ASSESSMENT OF NEEDED VOLUME OF CAPITAL INVESTMENTS IN EARLY PHASES OF INNOVATIVE PRODUCT DESIGN IN MULTI-NOMENCLATURE MECHANICAL ENGINEERING

V.G. ABRAHAMYAN
Doctor of Science in Economics, Professor and Lecturer at the Department of Management and Business of Yerevan State University
1 Alex Manoogian, 0025 Yerevan, Republic of Armenia
vahramabrahamyan@ysu.am

Abstract: *Economic-mathematical models have been developed and proposed to determine the amount of funds required in early stages of a new product design. This will allow reducing the volume of operations in the pre-production stage and will help structurally optimize the innovative product lifecycle.*
Keywords: *innovation, new product, design, funds, capital investment.*

To increase the levels of performance efficiency and competitiveness the manufacturing organization should coordinate all integrated processes ranging from design work (scientific research, experimental, structural and technical preparation) to finished product manufacture and sale. To that end, the logistics department of the manufacturing organization should constantly research the changes occurring in the finished product market utilizing the set of tools available in the marketing department forming part of its structure (chart 1).

Based on the data received a database necessary for the innovation policy development is created. Subsequently, the database is researched following which a relevant strategic plan for updating the launched product nomenclature (launched product upgrading, new product introduction) is formulated. Within the framework of the developed strategic plan implementation, relevant production-technological and organizational-innovation processes of restructuring are implemented in the manufacturing organization as result whereof new products that are highly demanded in the market are designed as well as advanced technological processes and up-to-date operational and manufacturing process management methods are learnt [2].

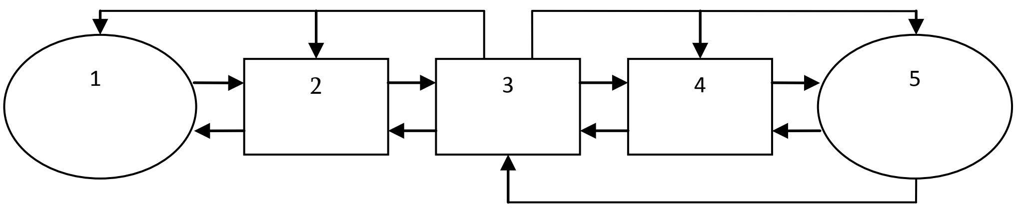

Chart 1. Correlation of the processes implemented in the logistics system (1- logistics market, 2-logistics supply, 3-manufacture, 4-sale, 5-finished product market)

When introducing a new product there might be a need for a new kind of logistic resources. To that effect, the logistics department of the organization using the capacities of the marketing department forming part of its structure, in parallel to the work being implemented, researches the logistic resources supply market and selects new suppliers that can provide the needed type, volume and quality of material resources according to schedules mutually agreed upon and for economically efficient prices.

The on-time implementation of the said processes provides the manufacturing organization an opportunity to rapidly respond to the changes occurring in the market and meet the new demand accordingly. The said processes take place incessantly since demand-related changes are of dynamic nature.

To optimize the efficiency level of innovation processes with regard to a new product design and introduction as well as new engineering processes it is necessary to curtail the volume of design work in the scientific research and technical preparation stage. It will allow improving the lifecycle structure of innovation processes timewise, since in that event, there will be a chance to extend the duration of the production and post-production stages and expand the new product manufacture and sale volumes during the lifecycle thereof at the expense of shortening the timespan allotted for the activities to be carried out in the preproduction stage. In such instances, the amount of the anticipated profits grows in the manufacturing organization as the innovation project developed is implemented in a more productive manner [1]:

To assess the effectiveness of the innovation process alternatives being developed, in early stages of design work when a comparative analysis and selection of innovation ideas are being carried out it is necessary to determine the types and quantity of new technological equipment needed for a new product introduction, for the acquisition whereof the needed amount of the nonrecurring funds makes up 60-70% of the costs envisaged for the implementation of the technical preparation activities of a new product introduction.

An effective solution to the issue in question will enable the manufacturing organization to project the amount of nonrecurring funds needed for the implementation of the innovation processes in early stages of new product design. This, in its turn, will provide the manufacturing organization with an opportunity to better determine the productivity level of the innovation processes being carried out, assess the chances of their implementation, make an informed decision on their implementation direction and optimize the product lifecycle structure timewise.

The utilization of economic-mathematical models (EMM) can greatly contribute to the successful resolution of this issue. The application of those models in early stages of design work makes it possible to define with great precision the labor intensity of a new product launch in various manufacturing stages (structural and technological labor intensity) as well as the material output ratio and the manufacturing costs thereof.

Defining the structural and technological labor intensity of a new product in the early design stage provides a scope for determining the quantity of all technological equipment and machinery needed in various stages of the manufacture thereof when carrying out technological processes.

This approach is successfully employed in multi-nomenclature mechanical engineering. The application of economic-mathematical models allow determining with great precision the structural (as per the basic stages of manufacturing) technological labor intensity of a new product manufacture in the early design stage which serves as a basis for defining the quantity of the technological equipment and machinery as well as the amount of the nonrecurring funds needed for the acquisition thereof [1,3].

In the preparatory stage of production, the technological labor intensity of the manufacturing process can be defined with great precision by the formula as follows:

$$T_1 = \sum_{j=1}^{k}\sum_{i=1}^{N_j} t_{1ij} = \sum_{j=1}^{k}\sum_{i=1}^{N_j} A_{ij}\left(\frac{m_{ij}}{k_{ij}^{m}}\right)^{x_{ij}} k_{1ij}k_{2ij} \qquad 1)$$

where t_{1ij} refers to the technological labor intensity of the i component preform manufacture using the j method, K_{1ij} indicates the coefficient which takes into account the impact of the production volume (launch scale) on t_{1ij}, K_{2ij} denotes the coefficient that takes into account the impact of the preform complexity level on t_{1ij}, K_{ij}^{m} refers to the coefficient of the material consumption in case of the i component preform manufacture through the j technological process, m_{ij} refers to the net weight of the i component in case of the manufacture of the preform thereof through the j technological process, A_{ij} represents the constant term and X_{ij} refers to the exponent [1,3].

The coefficient taking into account the impact of the production volume is defined by the following formula;

$$K_{1ij} = a_1 P_1^{x_1}\left(\frac{m_{ij}}{K_{ij}^{m}}\right)^{x_2} \qquad (2)$$

where P_1 refers to the preform production volume (pc/yr), a_1 indicates the constant term, x_1 and x_2 represent the exponents.

The coefficient taking into account the impact of the preform complexity level is defined by the following formula:

$$K_2 = a^{c-1} \qquad (3)$$

where c denotes the number of the groups specifying the preforms complexity level, a is a positive integer ($a > 1$).

In the production processing stage the technological labor intensity can be defined with great precision by the following formula:

$$T_2 = e^{a_2}\left(\sum_{j=1}^{K}\sum_{i=1}^{N_j}\frac{m_{ij}}{K_{ij}^{m}}\right)^{x_2}\left(\sum_{\varphi=1}^{t}\frac{\sum_{l=1}^{b}\Theta_{\varphi\ell}}{N_1}\right)^{y_2} e^{tz_2} K_{ПТ} \qquad (4)$$

where the first constituent element of the formula (e^{a_2}) is the constant term (e=2,71828...), x_2, y_2, z_2 represent the exponents, the second constituent element is the total mass of the component preforms being developed in the organization, the third constituent element is the coefficient of the technological equipment for production processing, the fourth consituent element takes into account the impact of the years of product launch in a given organization (excluding the design stage), the fifth constituent element is the coefficient of the advancement level of processing technologies [1,3].

The coefficient of the technological labor intensity of production processing on the φ equipment is defined by the following formula:

$$T_{2\varphi} = T_2\beta_{\varphi} \qquad (5)$$

where β_{φ} is the specific weight of the technological labor intensity with regard to the φ equipment within the general technological labor intensity of the finished product components processing stage.

The technological labor intensity in the product assembly stage can be defined with great precision by the following formula:

$$T_3 = e^{a_3} m_3^{x_3} N_3^{y_3} e^{tz_3} K_{MA} \qquad (6)$$

where e^{a_3} is the constant term (e= 2, 71828...), x_3, y_3, z_3 represent the exponents, m_3 is the mass of a single component forming part of the finished product structure (kg), N_3 is the number of the components forming part of the finished product structure (pc). K_{MA} refers to the coefficient denoting the level of mechanization and automation of assembly processes [1,3].

According to Fisher's criterion, the economic-mathematical models are correctly selected and it allows determining with great precision the coefficient of the structural technological labor intensity. The coefficient of multiple correlation is smaller than 0,95 and the coefficient of determination is smaller than 0,90.

The economic-technological models introduced for determining the structural technological labor intensity enable to, in the early stages of a new product design, define the quantity of the technological equipment necessary for the product manufacture in the basic phases thereof as well as the size of the production surface area for product assembly. Based on the data obtained it is possible to determine the amount of nonrecurring funds (capital investments) needed for a new product introduction in the given design stage.

In the preparatory stage of production, the volume of capital investments necessary for incorporating technological processes with regard to a new product introduction can be defined by the following formula:

$$K_1^{E} = \sum_{j=1}^{k}\left[U_j\sum_{i=1}^{N_j}\frac{t_{ij}P_{1ij}}{K_{1ij}^{b}F_{1ij}^{0}}\right] \qquad (7)$$

where U_j represents the costs relating to the acquisition and exploitation of new technological equipment necessary for the implementation of the j technological processes, t_{ij} is technological labor intensity of the i component preform manufacture through the j technological process, P_{1ij} refers to the volume of the i component preform launch in case of the j technological process, K_{1ij}^{b} denotes the time standards of the i

component preform manufacture in case of the j technological process, F_{1ij}^0 the annual labor time reserve of the equipment exploitation in the j technological process in case of the i component preform manufacture [1,3].

In the production processing stage the volume of capital investments necessary for incorporating advanced technological processes with regard to a new product introduction can be determiend by the following formula:

$$K_2^E = \sum_{\varphi=1}^{F} \frac{U_{2\varphi} P_{2\varphi} T_{2\varphi}}{K_{2\varphi}^b F_{2\varphi}^0} \qquad (8)$$

where $U_{2\varphi}$ refers to the costs relating to the acquisition and exploitation of new equipment necessary for the implementation of the φ technological operations of processing, $P_{2\varphi}$ denotes the launch volume of the components processed during the φ technological operations, $T_{2\varphi}$ represents the technological labor intensity during the φ technological operations of processing, $K_{2\varphi}^b$ denotes the time standards of the φ technological operations of processing, $F_{2\varphi}^0$ the annual labor time reserve of the equipment exploitation during the implementation of the φ technological operations of processing[1,3].

In the early design stage determining the amount of the nonrecurring costs (capital investments) necessary for a new product introduction will enable to assess the efficiency level of the innovation processes implementation alternatives, find out the level of the organization's capacity to carry them out on its own and make an economically efficient selection.

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