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FORMS OF ORGANIZATION OF PRODUCTION ACTIVITY OF ENTERPRISES IN TERMS OF PROBABILISTIC NATURE OF DEMAND

Purpose. To develop models describing forms of organization of production activity in terms of probabilistic nature of demand and determine their being effected by strategies of marketing interaction with the product consumers.

Methodology. The theoretical models were based on classic models of mass service, methods of sales planning, and studies on rational strategies of marketing interaction of a consumer of limited-demand products, the need in which is of probabilistic nature. Such parameters as maximum (peak) involved production capacity and maximum warehouse capacity required in terms of predicted production volumes are taken as the criterion of effect of a strategy of the manufacturer-consumer marketing interaction.

Findings. Certain dependences have been obtained making it possible to calculate the maximum (peak) involved production capacity depending on the predicted production volume, warehouse capacity, and organization of production activity of an enterprise. It has been shown that the organization of marketing interaction between a manufacturer and a consumer of limited-demand products, the need in which is of probabilistic nature, on the basis of marketing partnership strategy helps reduce considerably the peak loads of production facilities and warehouse capacity, which is necessary to maintain production activity of an enterprise.

Originality. On the basis of a mass service theory, a form of organization of production activity of an enterprise is substantiated that manufactures goods of differentiated need and limited demand of probabilistic nature. It has been proved that a current marketing strategy of interaction between a manufacturer and consumer of such a product influences considerably the organization of production activity of an enterprise-manufacturer. A form of organization of production activity of an enterprise has been substantiated; in terms of organization of interaction with a consumer on the basis of marketing partnership relations, it helps reduce significantly the peak loads of production facilities and the involved warehouse capacity to store ready-made products.

Practical value. The obtained results can be applied to plan the forms of organization of production activity of an enterprise that manufactures limited-demand products, the need in which is of differentiated nature, and to substantiate rational marketing interaction with a consumer of such kind of product.

Keywords: *random nature of ordering, probabilistic models, peak loads, warehouse capacity, marketing strategies*

Introduction. In terms of current external environment, activity of different enterprises is being influenced by both objective and subjective factors occurring due to the instable market and random nature of demand for products. As Mohammad Azadfallah (2017) proves in his works, turbulence, inconstancy, and uncertainty are the specific features of modern business environment. Such environment influences especially negatively the enterprises manufacturing products, the demand for which is of differentiated nature. Such enterprises become especially vulnerable due to fluctuations of current demand for their products; their burning problem is to adjust somehow their manufacturing activity to current conditions of their interaction with main orderers.

The represented problem is characteristic for industrial enterprises of machine-building industry of Ukraine. The Ukrainian economy is experiencing its transformation towards the change in the forms of industrial activity organization basing on the western practices, i.e. retreat from a bureaucratic form of production organization to a subject-specialized form, including the ones oriented to the peculiarities of marketing interaction with their business partners, first of all with product customers. In terms of such approaches, subject-specialized enterprises are capable of ensuring the production of wide and deep assortment, being typical but differentiated as for qualimetric characteristics, i.e. they can meet individualized demand in the industrial market. However, individualization in satisfying the demands requires searching for such forms of organization of production activity that meet to the full extent the marketing forms of interaction with customers of restricted consumption goods, the need in which is of differentiated nature. Such marketing forms should be based on the equally beneficial interrelations of all the partners of a demand and supply channel; first of all, we mean end consumers of goods.

Literature review. Theoretical studies of foreign scientists concerning the provision of stable production activity of an enterprise are focused, fist of all, on the problems of business organization. Their works prove that this is one of the marketing activity forms, and forms of organizations are evolving along with the transformations of external environment [1, 2]. Dynamism of market changes, current demand for goods produced by technologically specialized enterprises, and orientation to the individualized demand of the consumers of technically advanced products make enterprises pay more attention to the organization of activities in the medium of network structured, comparing with the issues of internal business organization of a company. It is highlighted that the selection of a rational form of organization of company interaction within the network structures depends on the degree of interconsistency of their goals and degree of uncertainty of market situation [3, 4]. Studies of national scientists concerning that problem are focused mainly on the aspects of logistic interaction [5, 6]. At the same time, there are no studies on the effect of the forms of organization of company interactions and selection of a rational form of production activity depending on the forms of organization of interaction between a manufacturer and a consumer of the product, the need in which is of differentiated character.

Modern classification of marketing forms of organization of enterprise activity in the network structures makes it possible to divide them in less detail into two key groups – the ones established on the basis of transactional approach and the ones relying on partnership relations. The first approach is based on the implementation of one-time operations like sales, exchanges and so on with other partners. It is aimed at minimizing operational costs to achieve competitive advantages [7]. The second approach is aimed at medium-term and long-term relations, for which transactional interaction is just a component of the interaction between companies. At the same time, the effect of marketing forms of organization of enterprise activity within the network structures on the production activity of an enterprise is quite considerable.

One of the tendencies in formalization of a process of searching for rational forms of interaction is the use of analytical models, in terms of which it is possible to single out conditionally two main types. One group of models describes a process of interaction from the viewpoint of readiness to interact and coordinate the interactions [8]. However, those models are described by general mathematical equations that do not allow calculating the parameters accompanying production activity of an enterprise. Another group of models involves determination of the optimal size of order, fixed interval between orders, and specified periodicity up to a certain level. These models are used by national scientists to substantiate the approaches to logistic management. However, a series of studies proves that consideration of the organization of enterprise interaction only from the logistic viewpoints makes it impossible to apply rational methods of the organization of production activity of an enterprise.

It should be noted that the considered analytical models, proposed to identify rational forms of the organization of enterprise interaction, are determined; they do not take into account the available random component of the arisen demand for products. As the performed research shows, [9] such a random component in a consumer of the product, the need in which is of differentiated nature, influences considerably his/her activity; and organization of interaction with a manufacturer/supplier of such a product, taking into consideration the random nature of the need in it, allows reducing risks as for the provision of rhythmical production activity of an enterprise and improvement of the interaction logistics.

Unsolved aspects of the problem. Summing up the aforesaid, it can be concluded that nowadays there are no models, which help manufacturers of goods, the need in which is of differentiated nature, take into account and organize reasonably their production activity, basing on the features of demand and marketing strategies of their interactions with consumers.

Solution of this issue is a constituent part of a problem dealing with the substantiation of a rational strategy of an enterprise in terms of unstable market and random nature of orders for its product.

Purpose. The objective of the research is to develop a model of the organization of activity of a company manufacturing goods, the need in which is of differentiated nature with a considerable random component in the volume of orders.

Methods. A research methodology is based on a model of consumption of goods, the need in which is of differentiated nature, and described with the help of Poisson law [9]. Such a consumer need in the goods also determines the random nature of ordering from the consumers of a product to its manufacturers.

That has helped describe a model of the production organization by Erlang equations and modified Erlang equations depending on the stiffness of terms of the orders being received by an enterprise-manufacturer of the goods, the need in which is of differentiated nature, taking into account capacity of its finished goods warehouse and product stock.

The final research stage involves analysis of the effect of marketing strategy of interaction between a manufacturer and a consumer of the product, the need in which is of differentiated nature, on the production activity of an enterprise-manufacturer due to workload of production facilities and maximum required warehouse capacity.

Statement of the basic material of the research. To formulate a strategy of interaction of the enterprises manufacturing products, the need in which is of differentiated nature, it is necessary to take into consideration complexity of evaluation and identification of attributes of goods for a manufacturer and complexity of the evaluation of goods amount for a consumer, being stipulated by multifactority of the influence. Since a consumer need in differentiated goods is of probabilistic nature and evaluation of the goods amount is performed on the basis of long-term plans, the manufacturer-consumer interaction may be flexible [9]. Such a situation influences the internal activity of an enterprise-manufacturer, including the production one.

Forms of organization of production activity of an enterprise manufacturing a product, the need in which is of differentiated nature, influence both peculiarities of the formation of demand for their goods and a form of manufacturer-consumer interaction. The results of such studies for consumers of expendables and component parts were represented in [9]; thus, it is expedient to analyze the effect of features of the formation of demand for that product and organization of marketing manufacturer-consumer interaction on the production activity of an enterprise-manufacturer of the goods, the need in which is of differentiated nature.

According to [9], due to sudden failure of a tool, the arising need in such a tool is of sudden nature as well, which is described by the simplest flow of events or Poisson flow.

The research mentioned above also shows that a production batch to be supplied per transaction Δ_m is determined by the density of flow of need in the corresponding product of consumer z and duration of one-time transaction T_m.

That helps represent an order for supply of expendables as the simplest Poisson flow as well, which is described in terms of distribution density $f_\lambda(t)$

$$f_\lambda(t) = \lambda \cdot e^{-\lambda \cdot t},$$

where λ is parameter of an exponential rule of distribution or density of ordering flow from one of the consumers of a nomenclature position of an expendable tool.

Density of the ordering flow may be calculated as follows

$$\lambda = \frac{z}{\Delta_m}.$$

Each consumer of expendable tools forms his/her own ordering flow, which generally has not only different density but also different volumes of batches being supplied. Thus, comparative analysis of different forms of organization of marketing interactions between a manufacturer and consumer of expendable tools as well as their effect on the organization of production will be considered with the average weighted ordering flows.

Consequently, in terms of the available n consumers with annual planned (predicted) consumption of expendable tools, $Z_1, \ldots, Z_i, \ldots, Z_n$ respectively and while analyzing marketing strategies, we will assume that we have n consumers with different planned (predicted) consumption of expendable tools Z

$$Z = \frac{\sum_{i=1}^{n} Z_i}{n}.$$

This year, general flow of events can be represented as the simplest Poisson flow, being described in terms of distribution density $f_\Lambda(t)$

$$f_\Lambda(t) = \Lambda \cdot e^{-\Lambda \cdot t};$$

$$\Lambda = n \cdot \lambda.$$

We will think that those are regular clients, i.e. they purchase all the required volume of expendable tools right at the specified manufacturer (supplier).

In terms of transactional form of marketing, two main forms of production organization are possible – "make-to-order" or "make-to-stock" with further formation of production batches according to orders.

Consider a strategy of production of expendable parts "make-to-order", i.e. articles of the specified nomenclature position being ordered are manufactured. Such a production strategy in terms of transaction-based marketing, provides minimum capital stagnation, i.e. it minimizes the circulating funds.

The possibility of parallel fulfilment of orders is determined by the number of production lines organized at an enterprise for their processing. Maximum annual production capacity in terms of nomenclature position V_B is possible when all the production lines, capable of manufacturing this nomenclature unit, are set for its manufacturing. Let us assume that their number is $n_{\max}$. Then production capacity of one line v_B is VB

$$v_B = \frac{VB}{n_{max}},$$

and mathematical expectation of the time of one order fulfilment by one line $M[T_f]$ is

$$M\left[T_f\right] = T_p \cdot \frac{\Delta_m}{v_v},$$

where T_p is annual volume of working time (days), and time for fulfilling one order is described in the systems of mass service in terms of distribution density $f_{T_f}(t)$ [8]

$$f_{T_f}(t) = \mu \cdot e^{-\mu \cdot t},$$

where μ is parameter of an exponential rule being equal to

$$\mu = \frac{1}{M[T_f]}. \qquad (1)$$

The main problem to be solved is determination of the number of production lines which should be involved for manufacturing a nomenclature unit to provide the fulfilment of ordering flow in terms of flow density Λ. During the order intake, the order, in case of available free production facilities, is taken to be fulfilled at once. If there are no free facilities, it can be queued up or declined.

In terms of transaction-based marketing strategy, time for order fulfilment is stipulated by both competitive terms of one-time transaction T_m and possibilities of production as for order fulfilment, but it should be as follows

$$T_m > M[T_f]. \qquad (2)$$

We should note as a remark for (2) that if the order production according to (2) cannot be physically provided by one line, then it should be fulfilled by several lines in parallel. Assume that the minimum number of physical lines, whose parallel operation for one order is minimally sufficient to meet condition (2), is equal to a lines. Then, we can assume that a physical line is one virtual production line; and the maximum number of such virtual lines $n_{\max}$ in terms of the available maximum number of physical lines $n_{\max\_ph}$ may be determined as $n = n_{\max\_ph}/a_{\max}$.

Thus, we can assume that condition (2) is always met. When in (1) the time of one-time transaction T_m is close to $M[T_f]$, we can take an order only in case when one of production lines is free. In this case, the state of the system can be described by the system of differential equations – Erlang equations. In our case, they are as follows

$$\begin{cases} \dfrac{dp_0(t)}{dt} = -\Lambda \cdot p_0(t) + \mu \cdot p_0(t) \\ \dfrac{dp_i(t)}{dt} = -\Lambda \cdot p_{i-1}(t) - (\Lambda + i \cdot \mu) \cdot p_i(t) + (i+1) \cdot \mu \cdot p_{i+1}(t), \\ \dfrac{dp_n(t)}{dt} = \Lambda \cdot p_{n-1}(t) - n \cdot \mu \cdot p_n(t) \end{cases} \qquad (3)$$

$p_0(t), p_1(_t), \ldots, p_i(t), \ldots, p_n(t)$ are probabilities of the system state when none of the lines, one line, two lines, i lines, or even n lines are engaged. Note that $0 < i < n$, a $1 \le n \le n_{\max}$.

Most often, transaction time T_m is considerably greater that the time for one order fulfilment by one line $M[T_f]$, and we have general time reserve to fulfil the order taken in terms of all n lines being engaged.

Following considerations can help evaluate the time and, respectively, possibility to postpone the orders for their later fulfilment in terms of preserved general duration of transaction relations.

To maintain the duration of transaction relations, it is necessary that after being taken, the order would be sent for production per time period τ_{pv} that can be evaluated according to the formula

$$\tau_{pv} = T_t - M[T_f]. \qquad (4)$$

The probability that more than k events will happen during that time – completion of current orders production in terms of k production lines $P_{\ge k}(\tau_{pv})$ will be as follows

$$\begin{aligned} P_{\ge k}(\tau_{pv}) &= \sum_{i=k}^{\infty} \frac{\left(n \cdot \mu \cdot \tau_{pv}\right)^i}{i!} \cdot e^{-n \cdot \mu \cdot \tau_{pv}} = 1 - P_{<k}(\tau_{pv}) = \\ &= 1 - \sum_{i=0}^{k-1} \frac{(n \cdot \mu \cdot \tau_{pv})^i}{i!} \cdot e^{-n \cdot \mu \cdot \tau_{pv}}, \end{aligned} \qquad (5)$$

where $P_{<k}(\tau_{pv})$ is probability of the fact that production of current orders will be completed in terms of less than k production lines per time period τ_{pv}.

Maximum queue length can be determined, having preset preliminarily $P_{z \ge k}(\tau_{pv})$, e.g. 0.95 or 95 %, or 0.9 or 90 %, by simple sorting k from 0 to n until the following inequality is met

$$P_{z \ge k}(\tau_{pv}) \ge P_{\ge k}(\tau_{pv}).$$

In case of maximum queue length of orders, which is admissible and equal to k, a system can be described by the modified Erlang equations

$$\begin{cases} \dfrac{dp_0(t)}{dt} = -\Lambda \cdot p_0(t) + \mu \cdot p_0\left(t\right) \\ \dfrac{dp_i(t)}{dt} = -\Lambda \cdot p_{i-1}(t) - \left(\Lambda + i \cdot \mu\right) \cdot p_i(t) + \left(i+1\right) \cdot \mu \cdot p_{i+1}(t) \\ \qquad \left(1 \le i \le n-1\right) \\ \dfrac{dp_n(t)}{dt} = \Lambda \cdot p_{n-1}(t) - \left(\Lambda + n \cdot \mu\right) \cdot p_n(t) + n \cdot \mu \cdot p_{n+1}(t) \\ \dfrac{dp_{n+j}(t)}{dt} = \Lambda \cdot p_{n+j-1}(t) - \left(\Lambda + n \cdot \mu\right) \cdot p_{n+j}(t) + n \cdot \mu \cdot p_{n+j+1}(t) \\ \qquad \left(1 \le j \le k\right) \\ \dfrac{dp_{n+k}(t)}{dt} = \Lambda \cdot p_{n+k-1}(t) - n \cdot \mu \cdot p_{n+k}(t) \end{cases}. \qquad (6)$$

Note that if $k = 0$, i. e. in terms of zero admissible queue length of orders, system (6) is transformed into system (3).

Thus, it is enough to consider system (6). Solution of that system together with the condition

$$\sum_{i=0}^{n+k} p_i = 1,$$

results in [8]

$$p_i = \frac{\dfrac{\alpha^i}{i!}}{\displaystyle\sum_{l=0}^{n} \frac{\alpha^l}{l!} + \frac{\alpha^n}{n!} \cdot \sum_{l=1}^{k} \left(\frac{\alpha}{n}\right)^l}, \quad (0 \le i \le n), \qquad (7)$$

and in case of $i = n + j$ $(j \ge 0)$

$$p_{n+j} = \frac{\dfrac{\alpha^{n+j}}{n! \cdot n^j}}{\displaystyle\sum_{l=0}^{n} \frac{\alpha^l}{l!} + \frac{\alpha^n}{n!} \cdot \sum_{l=1}^{k} \left(\frac{\alpha}{n}\right)^l}, \quad \left(1 \le j \le k\right).$$

Here, α is reduced density of an ordering flow

$$\alpha = \frac{\Lambda}{\mu}.$$

Proceed immediately to a methodology for determining the number of production lines n to be involved in the manufacturing of a nomenclature unit of a product to provide fulfilment of the ordering flow with ordering density Λ.

It is known that probability of the fact that the order will be declined for a system of mass service with the limited queue length is determined by the probability of the state of a system with maximum queue length, i.e. p_{n+k} [10]

$$p_{n+k} = \frac{\dfrac{\alpha^{n+k}}{n! \cdot n^k}}{\sum_{l=0}^{n} \dfrac{\alpha^l}{l!} + \dfrac{\alpha^n}{n!} \cdot \sum_{l=1}^{k} \left(\dfrac{\alpha}{n}\right)^l}.$$

It means that first we need to identify numerical value p_{n+k}. Actually, p_{n+k} defines a degree of risk that the next order will not be fulfilled. Thus, to solve that problem, we should determine a degree of risk for the order to be declined of untimely fulfilment p_{on+k}.

If p_{on+k} is known, determination of the number of production lines n required to be involved to fulfil the predicted number of orders can be defined according to the following algorithm.

1. Define preliminarily the minimum number of production lines n to be involved to fulfil the predicted number of orders in terms of their complete load

$$n = \frac{\Delta_m}{v_v} \cdot \Lambda \cdot T_p.$$

2. Calculate maximum queue length k as it was mentioned before ((4, 5) and comments to them).

3. Determine p_{n+k} according to (4) and compare it with $p_{(n+k)}$. If $p_{n+k} > p_{on+k}$, then increase n by a unit, i.e. $n = n + 1$, and move on to the second point of the algorithm. In other case, n is the amount of working lines to be determined.

4. If $n > n_{\max}$, then we conclude that in terms of current organization of production, it is impossible to fulfil the planned volume production of a nomenclature unit.

Maximum production capacity required to fulfil the orders in terms of company strategy "make-to-order" calculated as the annual production volume $V_{v\_pz\max}$ can be calculated according to the formula

$$V_{v\_pz\max} = v_v \cdot n. \quad (8)$$

Minimum production capacity that can be involved for orders fulfilment $V_{v\_pz\min}$ can be estimated, having preset the probability of the fact that the minimum number of lines will be not less than $n_{\min} - P_{z \geq n_{\min}}$. Then $n_{\min}$ can be defined in terms of sequential analysis p_i, calculated according to formula (7), beginning from $i = 0$ in ascending order till the inequality is being met

$$P_{z \geq n_{\min}} < \sum_{j=0}^{i} p_j. \quad (9)$$

Value i, in terms of which inequality (9) stops being met will be the value $n_{\min}$. Then, minimum production capacity $V_{v\_pz\min}$ is determined according to the formula being similar to (8)

$$V_{v\_pz\min} = v_v \cdot n_{\min}. \quad (10)$$

Determine maximum warehouse capacity $S_{pz\max}$ basing on the maximum number of production lines that can be involved and that is equal to the maximum number of orders being processed.

In terms of production batch Δ_m that is to be supplied per transaction and that is, correspondingly, equal to the batch manufactured according to one order, the average amount of products stored at a warehouse during the order fulfilment will be $\Delta_m/2$. It means that in terms of n operating lines, the following will be warehoused

$$S_{pz\max} = \frac{n \cdot \Delta_m}{2}.$$

Consider a strategy of production of expendables "make-to-stock" with further formation of production batches according to the order.

Such a strategy means a level of production load meeting the predicted need in a corresponding nomenclature unit of expendable tools in terms of available sufficient number of tools in stock to ensure the indicated time of fulfilling the orders in terms of fluctuation of their number within the identified limits. The production of a nomenclature unit of expendable tools for the next period of production planning T_{p_v} (e.g. for a month) is planned according to the orders for the tool supply within a current month, i.e. the tool batches according to the orders are supplied at the expense of both current-month production and the tools stored at a warehouse at the beginning of the month.

Assume that at the beginning of the adoption of "make-to-stock" strategy of the production of expendables with further formation of the production batches according to the orders (e.g. at the beginning of a year), a warehouse stored so products per S_0 orders

$$S_0 = \left]\frac{s_0}{\Delta_\delta}\right[, \quad (11)$$

where]] is operation of rounding down to the least whole number.

While planning the actions of the strategy under analysis for the first production period T_{p_v}, it is natural to specify an operating programme R_{p_v} according to the average predicted value of orders per planned period

$$R_{p\_v(1)} = \Lambda \cdot T_{p\_v} \cdot \Delta m,$$

and per each successive i^{th} period

$$R_{p\_v(i)} = R_{f\_v(i-1)}, \quad (12)$$

where $R_{f\_v(i-1)}$ is actual volume of products according to the orders taken during $(i - 1)^{th}$ production period (period of a production programme).

Assume that at the beginning of i^{th} period of a production programme $S_{0(i)}$ products were warehoused. Then at the beginning of $(i + 1)^{th}$ period of production volumes updating, the warehouse will contain $S_{0(i+1)}$ products

$$S_{0(i+1)} = S_{0(i)} - R_{f\_v(i)} + R_{p\_v(i)}. \quad (13)$$

Similarly, the number of products at a warehouse is determined at the beginning of $(i + 2)^{th} - S_{0(i+2)}S_{0Tk(i+2)}$,

$$S_{0(i+2)} = S_{0(i+1)} - R_{f\_v(i+1)} + R_{p\_v(i+1)}. \quad (14)$$

Substitution of (13) in (14) with the consideration of (12) results in

$$S_{0(i+2)} = S_{0(i)} + R_{p\_v(i)} - R_{f\_v(i+1)}.$$

While continuing sequentially such substitution, beginning from $i = 2$, it is simple to prove that for any $S_{0Tk(i)}$, $i > 1$ we have

$$S_{0(i)} = S_0 + R_{p\_v(1)} - R_{f\_v(i-1)}.$$

Thus, the warehouse stock at the beginning of any period of updating of the volumes of single-unit batches, not considering the first one, is equal to the total of the warehouse stocks at the beginning of the first period of updating of volumes of single-unit batches and the number of products minus actual consumption of products per previous period.

In other words, while adopting a "make-to-stock" strategy of the production of expendables with further formation of product batches according to the orders, a situation with orders fulfilling at any period of time is determined by the parameters of warehouse and production of the first (initial) period of adoption of this production strategy and actual demand for the expendable tools, which is formed during the previous production period.

If we take into account the fact that a production programme of the first (initial) period is determined, according to (11), in terms of average predicted value of orders per planned period, and in terms of flow of events described by Poisson law, the number of events per determined period of time does not depend on the number of events per other periods of time including the ones of the same duration, then, in the context of the known Poisson law, describing an ordering process, capability of orders fulfilment is stipulated by the initial product stocks at a warehouse and duration of a production period, while fluctuations of the planned volumes of production depend on the duration of a production period.

Basing on the random nature of ordering, minimum initial product stock at a warehouse determines risks of the fact that during a current production period a manufacturer will not be able to fulfil the orders taken per its term, i.e. when

$$R_{f\_v} > S_0 + R_{p\_v(1)}.$$

Probability of such an event can be determined according to the formula

$$P\sum_{i=0}^{R_{\max}\sum}\frac{\left(\Lambda\cdot T_{p\_v}\right)^i}{i!}\cdot e^{-\Lambda\cdot T_{p\_v}\cdot\Delta_m} > R_{\max},$$

where maximum threshold of the order level, which, considering (11), is equal to

$$R_{\max} = S_0 + \Lambda\cdot T_{p\_v}. \quad (15)$$

Then, having specified $P_{>R_{\max}} - P_{z>R_{\max}}$, it is possible to use numerical method by sorting $R_{\max}$ from zero through the positive integers in ascending order to identify such its number when the inequality starts being met

$$P_{>R_{\max}} < P_{z>R_{\max}}.$$

That value $R_{\max}$ will be the value of maximum planned production volumes that determines maximum level of the facilities involved in the production. Then, (15) will help to find easily minimally admissible initial warehouse stock $S_{0\min}$ (in the number of orders)

$$S_{0\min} = R_{\max} - \Lambda\cdot T_{p\_v},$$

or in the number of products $S_{0\min}$

$$S_{0\min} = S_{0\min}\cdot\Delta_m.$$

Maximum warehouse capacity can be defined from the same considerations as the minimum warehouse capacity but having specified the probability of taking minimum number of orders $P_{z<R_{\min}}$.

Probability of the event that we will have orders for $R_{\min}$ or less products is equal to

$$P_{<R_{\min}} = \sum_{i=0}^{R_{\min}\sum}\frac{\left(\Lambda\cdot T_{p\_v}\right)^i}{i!}\cdot e^{-\Lambda\cdot T_{p\_v}\cdot\Delta},$$

where $R_{\min}$ is determined by simple sorting through the natural integers from zero in ascending order until the inequality starts being met

$$P_{>R_{\max}} < P_{z>R_{\max}}.$$

Then, minimally required maximum warehouse capacity ($S_{pc\max}$ in the number of orders and $s_{pc\max}$ in the number of products) is defined as follows

$$S_{pc\max} = S_{0\min} - \Lambda\cdot T_{p_v} - R_{\min};$$

$$s_{pc\max} = S_{pc\max}\cdot\Delta_m.$$

Minimum and maximum production capacity $V_{v\_pc\min}$ and $V_{v\_pc\max}$ that can be engaged in terms of this method of production organization can be calculated according to the previously identified $R_{\min}$ and $R_{\min}$

$$V_{v\_pc\min} = R_{\min}\cdot\Delta_m\frac{T_Z}{T_{p\_v\min}};$$

$$V_{v\_pc\max} = R_{\max}\cdot\Delta_m\frac{T_Z}{T_{p\_v}}.$$

Consider the organization of production that is based on a marketing partnership strategy. As it is shown in [7], a marketing form based on the deepened flexible partnership relations is the most profitable one as for the consumers of expendables.

The marketing strategy is used to identify a period of supply of single-unit production batches of the corresponding nomenclature position T_{p_p} and volume of such batches Δ_{p_p} at the beginning of agreement and periods of updating of production batches $T_{k\Delta n}$, i.e. terms of corrections of value Δ_{p_p}. That is the correction that happens according to actual consumption of tools by a consumer per previous period $T_{k\Delta n}$.

Then, in terms of the marketing based on deepened flexible partnership relations, maximum and minimum volume of production is determined by the minimum and maximum amount of the product use by consumers respectively; the production is distributed equally in time of each of periods $T_{k\Delta n}$.

That amount can be determined by means of integrated parameters of consumption flows in all consumers-partners of the corresponding nomenclature position of the expendable tools

$$f_{\sum z}(\mathrm{t}) = \sum\left(z\cdot e^{-\sum z\cdot t}\right), \quad (16)$$

where $\sum z$ is density of the integrated flow of tool consumption in consumers-partners.

Density of the integrated flow of n consumers-partners may be determined as

$$\sum z = \sum_{i=1}^{n} z_i = \frac{\sum_{i=1}^{n} Z_i}{T_Z}. \quad (17)$$

Then, having specified probability of the fact that integrated volume of tool consumption with the present probability $P_{z>M_{\max}}$ will be more than $M_{\max}$ and with the present probability $P_{z<M_{\min}}$ it will be less than $M_{\min}$, it is possible to predict minimum and maximum volumes of production per period $T_{k\Delta n}$.

Maximum production volume per period $T_{k\Delta n}$ can be identified by sorting $M_{\max}$ in terms of positive integers from zero in ascending order until probability $P_{>M_{\max}}$, that is calculated according to the formula

$$P_{>M_{\max}} = \sum_{i=0}^{M\max}\frac{\left(\Sigma z\cdot T_{k\Delta}\right)^i}{i!}\cdot e^{-\Sigma z\cdot T_{k\Delta}},$$

becomes less than $P_{z>M_{\max}}$, i.e. till the following inequality is being met

$$P_{>M_{\max}} < P_{z>M_{\max}}.$$

Similarly, minimum production volume per period $T_{k\Delta n}$ can be identified by sorting $M_{\min}$ in terms of positive integers from zero in ascending order until probability $P_{z<M_{\min}}$, that is calculated according to the formula

$$P_{<M_{\min}} = \sum_{i=0}^{M_{\min}}\frac{\left(\sum z\cdot T_{k\Delta n}\right)^i}{i!}\cdot e^{-\sum z\cdot T_{k\Delta n}},$$

becomes equal or more than $P_{z<M_{\min}}$, i.e. till the following inequality is being met

$$P_{<M_{\min}} < P_{z<M_{\min}}.$$

Minimum and maximum production capacities in terms of deepened flexible partnership relations $V_{v\_cgp\ \min}$ and $V_{v\_cgp\ \max}$ respectively can be determined according to the formulas being similar to (16, 17).

The upper boundary of minimum value of warehouse capacity in terms of deepened flexible partnership relations $S_{cgp\ \max\ sup}$ can be defined theoretically by the accumulation at the end of a period of supply of the single-unit production batches of the corresponding nomenclature position T_{p_p} for all the consumers-partners basing on the maximum need $M_{\max}$ per period $T_{k\Delta n}$

$$S_{cgp\max\sup} = M \cdot \frac{T_{p\_p}}{T_{k\Delta p}},$$

and the lower boundary of minimum value of warehouse capacity $S_{cgp\max inf}$ can be defined according to a maximum batch of supply to a single consumer-partner

$$S_{cgp\max\inf} = \inf_{i=1 \cdots n_{i\_I}} \left\{ \Delta_{p\_p(i)} \right\},$$

where n_{p_p} is the total number of consumers-partners.

Compare the efficiency of the considered strategies by calculating basic parameters of the involved production capacities and warehouse for these strategies. Numerical data of the initial parameters for calculations are given in Table 1. They are based on the studies represented above and in [9].

The calculation results in terms of the aforementioned strategies are shown in Table 2. The calculation results demonstrate that in terms of an expendable tool manufacturer, a marketing strategy of deepened partnership for the production organization has considerable advantages over a transaction-based marketing strategy.

Thus, in terms of the same predicted volumes of production and establishing the relations with consumers on the basis of a marketing strategy of deepened partnership, production of one and the same volumes of orders requires reserving one and the same production capacities for their manufacturing, being by

Table 1

Initial data to calculate basic parameters of the involved production capacities and warehouse in terms of different strategies of the organization of expendable tool production

Parameters	Symbol	Numerical value	Unit of measurement	Note
Annual need in a nomenclature position of expendable tools of one consumer	Z	120	piece	
Annual term of the working time	T_Z	360	day	
Batch of products to be supplied per transaction	Δ_m	20	piece	
Average production capacity of one line	v_v	360	piece/year	1 piece/day
Period of production planning in terms of a transaction marketing form	T_{p_v}	30	day	
Period of supply of a single-unit production batches in terms of a marketing based on the partnership relations	T_{p_p}	15	day	
Period of updating of the volumes of single-unit batches	$T_{k\Delta n}$	90	day	
Assumed probability of risks	P_z	0.1 (0.001)	% (of a piece)	

Table 2

Results of calculation of production and warehouse capacities in terms of different strategies of organization of expendable tool production

Number of orderers	Forms of production organization	Maximum engaged capacity		Predicted production volumes	Maximum required warehouse capacity
		abs. piece/year	rel.	piece/year	piece
3	organization of production – "make-to-order"	2160	6.0	360	60
	organization of production – "make-to-stock" with further formation of production batches according to the orders	1440	3.89		140
	organization of production relying on a partnership marketing strategy	484	1.34		21
5	organization of production – "make-to-order"	2520	4.2	600	70
	organization of production – "make-to-stock" with further formation of production batches according to the orders	2160	6.0		200
	organization of production relying on a partnership marketing strategy	756	1.26		32
7	organization of production – "make-to-order"	2520	3.0	840	70
	organization of production – "make-to-stock" with further formation of production batches according to the orders	2640	3.1		240
	organization of production relying on a partnership marketing strategy	1024	1.22		43

2.5–4 times less, and warehouse capacity, being by 1.6–6.7 times more than in terms of establishing the relations with consumers on the basis of traditional marketing based on transactions.

The main factors of such effect are in the reduction of the number of products in single-unit batches, being supplied, with simultaneous increase in the number of batches, and medium-term production planning.

It should be highlighted that similar values of maximum engaged capacity to organize "make-to-order" production in terms of five and six orderers are connected with the fact that the maximum number of production lines that can be engaged for order fulfilment is not the same for these two cases; however, probability of that situation in terms of five orderers is less than in terms of seven ones. In other words, if there are five orderers, the work at maximum production capacity lasts less than in case of seven orderers.

It should be also emphasized that fluctuations of production capacities of the expendable tool manufacturer result in the same fluctuations in the needs in the corresponding spare parts and raw material used for production. It means that a situation in the suppliers of those spare parts, materials, and raw material reflects the manufacturer's situation; and all the analyses and studies mentioned in this paragraph are true for them as well.

Then, the task of establishment of deepened partnership relations between a manufacturer and supplier is of the same topicality as between a manufacturer and an orderer. However, if there is no partnership between a manufacturer and an orderer of expendable tools, formation of deepened partnership relations between a manufacturer and supplier is of limited sense as it does not provide any significant decrease in fluctuations of the engaged production capacities with the respective fluctuations of purchase volumes of the corresponding spare parts, materials, and raw material.

Thus, for a manufacturer of differentiated goods, establishment of deepened partnership relations provides considerable increase in technical and economic indices of its production; and formation of such relations is a top-priority task of marketing divisions of such enterprise. Consequently, development of methodology for the formation of partnership relations in the supply and sales channels is rather topical for this research.

Conclusions.

1. While organizing production of differentiated goods as "make-to-order", a process of order fulfilment is described by a system of Erlang equations that helps determine maximum need in production capacities to fulfil the orders while interacting with a consumer in terms of transaction-based marketing.

2. While organizing production of differentiated goods as "make-to-stock" on the basis of transaction marketing, a level of production is meant to meet the replenishment of warehouse stocks that was exhausted during the previous production period. Tool batches are supplied according to the orders at the expense of both current-period production and the tools being available at a warehouse at its beginning.

3. Organization of production relying on the deepened flexible partnership relations means determining a period of supply of single-unit production batches of corresponding nomenclature position. Volumes of such batches and periods of updating of single-unit batches, i.e. the correction, are performed according to actual consumptions of tools by a consumer per previous period.

4. Flexible organization of production relying on partnership relations provides considerable reduction of production capacities in terms of changeable demand for meeting it, comparing with the strategies oriented to a transaction marketing form. Thus, in terms of the same predicted volumes of production and establishment of the relations with consumers on the basis of a marketing strategy of deepened partnership, production of one and the same volumes of orders requires reserving one and the same production capacities for their manufacturing, being by 2.5–4 times less, and warehouse capacity, being by 1.6–6.7 times more than in terms of establishing the relations with consumers on the basis of traditional marketing based on transactions.

References.

1. Jiang, Z., Shiu, E., Henneberg, S., & Naude, P. (2016). Relationship Quality in Business to Business Relationships. *Psychology and Marketing*, *33*(4), 297-313. https://doi.org/10.1002/mar.20876.

2. Jonathan, Z., George, F., & Robert, W. (2016). Dynamic Relationship Marketing. *Journal of Marketing*, *80*(5), 53-75. https://doi.org/10.1509/jm.15.0066.

3. Kenneth, H. Wathne, Jan, B. Heide, Erik, A. Mooi, & Alok Kumar (2018). Relationship Governance Dynamics: The Roles of Partner Selection Efforts and Mutual Investments. *Journal of Marketing Research*, *55*(5), 704-721. https://doi.org/10.1177/0022243718801325.

4. Wasike, S., & Joseph, O. (2020). Top Management Team Characteristics, Competitive Environment and Strategy Implementation. *International Journal of Business and Management*, *15*(7), 147-157. https://doi.org/10.5539/ijbm.v15n7p147.

5. Larina, Y., & Lutsii, K. (2018). Formation of organizational economic mechanism of marketing based partnership between enterprises. *Marketynh i Tsyfrovi Tekhnolohii*, *2*(1), 96-107.

6. Krykavskyy, Ye., & Yakymyshyn, L. (2018). Complementarity of marketing and logistics strategies in the chain of supply of goods of daily demand. *Marketing and Digital Technologies, 2*(1), 21-32. https://doi.org/10.15276/mdt.2.1.2018.2.

7. Hernández-Mogollón, J., & Alves, H. (2020). Integrating transactional and relationship marketing: a new approach to understanding destination loyalty. *International Review on Public and Nonprofit Marketing, 18*, 1-24. https://doi.org/10.1007/s12208-020-00258-z.

8. Azadfallah, M. (2017). Supplier Performance Prediction for Future Collaboration: Based on Markov Chain Model. *International Journal of Business Analytics*, *4*, 48-59. https://doi.org/10.4018/IJBAN.2017100103.

9. Kuvaieva, T. (2017). Assessment of competitive advantages of the enterprise functioning in network structures partnership type. In M. Bezpartochnyi (Ed.). *Mechanisms interaction competitiveness and innovations in modern international economic relations: collective monograph, in 4 Vol. ISMA University,* (pp. 30-38). Riga: "Landmark" SIA.

10. Baetens, J., Steyaert, B., Claeys, D., & Bruneel, H. (2020). System occupancy in a multiclass batch-service queueing system with limited variable service capacity. *Annals of Operations Research, 293*, 3-26. https://doi.org/10.1007/s10479-019-03470-1.

Форми організації виробничої діяльності підприємства за умов імовірнісної природи попиту

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Мета. Розробка моделей, що описують форми організації виробничої діяльності підприємства за умов імовірнісної природи попиту, та визначення впливу на них стратегій маркетингової взаємодії зі споживачами продукції.

Методика. Теоретичні моделі базувалися на класичних моделях теорії масового обслуговування, методах планування продажів і дослідженнях раціональних стратегій маркетингової взаємодії споживача товару обмеженого попиту, потреба в якому носить імовірнісний характер. У якості критерію впливу стратегії маркетингової взаємодії виробника зі споживачем прийняті такі показники як максимальна (пікова) задіяна виробнича потужність і максимальна ємність складу, що потрібна при прогнозованому обсязі виробництва.

Результати. Отримані залежності, що дозволяють розрахувати максимальну (пікову) задіяну виробничу потужність у залежності від прогнозованого обсягу вироб-

ництва, ємності складу та організації виробничої діяльності підприємства. Показано, що організація маркетингової взаємодії між виробником і споживачем товару обмеженого попиту, потреба в якому носить імовірнісний характер, на підставі стратегії маркетингового партнерства дозволяє суттєво знизити пікові навантаження виробничих потужностей та ємність складу, що потрібна для забезпечення виробничої діяльності підприємства.

Наукова новизна. Полягає в обґрунтуванні, на базі теорії масового обслуговування, форми організації виробничої діяльності підприємства, що виготовляє товар, потреба в якому носить диференційований характер, а попит на нього є обмежений і має ймовірнісну природу. Доведено, що поточна маркетингова стратегія взаємодії виробника зі споживачем такого товару суттєво впливає на організацію виробничої діяльності підприємства-виробника. Обґрунтовано форму організації виробничої діяльності підприємства, що при організації взаємодії зі споживачем на основі маркетингу партнерських відносин дозволяє суттєво знизити пікові навантаження виробничих потужностей і задіяну ємність складу готової продукції.

Практична значимість. Отримані результати можуть бути використані для планування форм організації виробничої діяльності підприємства, що виготовляє товари обмеженого попиту, потреба в якому носить диференційований характер, та обґрунтування раціональної маркетингової взаємодії зі споживачем такого товару.

Ключові слова: *випадковий характер замовлень, імовірнісні моделі, пікові завантаження, ємність складу, маркетингові стратегії*

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