If the demand for the company's products is characterized by random fluctuations over short periods of time, then its production activity with constant intensity is accompanied by losses. They arise either due to the lack of sales of part of the finished product (storage costs, “freezing” of funds), or due to lost profits in connection with the underproduction of products in the presence of demand. These losses can be reduced by rational selection of production intensity at individual time intervals during operational planning. However, adjusting the intensity of production leads to losses of a different kind. Changes in production volumes in the direction of reduction cause payments to staff in the event of downtime, the cost of storing unused circulating material resources and the “freezing” of funds for their purchase. Losses from


978-x-xxxx-xxxx-x/20/$31.00 ©2020 IEEE

changes in production volumes in the direction of increase are caused by surcharges to staff for excess working hours and the purchase of additional working material resources at higher prices. Thus, in conditions of fluctuations in current demand, there are loss risks that depend on decisions made during operative planning. Therefore, increasing the efficiency of the use of enterprise resources is closely related to mathematical modeling and risk management optimization.

Many Ukrainian scientists, in particular V. Afanasyev, V.V. Vitlinsky L.S. Guryanova, T. S. Klebanova, M. S. Syavavko, devoted their publications to mathematical modeling of risks and managers' preferences regarding risks [9-12]. The aim of this work is to develop models of operative production planning in the face of risk of losses from fluctuations in current demand. The paper systematizes the results of previous studies published in [13–15].

## II. Mathematical model of the situation

We introduce the following notation: $\mu$ - the number of products produced per unit time (enterprise productivity) under normal (normative) capacity utilization; $\xi$ - total volume of orders received per unit of time (demand intensity). In the case where enterprise performance $\mu$ and demand intensity $\xi$ are constants, then the resources of the enterprise and the flow of orders will be balanced, if $\mu=\xi$ . After the collection period for orders will be followed by equal in duration execution period. In this case, for any length of the period of collection of orders and planning, production losses will be absent.

In a situation where demand intensity $\xi$ is a variable random variable, as before, for the efficient organization of production, the period for fulfilling orders will be preceded by the period of their collection and operative planning. Enterprise resources and the flow of orders will be balanced if $\mu=\lambda$, where $\lambda$ - mathematical expectation of $\xi$. However, in this situation, losses occur and they depend on the operative planning policy of the enterprise.

For a formalized description of the planning situation in conditions when the demand intensity $\xi$ is a random variable, we introduce the following notation:

$n$ - the duration of the operative period, which coincides with the duration period of the collection of orders and with the duration of their execution;

$x^{\min}$ - the summary volume of pre-received orders for products of this type;

$x^{\max}$ - the maximum volume of new orders that may arrive during the execution of pre-orders;

$x$ - the possible volume of additional orders, $x \in [0, x^{\max}]$;

$\delta^{\max}$ - the maximum volume of all orders, $\delta^{\max} = x^{\min} + x^{\max}$;

$z$ - the amount of finished product residues at the beginning of planning;

$y^{\Sigma}$ - the total volume of finished products that will be available for the period in question, $y^{\Sigma} = u + z$;

$u$ - the production volume planned for the current operative period of time;

$u_r$ - the normative production volume for the operative period of time $n$, $u_r = n\mu$;

One part of the total number $y^{\Sigma}$ the finished product is intended to satisfy the guaranteed component $x^{\min}$ total demand, and another part in the amount of $y$ - to meet additional incoming orders, $y^{\Sigma} = x^{\min} + y$. Therefore $u = x^{\min} + y - z$. We will assume that the resources of the enterprise provide the satisfaction of demand in the full maximum amount $\delta^{\max}$.

Operative effect dependency $E = E(n)$, that will be obtained at the end of the operating period with a duration $n$, from value $x$ additional orders and planned additional quantity $y$ the finished product is determined by the function $f(x, y)$:

$$f(x, y) = f_1(x, y) \text{, if } x \in [y, x^{\max}], \tag{1}$$

$$f_1(x, y) = dx^{\min} + dy - d(x - y) - q(y), \tag{2}$$

$$f(x, y) = f_2(x, y), \text{ if } x \in [0, y], \tag{3}$$

$$f_2(x, y) = dx^{\min} + dx - a(y - x) - q(y), \tag{4}$$

where $f_1(x, y)$ , $f_2(x, y)$ - functions determining effect E accordingly, in cases of lost profits and the presence of unsold products;

$a$ - the amount of losses due to the lack of sales of part of the finished product, in calculation per unit of output;

$q(y)$ - loss function due to downtime or excess capacity utilization;

$$q(y) = b(u_r - (x^{\min} + y - z)) \text{, if } u_r \geq x^{\min} + y - z \text{;}$$

$$q(y) = c(x^{\min} + y - z - u_r) \text{, if } u_r \leq x^{\min} + y - z \text{;}$$

$b$ – loss value per unit of production caused by downtime;

$c$ - the loss value of per unit of production due to excess capacity utilization;

$d$ - the value of profit from the production and sale of a unit of production, taking into account surcharges to staff for excess work;

$d(x - y)$ - the amount of losses (lost profits) from the underproduction of products in the presence of demand.

On the value of the operative effect $E = E(n)$ is affected by the statistical characteristics of a random variable $\eta(n)$ of the total volume of orders for the operative period of duration $n$. In particular, the value $\eta(n)$ determines a random value $x$ of the possible volume of additional orders. The initial information about the probability distribution function of a random variable $\eta(n)$ is contained in the statistics of enterprises on the volumes $\xi_1, \xi_2, ... \xi_M$ of orders for its products, which were received in each unit time interval over a period of time $M$. These values can be considered as realizations of a random variable $\xi$ of demand intensity at time intervals 1, 2, ... $M$. We will find the statistical characteristics of the value $\xi$, assuming that they do not change with time.

Denote by $\xi^{\min}, \xi^{\max}$ minimum and maximum values implementations of intensity $\xi_1, \xi_2, ... \xi_M$. We will distribute the volume of orders for unit time intervals by $R$ intensity levels. To do this, let us divide the interval possible values of demand intensities $[\xi^{\min}, \xi^{\max}]$, for an odd amount $R$ equal in size component intervals $[h_{r-1}, h_r)$ ($r = 1, 2, ... R-1$), $[h_{R-1}, h_R]$ so that $h_r = h_{r-1} + \Delta h$ ($r = 1, 2, ... R$), where $\Delta h$ - the size of each interval $r$, $\Delta h = \dfrac{\xi^{\max} - \xi^{\min}}{R}$. We introduce the following notation:

$M_r$ - the lots of numbers of such unit time intervals at which the orders volumes $\xi_m$ corresponded to the level $r$ of intensity:

$m \in M_r$ if $\xi_m \in [h_{r-1}, h_r)$; $m \in M_R$ if $\xi_m \in [h_{R-1}, h_R]$;

$m_r$ - the amount of elements forming a set $M_r$, $\sum_{r=1}^{R} m_r = M$.

We will interpret the quantity $p_r = \dfrac{m_r}{M}$ as the probability that the demand intensity corresponds to the level $r$. We will further consider the quantity $\xi$ of demand intensity as a discrete random variable that takes $R$ possible values $\bar{h}_r = \dfrac{h_{r-1} + h_r}{2} = (r-1)\Delta h + \dfrac{\Delta h}{2} = (2r-1)\dfrac{\Delta h}{2}$ $(r = 1, 2, ... R)$ with probabilities respectively $p_r = P\{\xi = \bar{h}_r\}$. Function $f_\xi(z)$ such that $f_\xi(z = \bar{h}_r) = p_r$ ($r = 1, 2, ... R$), we will call the probability density of a discrete quantity $\xi$.

In [13], an algorithm for calculating the probability density of the sum of several random discrete quantities given by their probability densities is proposed. His can be used to find the probability density $\eta(n) = \sum_{i=1}^{n} \xi_i$ for a given probability density for value $\xi$ demand intensity. The idea of such an algorithm is as follows. Each summand $\xi_i$ of magnitude $\eta(n)$ is considered as a source $i$ of receipt of orders with volumes $\bar{h}_{ri}$ and probabilities $p_{ri}$, $r = 1, 2, ... R$. The pair $s_i = (\bar{h}_{ri}, p_{ri})$ determines the state of the source $i$, and the vector $s = (s_i, i = 1, 2, ... n)$ - determines the state of the entire set of $n$ sources. The totality of all vectors $s$ corresponds to the set of mutually exclusive events for the time interval $n$. In this case, the state vector $s$ uniquely determines the total volume of orders for the time interval $n$ and its probability, which correspond to the level of the value of $\eta(n)$ and its probability.

If as the periods for collecting orders and production, intervals with a unit duration are selected, then, due to the uneven demand, the $\xi_1, \xi_2, ... \xi_n$ values will differ from the enterprise's productivity, both in large and in the smaller side. If the company chooses a period of order collection $n$ times larger and sets production volumes equal to the average demand intensity $\bar{x}(n) = \dfrac{1}{n}\sum_{i=1}^{n} \xi_i$, deviations of order volumes from productivity $\mu$ will be mutually compensated, and losses due to uneven demand will decrease:

$$\sum_{i=1}^{n} |\xi_i - \lambda| \geq |\sum_{i=1}^{n} (\xi_i - \lambda)| = |\sum_{i=1}^{n} \xi_i - n\lambda|.$$

Since the quantities $\xi_i$ $(i = 1.2, ... n)$ are realizations of the random variable $\xi$, the quantity $\bar{x}(n)$ turns out to be the realization of the random variable $\chi = \chi(n) = \dfrac{1}{n}\eta(n)$, where $\eta(n) = \sum_{i=1}^{n} \xi_i$ - random variable of sum of random variables $\xi_i$ $(i = 1.2, ... n)$, which have the same distribution laws with $\xi$.

It is known from probability theory that

$$M[\eta(n)] = \sum_{i=1}^{n} M[\xi_i] = n\lambda,$$

$$M[\chi(n)] = M[\frac{1}{n}\eta(n)] = \frac{1}{n} M[\eta(n)] = \lambda,$$

$$D[\eta(n)] = \sum_{i=1}^{n} D[\xi_i] = nD[\xi],$$

$$D[\chi(n)] = D[\frac{1}{n}\eta(n)] = \frac{1}{n^2} D[\eta(n)] = \frac{1}{n} D[\xi],$$

where the symbols $M[...], D[...]$ denote the mathematical expectation and variance of random variables. Thus, operative planning with a period $n$ is equivalent from the point of view of statistics to operative planning with a unit period at demand intensity determined by a random variable $\chi(n)$, the variance of which is $n$ times smaller than the variance of a random variable $\xi$.

To assess the effectiveness of various operative planning policies, we will use indicator $\zeta$ of the marginal effectiveness of operative activity,

$$\zeta = \lim_{T\to\infty} \frac{1}{T} \sum_{t=1}^{T} \frac{E_t(n)}{d\lambda},$$

where $E_t$, $t = 1, 2, ... T$, - effects for unit periods of time $t = 1, 2, ... T$, with a duration $n$ of the operative planning period. Since it is assumed that $\lambda = \mu$,, the value of $d\lambda$

determines the profit corresponding to the normative productivity of enterprise $\mu$. We will use the lower index $t$ to denote the values that change over periods of $t$.

## III. The effectiveness of operative planning policies

In practice, the following operative planning policies are most common: rational execution of orders, production with constant intensity and planning of production volumes with a forecast of future orders. In accordance with the policy of rational execution of orders, the volume of production $u$ for the current operative period of time is chosen equal to the volume $x^{\min}$ of orders received. Therefore, $y=0$, $x=0$, residues $z$ of finished products at the beginning of planning are absent, $z=0$, $y^{\Sigma}=x^{\min}$, $q(y)=q=\max\{b(\lambda n-x^{\min}),c(x^{\min}-\lambda n)\}$. We denote by $T^{-}$ the number of such unit time periods $t$, $t\in\{1,2,...T\}$, for which $\mu-v_t\le 0$, $q_t^o=c(v_t-\lambda)$, and by $T^{+}$ the number of unit time periods $t$, in which $\mu-v_t\ge 0$, $q_t^o=b(\lambda-v_t)$, where $v_t=\frac{1}{n}x_t^{\min}$, $q_t^o$ are the losses of $q$ per unit time period $t$,

$$T^{-}+T^{+}=T\,,\ T^{-}=T^{-}(T)\,,\ T^{+}=T^{+}(T)\,.$$

Given that $v_t$ is a realization of a random variable $\chi(n)$, and also that

$$\lim_{T\to\infty}\frac{1}{T}\sum_{t=1}^{T}v_t=M[\chi(n)]=\lambda,$$

$$\lim_{T\to\infty}\frac{T^{-}(T)}{T}=P\{\lambda\le\chi(n)\}=P^*,$$

$$\lim_{T\to\infty}\frac{T^{+}(T)}{T}=P\{\lambda\ge\chi(n)\}=1-P^*,$$

we get, that $\zeta=\frac{1}{d\lambda}\lim_{T\to\infty}\frac{1}{T}\sum_{t=1}^{T}(dv_t-q_t^o)=1-S_1-S_2$, where

$$S_1=\frac{c}{d\lambda}\lim_{T\to\infty}\frac{1}{T}\sum_{t=1}^{T^{-}}(v_t-\lambda)=\frac{c}{d\lambda}P^*(\rho^{+}-\lambda),$$

$$S_2=\frac{b}{d\lambda}\lim_{T\to\infty}\frac{1}{T}\sum_{t=1}^{T^{+}}(\lambda-v_t)=\frac{b}{d\lambda}(1-P^*)(\lambda-\rho^{-}),$$

$\rho^{+}$ is the mathematical expectation of a random variable $\chi(n)$ provided that it falls on the interval $[\lambda,\xi^{\max}]$ of intensity implementations $\xi$, $\rho^{+}=\sum_{r=m}^{R}p_r\bar{h}_r$, $\rho^{-}$ is the mathematical expectation of a random variable $\chi(n)$ provided that it falls on the interval $[\xi^{\min},\lambda]$ of intensity realizations $\xi$, $\rho^{-}=\sum_{r=1}^{m}p_r\bar{h}_r$, $\bar{h}_m=\lambda$. Then

$$\zeta=1-\frac{1}{d\lambda}(cP^*(\rho^{+}-\lambda)+b(1-P^*)(\lambda-\rho^{-}))$$

If the probability density of a quantity $\chi(n)$ is a symmetric function with respect to its mathematical expectation $\lambda$, then $P^*=0{,}5$, $\rho^{-}+\rho^{+}=2\lambda$. In this case,

$$\zeta=1-\frac{\lambda-\rho^{-}}{2d\lambda}(b+c)\qquad(5)$$

It was shown in [14, 15] that with an increase in the duration $n$ of the operative period, the conditional expectation $\rho^{-}$ of a random variable $\chi(n)$ increases to a value $\lambda$. At the same time, the value of the efficiency indicator $\zeta$ increases to 1. It can also be seen from formula (5) that with an increase in indicators $b,c$ of unit costs from 0 to $d$, the indicator $\zeta$ of marginal efficiency decreases.

In the case of applying a production policy with constant intensity, the production volume $u$ for the operative period of time is determined by the formula $u=\min\{x^{\min},u_r\}$. So, $y=0$, $z=0$,

$$y^{\Sigma}=u=\min\{x^{\min},u_r\},q(y)=q_b=b(u_r-x^{\min}),q_t^o=b(\lambda-v_t)$$

$$E_t=d\lambda-d(v_t-\lambda),\ \text{if}\ \lambda\le v_t,$$

$$E_t=dv_t-b(\lambda-v_t),\ \text{if}\ \lambda\ge v_t.$$

Then $\zeta=Q_1+Q_2$, where

$$Q_1=\lim_{T\to\infty}\frac{1}{T}\sum_{t=1}^{T^{-}}\frac{d\lambda-d(v_t-\lambda)}{d\lambda}=P^*-\frac{1}{\lambda}\lim_{T\to\infty}\frac{1}{T}\sum_{t=1}^{T^{-}}(v_t-\lambda)=$$

$$=P^*(1-\frac{\rho^{+}-\lambda}{\lambda})$$

$$Q_2=\lim_{T\to\infty}\frac{1}{T}\sum_{t=1}^{T^{+}}\frac{dv_t-b(\lambda-v_t)}{d\lambda}=(1-P^*)(1-\frac{b(\lambda-\rho^{-})}{d\lambda}),$$

$$\zeta=1-P^*\frac{\rho^{+}-\lambda}{\lambda}-(1-P^*)\frac{b(\lambda-\rho^{-})}{d\lambda}.$$

If $P^*=0{,}5$, $\rho^{-}+\rho^{+}=2\lambda$, then

$$\zeta=1-\frac{1}{2\lambda}(\rho^{+}-\lambda+\frac{b(\lambda-\rho^{-})}{d})=1-\frac{\lambda-\rho^{-}}{2d\lambda}(b+d)$$

Since $d>c$, then in the case of a production policy with constant intensity, the value of the efficiency indicator $\zeta$ is lower than its value in the policy of rational execution of orders. This is due to loss of profits that accompany production with constant intensity.

When planning production with a forecast of the volume of future orders, the quantity of finished products intended to satisfy additional incoming orders is selected.

We denote by $w_k$, $k=1,2...K$, the forecasted volumes of additional orders and by $p_k$, $k=1,2...K$, the probabilities of the receipt of additional orders in these volumes, which correspond to the probability density of a random variable $\eta(n)-x^{\min}$. The dependence of the expected effect $E=E(n)$, obtained at the end of the operative period of duration $n$, on the planned additional quantity $y$ of finished products is determined by the function $G(y)=\sum_{k=1}^{K} G(w_k, y)$, where $G(w_k, y)$ is a component of the expected effect, corresponding to the volume $w_k$ of additional orders, $G(w_k, y) = p_k f(w_k, y)$, and the function $f(w_k, y)$ is determined by formulas (1)-(4). The optimal quantity $y^*$ of finished products intended to satisfy additionally incoming orders is selected from the condition: $G(y^*) = \max\{G(y) \mid y = w_1, w_2, ...w_K\}$.

It should be noted that the managers performance evaluation systems existing at most enterprises do not create their interest in choosing the volume of finished products in excess of the guaranteed value $x^{\min}$ of demand. This is explained by the fact that losses from underproduction of $y < x$ are considered at enterprises as virtual, since they are not related to the registration of cash flows. At the same time, the risks of overproduction of $y > x$ are real, since they cause additional costs for storage facilities and the "freezing" of spent money. Let us designate as $H_{-w}^{\Sigma}(y)$, $H_{+w}^{\Sigma}(y)$ the expected losses from the overproduction of products and the expected profit from the implementation of possible orders when choosing finished products in the volume $y$,

$$H_{-w}^{\Sigma}(y)=\sum_{k=0}^{k(y)} H_{-w}(w_k, y), H_{+w}^{\Sigma}(y)=d\sum_{k=0}^{k(y)} p_k w_k ,$$

where $w_{k(y)} = y$, $H_{-w}(w_k, y) = p_k(d(y-w_k)+q(y))$.

A survey of managers of a number of enterprises showed that the following indicators have the main influence on their assessment of the acceptability of risks when choosing the value of finished products:

risk coefficient $R = R(y)$, which is the ratio of the value $H_{-w}^{\Sigma}(y)$ of the expected losses to the expected value $H_{+w}^{\Sigma}(y)$ of profit, $R=\frac{H_{-w}^{\Sigma}(y)}{H_{+w}^{\Sigma}(y)}$:

the probability $P_L = P_L(y)$ of losses from overproduction of products arising in connection with the realization of demand in the volume $w_k$, which is less than the value $y = w_{k(y)}$ of the finished product, $P_L = \sum_{k=0}^{k(y)} p_k$.

Therefore, the risks that arise when choosing the volume $y$ of finished products are acceptable if the following conditions are met: $R(y) \le R^{\max}$, $P_L(y) \le P_L^{\max}$, where $R^{\max}$, $P_L^{\max}$ are the maximum permissible values of the risk coefficient $R$ and the probability of losses $P_L$.

If the set $Y$ of volumes of finished products acceptable from the point of view of risk consists of a single value $y$, then this value of the finished products should be planned for the current operating period of time. If the set $Y$ is empty, then the value of $y$ should be set equal to zero. If it turns out that the set $Y$ includes several elements, then it is necessary to choose a value $y^0 \in Y$ of the finished product that corresponds to the maximum expected total effect $G^{\Sigma}(y)$.

Production planning with a forecast of future demand helps reduce downtime losses by completing additional orders that would have to be received in a future time period following the period in question. In addition, with such a policy of operative planning, the intensity of profit receipt increases, the average lead time decreases, which increases the competitiveness of the enterprise. However, with operative planning with a forecast, the risks of current overproduction arise, and the economic results of operating activities depend on the attitude of managers to risks.

## IV. Conclusion

In the event of random fluctuations in the current demand for the company's products in the short-term periods of time, risks of losses arise, which depend on decisions made during operational planning. A model of the planning situation is developed for the case when the volume of orders for products for one period of time is described by a random variable with stationary statistical characteristics. It was proposed to evaluate the effectiveness of decisions made during operational planning by an indicator of the average economic effect per unit of time over an infinite time interval. The model of the planning situation was used for a comparative analysis of the effectiveness of operational planning policies based on the rational execution of orders received, production with constant intensity and planning of production volumes with a forecast of future orders. It is shown that operative planning with a forecast has advantages, despite the risks of ongoing overproduction.

## References


[1] Kumar, Rakesh and Srivastava, Samir K (2014)“"A Framework for Improving 'Sales & Operations Planning", Metamorphosis, 13(1), 2014, pp.16-25.

[2] Dunkan, Alexander (2013)“S&OP and Strategy – Building the Bridge and Making the Process Stick”. Journal of Business Forecasting, Spring 2013, 32, pp.16 – 28.

[3] Larry Lapide "Sales and Operations Planning Part I, The Process". Access mode: Sales and Operations Planning Part I: The Process pdf.

[4] Chen, Y. F., Z. Drezner, J. K. Ryan and D. Simchi-Levi (2000), “Quantifying the Bullwhip Effect in a Simple Supply Chain: The Impact of Forecasting, Lead Times and Information”. Management Science, 46, pp. 436–443.

[5] Aloini D., Dulmin R, Mininno V. (2007) "Risk Management in ERP Project Introduction: Review of the Literature". Information & Management., 44(6)., pp. 547-567.

[6] Menon, S.A.; Muchnick, M.; Butler, C.; Pizur, T. (2019). "Critical Challenges in Enterprise Resource Planning (ERP) Implementation". International Journal of Business and Management. 14 (7) pp. 54–69.

[7] Menon, Sreekumar (2019). "Benefits and Process Improvements for ERP Implementation: Results from an Exploratory Case Study". International Business Research. 12(8): 124–132.

[8] Pelphrey, M.W. (2015). "Directing the ERP Implementation: A Best Practice Guide to Avoiding Program Failure Traps While Tuning System Performance". CRC Press. pp. 92–111.

[9] E.V. Afanasev, (). “Ekonomiko-matematychne modeliuvannia ryzyku velykykh promyslovykh pidpryiemstv z monoproduktovym vyrobnytstvom [Economic and mathematical modeling of risk of

large industrial enterprises with monoproduction production]". *Dnipropetrovsk: Nauka i osvita*, 230 p., 2005. (in Ukrainian).

[10] V.V.Vitlinskiy, V.V. Velikoivanenko "Ryzykolohiia v ekonomitsi ta pidpryiemnytstvi [Risks in economics and entrepreneurship]" *Kiev: KNEU*, p. 480, 2004 . (in Ukrainian).

[11] "Matematychni metody i modeli rynkovoi ekonomiky[Mathematical methods and models of market economy*]" Kh .: VD "INZHEK*", 456 p., 2010. . (in Ukrainian).

[12] M.S. Syavavko "Optymizatsiini modeli vyrobnychoi prohramy pidpryiemstva za umov nevyznachenosti [Optimization models of the production program of the enterprise under conditions of uncertainty]" *Economic Cybernetics*. 21-2 (31-32), pp. 27-40, 2005/. (in Ukrainian).

[13] V.Ia. Zaruba "Optimizatsiia planov proizvodstva po otsenkam veroiatnosti budushchikh zakazov [Optimisation of plans of manufacture by estimations of probability of the future orders]", Marketing and Management of Innovations, 2, pp. 222-232, 2017. . (in Russian).

[14] V. Ia Zaruba. "Optimization of the duration of collection of orders on the enterprise's products" Innovative management: theoretical, methodical, and applied grounds *Prague Institute for Qualification Enhancement: Prague*, 2018, ISBN 978–80-906210-1-5, pp.76 - 82.

[15] V.Y. Zaruba, I.A. Parfentenko "Modeli pohodzhuvannia vyrobnychykh resursiv pidpryiemstva z potochnym popytom na produktsiiu [Models of coordination of production resources of the enterprise with the current demand for products]", *Bratislava-Kharkov, GSEM – KhNEU*, ISBN 978–80-89654-45-1. pp. 469-481p., 2018. /. (in Ukrainian)