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Modelling of the Supply Chain Planning for the Business and Economic Security

Vlasov M. P. [1] Modenov A. K. [2] Harchenko O. V. [3]

[1,2,3]*Saint-Petersburg State of Architecture and Civil Engineering, Russia;*

Abstract— **Strategic supply-chain planning that combines aspects of business-strategy formulation with aspects of tactical supply-chain planning can make each far more valuable to the planning effort than either would be alone. The purpose of this article is to assess the economic security of the enterprise in terms of the efficiency of the use of supply chain planning, taking into account the possibility of production and sale of manufactured products. In case of falling demand for products, there are free capacities in the enterprise, which are useful to use to organize the production of additional items. Underutilization of the enterprise leads to higher costs, lower profitability and lower revenues, thus reducing the interest of the owners in the enterprise and thus threatening its existence. The article proposes a system of mathematical models, which allows to effectively use the capacity of the enterprise to increase its profitability due to the self-contained production of additional nomenclature, due to the use of temporarily increasing capacity. As the main hypothesis in the construction of the model, it is assumed that the economic security of the enterprise is determined by the degree of satisfaction of the economic interests of persons interested in the results of its activities. Therefore, it is proposed to consider the economic security of the enterprise from the point of view of effective use of the assets of the enterprise, which creates prerequisites for timely and full fulfilment of mutual obligations by the enterprise on the one hand, and by the owner, personnel, clients, partners, the State on the other. The proposed system of mathematical models implies that the enterprise is oriented towards the production of mass products, the realization of which involves a certain risk. The model assumes that the enterprise produces several types of industrial nomenclature and has the possibility to organize the production of additional nomenclature using available free capacities. The proposed model is intended to assess the feasibility of production, determine the best value for money and thereby increase the profitability of the enterprise. The use of a system of models improves the current activities of the enterprise, the feasibility and effectiveness of the existing innovation policy for the renewal of the production programme. The article provides recommendations for practical use of the model.**

Keywords— *supply chain management, Enterprise economic security, planning, mathematical model, risk*

1.   Introduction

Any company that has a global supply chain should consider introducing its strategic left hand to its operational right hand. Economic security of the enterprise is built primarily upon the results of own activities, efficient use of all the capacity. The central position in this process is occupied by the stage of planning of production, which is designed to ensure the efficient use of the enterprise assets, and, hence, its economic security based on the long-term contracts for production supply and forecast of the demand for its products [1-3]. Economic security for the enterprise is defined by the degree of satisfaction of the economic interests of the parties interested in its activities. Among them are enterprise staff, consumers of the production, owners, partners, who supply the material necessary for the production, as well as the State. In case of consumers consuming the enterprise's products and making the payment timely, the incoming revenue not only shall recover the costs, including for partners' supply of the components and services necessary for production and realization, but also ensure the profit for owners and staff, tax deductions to the State. The efficiency of enterprise asset use is directly linked to the activities of the enterprise staff, which should:

-      through forecast identify the sales prospects of a specific production (mission of the enterprise);

-      assess the enterprise's capacity on the organization of the production of the most promising products in terms of profitability (vision of the enterprise);

-      identify the necessary output volumes of all the products assigned for the output in order to achieve the minimum necessary profitability (general strategy of the enterprise);

-      identify the staff competencies necessary to achieve sufficient product competitiveness (business strategies necessary for the general strategy implementation);

-      design the enterprise architecture, which includes production structure, logistical structure, managerial, and organization structures, and ensure information system functioning for defining the required operational and logistical expenses, pricing policy (functional strategies).

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The operational expenses include numerous recurring costs related to the production and sale of the products and enterprise management.

Logistical expenses represent the costs on the maintenance of the material and information flows necessary for the realization of the final goods and supply of the enterprise with necessary components and resources.

For enterprises engaged in mass and large-scale production, all the nomenclature of the produced goods can be divided into two groups: main and additional ones.

Nomenclature means a set of all groups of enterprise' products offered to the customers (Fig. 1). Product range is a ratio inside the product group by dimension-type, design, material used, package according to the preference and paying capacity of certain market segments.
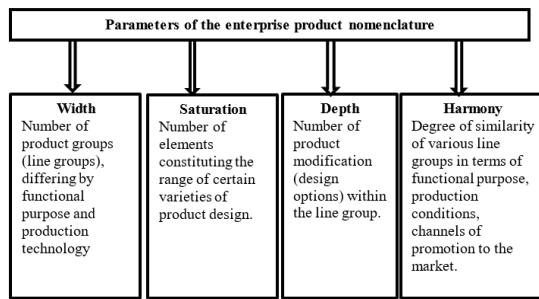

Figure 1: Parameters of the product nomenclature

2.   Literature Review

Strategic supply-chain planning falls in the middle of a decision-making spectrum that has business-strategy formulation at one end and tactical supply-chain planning at the other. (See "Strategic Supply-Chain Planning and the Planning Spectrum.") With a focus on fundamental changes in manufacturing and distribution capacity, it is long-term in scope and impact but can benefit from detailed optimization models and advanced planning-and-scheduling (APS) technology that is more often associated with medium- and short-term planning. Used in this strategic context, the tools help determine what would be an appropriate supply-chain configuration for sourcing and which plants or distribution centers should be closed or kept open [4]. The nomenclature of goods produced by the enterprise should contribute to:

development of production, increasing output, reducing unit costs;

enhancing the competitiveness of the enterprise by increasing quality and reducing unit costs;

development of production in order to increase

output and enhance market presence.

The main nomenclature is a list of products that characterize the enterprise specialization, which determines the necessary variety of business processes (technological processes and equipment, competencies and qualifications of the main production staff). The structure of the product nomenclature and its output volume should correspond to the structure of demand for the enterprise's products and generally contribute to producing profit, although some types of products may be unprofitable, for example, new promising products, production of which is only at the stage of organization.

The additional nomenclature includes products that do not correspond to the enterprise specialization, that use temporarily available capacity due to the availability of technologically necessary equipment that is not used continuously. Production units employed in assembly operations can be formed for the production of products related to the additional nomenclature [5]. Moreover, when necessary, the required components can be supplied. The purpose of organizing the production of additional product nomenclature is to reduce the cost of production of the main nomenclature.

Reducing the nomenclature of products leads to narrowing the specialization of the enterprise and, as a result, improves the use of assets of the enterprise, reducing the operational cost and improving the quality of products, the possibility to automate the production. On the other hand, narrow specialization makes it difficult to update the product nomenclature and leads to high expenses for production update, which results in the loss of competitiveness, drop in output volume, and reduced financial stability of the enterprise. Thus, reducing the nomenclature is useful in the short term and not profitable in the long term.

The distinct feature of enterprises focused on mass and large-scale production is that they first produce products, and then offer their sale to wholesalers and retailers. Enterprises of single-piece and small-scale production, advertising their capabilities, first have to look for the consumers of their products, conclude contracts with them, and only then proceed to the production [6-9]. Therefore, enterprises focused on mass and large-scale production advertise their products, while enterprises engaged in single-piece and small-scale production advertise their capabilities. The main product nomenclature of the enterprise should be profitable, in contrast to the additional one, which aims to reduce costs and enhance the competitiveness of the enterprise. The reason for the

establishment of additional nomenclature lies in the existence of periodically used capacities that are technologically necessary. Having these capacities, the enterprise is faced with increased costs. While their use even for the production of low-profit or unprofitable products due to prevailing market prices allows increasing the profitability of the enterprise as a whole by reducing costs per unit of the main product of the main nomenclature.

For a long period of time, due to the need to respond fast to changes in market demand, the emergence of unplanned trends in consumer behaviour requires changes in the composition of the nomenclature and output volumes, which causes the formation of "bottlenecks" and excess capacity.

3. Materials and Methods

The supply-chain team develops or modifies its supply-chain model on the basis of input from the strategy team regarding possible decisions. The two teams then validate the model. The strategy team garners useful information about the supply chain and updates its notions about how long-term supply-chain configurations affect total supply-chain cost. Next, the strategy team fleshes out the business scenarios using this information and data-on-demand forecasts, plant locations, distribution centers and so on. Finally, the supply-chain team develops multiple model scenarios for each business scenario to run through its software. Such an imbalance of capacity relatively to the production programme of enterprises focused on mass and large-scale production makes it necessary to plan production in two stages [10]. The first stage involves considering the possibility of organizing the output of the main product nomenclature in order to maximize the enterprise's revenue. The second stage aims to reduce unit costs.

Thus, the production programme of the enterprise includes many types of products of the main nomenclature I^o and many types of products of the additional nomenclature I^d. In turn, the enterprise is described by numerous business processes J, presented with sufficient detail to describe the production programme. Each business process must have staff with certain competencies and qualifications, and equipment that together determine its technological specialization. As a result, each business process $\forall j \in J$ is characterized

by a certain power b_j, calculated in hours.

The main product nomenclature $\forall i^o \in I^o$ is characterized by the vector $\{a_{(i,j)}^o\}$, where $a_{(i,j)}^o$ is the value of business process resources $j \in J$ required for the production of a production unit $\forall i^o \in I^o$. In addition, the unit price c_{i^o} for the main nomenclature is determined.

It is assumed that for all operations of the value chain of products of the main nomenclature, the necessary basic business processes already exist in the enterprise (set J). For additional nomenclature, some of the business processes required for production are missing. Therefore, the task of planning the production of additional nomenclature is to minimize the costs of missing business processes that ensure the production of the products and that only increase the costs of the enterprise, since the output of additional nomenclature production is either low-profitable or even unprofitable.

The organization of production of additional nomenclature is not a necessary component of the enterprise's mission, as it is aimed at reducing the cost of production of the main nomenclature. The purpose of production of additional nomenclature is to increase the competitiveness of the main nomenclature products by minimizing the enterprise's costs, as well as selecting and implementing an effective marketing policy.

For the main product nomenclature then, the problem of output maximization should be resolved, i.e. it is necessary to define such values of the elements of the vector $\{x\}_{i^o}$, each element x_{i^o} of which determines the output volume of the main production nomenclature $i^o \in I^o$, so that the functionality characterizing the output volume of the main nomenclature in value terms considering the probability of the total output volume p_{i^o}, i.e.

$$F^o = \sum_{i^o \in I^o} p_i^o c_i^o x_i^o \rightarrow max,$$

reaches the maximum when the following restrictions are met:

the value of resources used in the output of the main nomenclature for each business process does not exceed its capacity

$$\sum_{i^o \in I^o} a_{i,j}^o x_i^o \leq b_j, for \ \forall j \in J,$$

the profitability of each type of products of the main nomenclature must not be lower than the specified level of profitability $x_{(i,min)}^o$, i.e.

$$x_i^o \geq x_{i,min}^o,$$

where $x_{(i,min)}^o$ defines the minimum volume required to achieve the specified profitability of the products of the main nomenclature.

The probability of realization in a given volume assumes receiving all (if the probability is 1) or part ($1⟦>p⟧\_i^o > 0$) of payments for the product. Assuming that payments for products are stretched over time, there is a need to increase circulated funds to finance current production. This negatively affects the return on equity and leads to a drop in the income of the owner, thereby weakening his interest in the income and, consequently, reducing the economic security of the enterprise.

Two sets of business processes are specified for the production of additional product nomenclature. The first consists in already existing business processes, which are denoted as J^d, and for $\forall j^d \in J^d$ the value of its capacity $b\_(j^d) > 0$ is set. The missing business processes represent the second set $J^{(d,d)}$. These are business processes that are necessary for the production of a particular product of the additional nomenclature, such as assembly or testing processes. The costs for the second set $J^{(d,d)}$ must be minimized, since they increase the costs of the enterprise and thus reduce its competitiveness.

To plan the volume of production of the additional nomenclature, the set of available capacity is defined

$$J^d, \text{for } \forall j^d \in J^d \; \exists b_{j^d} > 0, \text{ where}$$

$$b_{j^d} = b_j - \sum_{i^o \in I^o} a_{i,j}^o x_i^o > 0, \text{ for } \forall j^d \in J^d$$

Two vectors are specified for additional nomenclature products. The first of these is $\{a\_(i^d, j^d)\}$ for the additional nomenclature $i^d \in I^d$, where $a\_(i^d, j^d)$ is the value of resources of the existing business process $j \in J$ required for a production unit $\forall i^o \in I^o$. The second vector $\{a\_(i^d, j^{(d,d)})\}$ defines the value of resources required for the production of additional nomenclature products for the missing business processes that form the set $J^{(d,d)}$. The unit price $c\_(i^d)$ for additional items is also defined.

Therefore, the task of production planning for the additional nomenclature is to determine the set $\{x\_(i^d)\}$, each element $x\_(i^d)$ of which defines the output volume for the additional items $i^d \in I^d$, so that functionality characterizing the output of the additional product nomenclature considering the probability of its implementation in the volume of sales $p\_(i^d)$, i.e.

$$F^d = \sum_{i^d \in I^d} p_{i^d} c_{i^d} x_{i^d} \to max$$

reaches the maximum when the following restrictions are met:

the cost of missing business processes required for the production of additional items should not exceed the value of available capacity for existing business processes

$$\sum_{j^{dd} \in J^{dd}} \sum_{i^d \in I^i} a_{i^d, j^{dd}} x_{i^d} \leq \sum_{j^d \in J^d} b_{j^d},$$

Otherwise, the products of the additional nomenclature are transferred to the main category. However, since these products were assumed to be at least low-profit, this ratio determines the upper limit of the expansion of the enterprise's capacity for additional nomenclature. This restriction can be true in case of all the available capacities of existing business processes being used for the production of additional items. Whereas when only part of the available capacity of the existing business processes is used, then the right part of the considered restriction contains capacity only for those existing business processes that were used for the production of the additional items.

the value of resources used for the production of additional nomenclature for each of the existing business processes does not exceed its capacity

$$\sum_{i^d \in I^d} a_{i^d, j^d} x_{i^d} \leq b_{j^d}, \text{ for } \forall j^d \in J^d$$

Thus, first, the boundary between the main and additional nomenclature is established, and second, the limit of expansion of the enterprise's capacity for the production of additional nomenclature is identified.

4. Results

Each of the models presented above is a linear programming problem, it is solved without any difficulties, and the given model system can be widely used [1, 2, 3]. The proposed model system is designed to evaluate the reliability of the enterprise planning systems and the related risks, which are primarily associated with production volume and timeliness of supply of the main product nomenclature, which is typically sold under long-term contracts to the vital for the company strategic business zones. As a result of the practical use of the model, there is assessment of both the content of the main nomenclature and the resulting profit, based on the reliability of its receiving, and the use of the enterprise's capacity.

The proposed system of mathematical models makes it possible to perform the following activities in an interactive manner:

to make a reasonable choice of the main and additional product nomenclature, considering the possibility of its sale;

to provide the most complete use of the enterprise's production capacity;

to reduce as low as possible the cost per unit of the main product nomenclature, thereby increasing the competitiveness of the enterprise;

to implement the continuous use of production equipment, including technologically-necessary one.

This system of models focuses on ensuring the reliability of product sales, the amount of production volumes and the timely execution of long-term contracts for the main nomenclature.

The system of models implicitly considers the restriction on the amount of costs, which can affect the amount of profit that determines the interest of owners in the continued operation of the enterprise. Among the advantages of the model system is the separate planning of the main and additional nomenclature, which not only contributes to the increase in profitability, but also allows for more efficient use of the enterprise's capacity.

The possibility of minimizing costs as a result of the more complete use of the enterprise's capacity is considered as an additional effect from the use of the model system. Minimization of costs and maximization of profit with a more careful approach of the enterprise to keeping the market outlet for its products contributes to increasing the economic security of the enterprise. Efficient use of assets allows to increase the profitability of the enterprise and, as a result, increase the income of the owner.

A sufficient variety of the model system parameters makes it possible to analyse different variants of the enterprise's production and sales policy relying on different scenarios. These scenarios involve changes in the product nomenclature, production volumes, and prices, depending on the pricing policy.

The restriction of funds allocated for the production of the additional product nomenclature contributes to the fulfilment of the enterprise's obligations related to labour remuneration, settling accounts payable, tax payments and owner's income. At the same time, it is assumed that the output volume of the products in demand is sufficient to fulfil these obligations.

In this case, the planned production is the factor that is intended to fulfil the listed obligations of the enterprise and, thereby, ensure its economic security. The proposed model system is the manager's tool that allows not only to justify the production policy, but also to check the effectiveness of the enterprise's general strategy.

5. Discussion

One important element in any supply chain is the talent. The supply chain depends on smart supply chain managers and how they deal with people, relationships and contemporary issues. In this special issue, we focus on knowledge, talent and human resources. Contemporary supply chain management faces many challenges, such as globalisation, increasing in logistics cost, greater product variety, shorter product life cycles, increased level of risk, increased labour costs in developing countries, rapid development of information technology, sustainability and volatility of commodity prices. These challenges require capable workers with dynamic skills to make the supply chains of the future successful. The proposed system of the economic and mathematical planning models structures the goals of the enterprise's economic activity with restricted available capacity [4, 6]. The first model is aimed at timely fulfilment of long-term contracts for the supply of products to the market (the main nomenclature). The second model is aimed at reducing the enterprise's costs for the production of a unit of the main product nomenclature. This effect is achieved by using temporarily available capacity to produce items that are beyond the enterprise's specialization (additional nomenclature).

Despite the fact that production planning is considered as a process of enterprise asset management, many researchers cite long-known economic and mathematical models in their works, without specifying their purpose and use [5, 7, 8, 9].

In this case, the works consider the processes of planning and output of production without its division into the main and additional nomenclature. This leads to short-term benefits at the expense of the long-term interests of the enterprise, as far as failure to fulfil contracts for the supply of products from the main nomenclature results in the violation of contractual obligations, which leads to the loss of the sales market.

The existing approach without separating the planning processes of the main and additional nomenclature reduces economic security in the long run. Thus, the interests of the owner are ignored, since this approach ultimately leads to a decrease in income and

profitability in the long term due to the desire to make a profit in the short term at the expense of the enterprise's specialization and its reputation in the market.

It is quite natural that the proposed models provide for the consideration the impact of various external factors that affect the amount of income when selling a particular type of product [10].

As a result of the proposed approach in the production planning processes, methods of decision-making theory under uncertainty are becoming increasingly popular, which implies the formalization of the scenario approach in the form of a goal tree. In this case, optimization consists in determining the best parameters that maximize the final economic result. The proposed system of economic and mathematical models considers the capabilities of the enterprise to implement the production programme from the position of simultaneously obtaining maximum income and minimizing costs, taking into account the conditions of product realization. This distinguishes it from the existing economic and mathematical models.

6. Conclusion

In particular, the need for effective supply chain management has never been greater. Regardless of size or tenure, companies are outsourcing most or all of their manufacturing operations to regions often outside their target markets, dramatically increasing supply chain complexity and volatility. The result of this research consists in the formalization of the production planning process in order to maximize the income (gains, revenue) when fulfilling obligations to customers for the supply of products of the main nomenclature, which determines the specialization of the enterprise and its position in the market. The process is considered from the perspective of determining the best enterprise operating conditions, which ensures the best use of the enterprise's capacity and minimizing the costs per unit of production of the main nomenclature, which allows to increase the competitiveness and, at the same time, the income of the enterprise, owner and staff. The models reflect the explicit dependence on the product nomenclature and output volume, as well as the possibility of its implementation.

As a rule, when modelling such processes, the emphasis is put on the use of capacities by varying their value to fulfil the contractual obligations. At the same time, the entire production programme is considered, without taking into account the priority and timelines of contracts. With this approach, the costs of the enterprise as a whole are usually overlooked. The proposed system of economic and mathematical models establishes a close relationship between incoming revenue from the sale of products and costs, between the capabilities and obligations of the enterprise. In this system of models, the focus is on obtaining the maximum revenue through more complete use of capacities and simultaneous minimization of costs per unit of production of the main nomenclature. This ensures the economic security of the enterprise.

Moreover, the proposed model system helps to identify the "bottlenecks" that impede the increase in production volumes from the perspective of the established production program, which in itself also contributes to minimizing the costs of producing a specified volume of the main product nomenclature. The proposed system of models can be used to assess the possibility of implementing both current and prospective production programmes, in order to make timely decisions about changing the structure of capacities, increasing production volumes, so that to fully take advantage of the cost-saving effect on the production scale. Although companies routinely weigh long-term supply-chain-related decisions in light of alternative sources of supply, new geographic markets or new products, various levels of management use different approaches, often in isolation. Senior managers make such decisions as part of formulating business strategy; supply-chain planners, as an extension of their tactical supply-chain planning. The proposed model system can also be applied in the evaluation of the enterprise's specialization, or when updating the production program. This allows considering production, innovation and investment processes in a systematic unity.

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