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MODEL FOR PLANNING AN OPERATIONAL-INNOVATIVE PROGRAMME FOR AN INDUSTRIAL ORGANIZATION

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Abstract. *The complex nature of modern technologies and organizational solutions in modern corporations requires adequate conceptual approaches to their planning. In this paper, the authors propose a model of an operational and innovative programme for which methodological principles are formulated and a systemic formulation of the planning task designed to optimize the process of resource use, including: investment, technological, and innovative capabilities of the corporation.*
In the instrumental sense, the task of forming a production programme must be based on optimization models. Some researchers supplement the models for calculating production programmes by analysing subsystems and forming the profile of economic risk.
The purpose and essence of the proposed in this paper model of product planning in the context of continuous investment in innovation can be formulated as follows.
On the basis of a number of parameters of the forecast cycle of production of each product of the production programme, it is necessary to determine such terms for launching new products in production in order to perform tasks regarding the rate of growth of the value of the corporation, to provide basic economic and financial indicators of efficiency and sustainability within the resources allocated by the corporate budget. At the same time, it is necessary to determine the optimal volumes and rates of investment in innovations, observing, on the one hand, the balance between profitability and liquidity, on the other hand, the optimal start date for the sale of a new product in order to maximize the rent from possessing unique competencies.
Keywords: *innovations; product life cycle; production program; simulation.*

Introduction

One of the vital problems in managing a modern corporation is the construction of its economy according to an innovative production pattern (Danilin, 2006). The science lacks the methodological substantiation of the concept of building the innovative economy. Therefore, there is a need of formation of theoretical and methodological foundations for the organization and management of modern innovation-oriented corporations (Kleyner, 2012).

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The aim study is to develop a solution to the problem of planning the optimal output of products taking into account the demand and the forecast of the year of replacement of one type of product for another.

Methods. The formation of such a solution in the form of a model is methodologically based on the concept of product life cycles and the algorithm of optimization-simulation calculations. The optimization block is designed to calculate the basic variables of the model. Also, it logically links the whole algorithm of optimization-simulation calculations to a consistent iterative chain of forecasting of the production plan, financial indicators of sustainability and the need for sources of investment. At the same time, an optimization model is constructed for each iteration step.

The model assumes the formation of the most rational options for financing R & D. Under these options (strategies), we mean logically related, consistent volumes of investment for each stage of R & D, as well as the speed of production and the launch of a new product on the market.

Methodological aspects of this problem are reflected in the works on instrumental methods of research (Al-Fawzan & Al-Hargan, 2014; Baniak & Dubina, 2012; Carayannis et al., 2015; Higgins, 2012; Rosiello et al., 2013; Shichkov, 2016), i.e., on the assessment of innovative potential, the economic and mathematical modelling of innovation planning. Still, there is no clear understanding that large industrial companies are the core of development strategies (Chesbrough et al., 2006; Gurkov, 2013; Kondratyev, 2009; Schumpeter, 2003; Untura, 2013). Not enough attention is paid to the problem of efficiency of innovations from the perspective of coordination of production and innovation processes in an industrial enterprise. Methods of corporate modelling require clarification and development to become the efficient planning tools.

A production programme is the most important element of corporate planning. At that, this task allows rather clear formalization and application of programming tools of decision-making. A production programme stipulates optimum availability of resources and calculates all the technical, economic, and financial indicators and parameters. However, production planning is much more complicated for an enterprise which competitive capacity is based on innovations and a constant launch of new products. The authors take as a premise that (1) production plans should include the planning of innovations and investments in innovations; (2) assessment of investment efficiency requires a simultaneous and coordinated forecast of cash flows from all activities; and (3) the production planning shall be a long-term prospective forecast.

The research of production structures with innovative potential that allows covering all the stages of innovation process on the basis of constant renewal of products and receiving the rent during a long period of time methodologically relies on the introduced notion of an innovation-oriented corporation. This notion summarizes and systemizes those variants of defining the enterprises oriented on innovations, which are most popular in scientific literature.

Solving the problem
Model for forming an operational and innovation programme of activity of an enterprise

We will form a system optimization model of functioning and development of the enterprise, which takes into account the plans of innovation activities, funding and evaluation of parameters of stability of growth of the economy of the enterprise (Mezhov S., 2010; Mezhov I. & Mezhov S., 2011):

Let the company produce commodities, indices, where $j \in J$, x_{jt} is the volume of sales in year t, $t = 1,\dots, T$ in physical measurement units, the base price of the output is c_j, by years, taking into account the relative change in rent in the first years of new products - c_{jt}. The index j corresponds to the new product $j \in J1 \subset J$ if it does not go to replace the old products. When such a substitution is envisaged, the index j, $j \in J2 \subset J$ of the product being replaced is assigned the index $j_н \in J3 \subset J$, i.e. a lot of indices of new products, which are used to replace old products. For a while, both products can be produced simultaneously. There are two mechanisms for such replacement. One purely economic: with a decrease in demand for the old product in accordance with its life cycle, production costs increase (they are reflected as direct costs). In this case, as soon as the profit on this product does not cover the growth of overhead costs and the financing of the growth of working capital, in the model the products are “removed” from production. For new products, the release will be planned only when prerequisites are created: R & D is carried out, technical preparation of its production is carried out. The increase in sales of such products is determined by the demand and capacity, the nature and time of their development. Such a situation should be presented in the model. In the second case, a directive replacement mechanism is used, that is, parameters α_τ, $0 \le \alpha_\tau \le 1$, are specified; $\tau = 1, \dots, \tau_j$; τ_j - the period of development of new products; $\alpha_\tau = 1$ if $\tau \ge \tau_j$.

On the basis of data on the life cycle of products for each set of expected demand $M(G_{jt}^*)$, an average, standard deviation is calculated. With the help of simulation, a lot of options are set: demand for products, lower bound G^n_{jt} and upper G^w_{jt} fixed restrictions on demand:

$$G^n_{jt} \le x_{jt} \le G^w_{jt}, \quad j \in J, t = 1, 2, \dots, T \tag{1}$$

Consequently, there will be restrictions on the demand for products in each version of the calculation.

The sales volume in each variant of the calculation can be determined as follows. For the first variant of calculations:

$$U_t = \sum_{j \in J} c_{jt}\, x_{jt}\,; \tag{2}$$

for the second variant of calculations:

$$U_t = \sum_{j \in J1} c_{jt}\, x_{jt} + \sum_{j \in J2} (1 - \alpha_t)\, c_{jt}\, x_{jt} + \sum_{j \in J3} \alpha_t\, c_{j_{н},t}\, x_{j_{н},t}. \tag{3}$$

In this case, if t_j is the period of the beginning of product sales $j \in J1$, $j \in J3$, then untill the $t = t_j$ - $\alpha_t = 0$, and from the period $t = t_j + \tau_j$ - $\alpha_t = 1$.

The information for calculations is prepared for the pre-planning year $t = 0$, in which the volume of the sold commodity is fixed as U_0. Hence the indices of the growth of sales by years relative to the base period are calculated as follows:

$$u_t = \frac{U_t}{U_0} - 1; \quad t = 1, 2, \ldots, T. \tag{4}$$

All innovative changes occur on the basis of the implementation of projects (innovations) z, $z \in Z = \{1, \ldots, z^*\}$. Projects reflect the design and implementation of new products manufactured using new technology etc. are connected with the introduction of new production capacities.

Using the production capabilities of the enterprise, changing capacities through the implementation of projects (innovations, organizational and technical measures) $z \in Z$ can be taken into account as follows:

$$\sum_{j} m_{ljt}\, x_{jt} - \sum_{z} q_{lzt}\, y_{zt} \le M_{lt},\ l \in L_1, \tag{5}$$

$$\sum_{j} m_{ljt}\, x_{jt} - \sum_{Z_j} q_{lzjt}\, y_{zjt} \le 0;\ l \in L_2,\ j \in J1,\ j_{н} \in J3,\ t = 1,2,\ldots,T, \tag{6}$$

where m_{ljt} – is the time expenditure (in machine-hours, in other units) for the production of a unit of product j by exploiting the equipment of group l;

M_{lt} – is the effective fund for operating time of the equipment of group l in the planning period under review;

q_{lzt} – is the value of the change in the operating time fund for the equipment of the group l from the period t when the innovation z is introduced;

z_j – the index of the project z associated with the release of the new product j;

y_{zt}, (y_{zjt}) – are integer variables that take the value 1 if the project z, z_j is accepted for implementation, and 0 otherwise;

L_1 – a set of indices of existing groups of equipment, which is the most important one and limits and determines the production capacity (capacity) of the enterprise;

L_2 – a set of indices of newly created groups of equipment with changes in technology improving the quality of products, organizing the release of new products, etc. At the same time, if the measure z_j is not realized, the output of j cannot be realized.

Let's denote by I_t the volume of capital investments, $I_t = I_{1t} + I_{2t}$, sent to the enterprise's operational and innovation programme (OIP) in year t. Part of this investment, I_{1t}, is directed to the implementation of the set list of the largest innovative projects. The effect will be taken into account through the release of additional and new products. The other part of the investment I_{2t}, is designed to implement a still unknown set of innovations. In the case of prospective planning, the principle of two budgets is used. The profitability of such investments, h_{2q}, is determined on the basis of the work of the enterprise before the beginning of planning. The parameter h_{2q}, is given as a mathematical expectation and must change under multivariate calculations. Then the cumulative effect can be determined by taking into account the fixed lag, for example, in one year:

$$H_t = h_{2q} \sum_{\tau=1}^{t-1} I_{2\tau}, \quad H_1 = 0, t = 2, \dots, T. \tag{7}$$

Direct costs associated with the release of marketable products in the base year are fixed in value form at the level sj. Then the direct costs for the volume of the sold commodity in the year t are equal to:

$$S_{dc,t=} \sum_j s_j x_{jt}\ , \ \ t = 1,2, \dots, T. \tag{8}$$

Denote by S_{mo} - mixed overhead in the base year. As production increases, so does the overhead. On the basis of regression analysis, the forecast of the level of overhead costs is as follows:

$$S_{mo,t} \ = \ S_{mo} \ + \ \mu S_{mo} u_t + \ \sum_{\tau=1}^{t} A_\tau, \tag{9}$$

where μ is the percentage of incremental overheads with an increase in sales by one percent (μ and u are expressed by coefficients).

The value of $S_{mo,t}$ is corrected by the amount of depreciation deductions from the value of newly introduced fixed assets, $A_t = aI_{t-1}$, a, a is the weighted average depreciation rate. The increase in depreciation can be directed to investment. Cost of sales in the year t:

$$S_{cs,t} = S_{dc,t} + S_{mo,t} - H_t - H^t \qquad (9)$$

where $H^t = \sum_z h_{zt}$, h_{zt} – the cumulative cost savings from the implementation of innovations (z), not related to the commissioning of capacities and the release of new products. We denote by w_r the level of the receivables relative to the value of U_t. Then the volume of revenue V_t in year t is defined as follows:

$$V_t = (1 - w_r)U_t + w_r U_{t-1} \qquad (10)$$

The profit $P_{v,t}$ from the proceeds of production and other activities is similar. The profit from the products sold in the period t will amount to:

$$P_{s,t} = Ut - S_{cs,t} \qquad (11)$$

Part of this profit will remain in receivables. Consequently,

$$P_{v,t} = (1 - w_r) P_{s,t} + w_r P_{s,t-1} + P_{o,t} - P_{i,t}, \qquad (12)$$

where $P_{o,t}$ - level (approximate evaluation) of other profit (other losses), $P_{i,t}$ - interest payment for a loan. Hence the net income is determined: $P_{n,t} = (1\text{-}tax) P_{v,t}$.

Net income is directed to replenishment of working capital $P_{wc,t}$ and investment $P_{inv,t}$, payment of dividends $P_{div,t} = w_{div} P_{n,t}$, w_{div} - level of payment of dividends relative to net income. From here, the following condition must be satisfied: $P_{wc,t} + P_{inv,t} = P_{n,t} - P_{div,t} = P_{un,t}$ – undistributed profit. Payment of long-term loans in the amount of $P_{ltd,t}$ is made from funds for investment ($P_{inv,t}$).

Hence $I_{2q,t} = k_{2q} P_{inv,t}$ - the volume of investments from the profit, which is directed to other innovations.

Equity capital in year t is increased by the amount of retained earnings and by the amount of repayment of long-term loans in the amount of $P_{ltd,t}$ from the net income that went to finance capital investments:

$$LBL_{1t} = LBL_{1,t-1} + P_{un,t} + P_{ltd,t} \qquad (13)$$

Thus, the level of long-term liabilities is decreasing in the balance sheet by the amount of $P_{ltd,t}$, but the additional capital increases by the same amount.

The growth of working capital is determined through the level of current assets (balance sheet data)

$$A_{2t} = w_r U_{t-1} + w_{ri} S_{cs,t} \quad (14)$$

where w_{ri} - the level of stocks relative to the cost of commodity output (the standard for the past years). Then the gain:

$$\Delta A_{2t} = A_{2t} - A_{2t-1} \quad (15)$$

Denote by D_t the amount of long-term loan in year t to ensure financing of the innovation process. The loan is taken for a year, then returned. This simplifies the calculations. Then the level of the liabilities is defined as follows:

$$LBL_{2t} = LBL_{2,t-1} + D_t - P_{ltd,t}. \quad (16)$$

The volume of investments directed to the implementation of specific innovations (projects) in the year t:

$$I_{1t} = P_{inv,t}(1 - k_{2q}) + A_{inv,t} + D_t, \quad (17)$$

where $A_{inv,t}$ - the volume of depreciation allocated to investments in the year t, $A_{inv,t} \leq \sum_{r=1}^{t} \mathrm{Ar}$. Hence the level of non-current assets at the end of the period t: $A_{1t} = A_{1,t-1} - A_{inv,t} + I_t$

Given the equality of liabilities and assets of the company's balance sheet, an estimate of the value of short-term liabilities can be given:

$$LBL_{3t} = A_{1t} + A_{2t} - LBL_{1t} - LBL_{2t}. \quad (18)$$

The level of accounts payable: $AP_t = LBL_{3t} - K_t$,

K_t - level of short-term debt in the year t; the increase in accounts payable: $\Delta AP_t = AP_t - AP_{t-1}$.

The total level of interest payment for the debt is:

$P_{i,t} = \eta_{stl,t} K_t + \eta_t D_{t-1}$; $\eta_{stl,t}$, η_t - interest rates for short-term and long-term debt in year t. Since the calculations are carried out without taking into account inflation in constant prices, the parameters $\eta_{stl,t}$, η_t are set without taking inflation into account.

The growth of accounts payable serves as one of the main sources of financing working capital growth. Further, the volumes of financing the growth of working capital from profit and short-term credit are determined. The working capital gain ΔQ_t, which is financed from net profit and a short-term loan (K_t), is determined from the following restriction:

$$\Delta A_{2t} - \Delta AP_t - \Delta Q_t \leq 0 \tag{19}$$

that is, if the liabilities exceed the corresponding assets $\Delta A_{2t} - \Delta AP_t \leq 0$, then $\Delta Q_t = 0$. Then the values of $P_{wc,t}$ and K_t as sources of replenishment of current assets are found from the following condition:

$$K_t - K_{t-1} + P_{wc,t} - \Delta Q_t = 0. \tag{20}$$

The main difficulty in planning the operational and innovative activity relates to the formation and justification of the investment flow, which, in this paper, is referred to as the “investment strategy”.

All technical and economic information related to the implementation of the project z is given as a set of quantitative parameters agreed with the time of the start of the innovation investment project. The periods of development of projects are fixed by the index τ. Then the investment costs for the project $z \in Z$ are marked as $E_{z\lambda}$, $\lambda = 1, \ldots, \lambda_z^*, \lambda_z^* + \tau$; $\tau = 1, 2, \ldots, \tau_z$; λ_z^* – duration of the project, τ_z - duration of development of the project z. The values of $E_{z\lambda}$ take into account the costs of capital investments in the prices of the base year. The model should take into account the level of complexity of projects, possible deviations of such costs from planned. The engineering process is financed, mainly due to overhead costs.

The system of restrictions associated with ensuring a balance of financing the implementation of projects and cash flows in any period t will look like this:

$$\sum_Z E_{z\lambda} y_{z\nu} - I_{1t} + P_t - P_{t-1} = 0 \;\; t = 1,2,\ldots,T;\; \lambda = t - \nu + 1, \\ \nu = t_{zj} - \lambda_z^*, \ldots, t_{zj} - 1, t_{zj}, t_{zj} + 1 \tag{21}$$

where P_t are the residuals of net income expressed as a cumulative total, t_{zj} is the period from which the development of new products can be started, $t_{zj} - \lambda_z^*$ – the time from which the engineering of new products can be started.

Typically, in a real situation, investment resources are not always sufficient. However, there may be the opposite. This is why the variables P_t are introduced in the model. If they are in some years different from 0, then the remainder of the net income should be directed to the implementation of other innovations, and the effect of $h_{2q}P_t$ should be taken into account when calculating the prime cost.

Since the implementation of the project z can be started later than the time $\nu = t_{zj} - \lambda_z^*$, then the project implementation should be multivariant and allow for the following restriction: $\sum_{\nu} y_{z\nu} \leq 1,\ z \in Z$.

The optimization criteria in the model can be different. When maximizing sales volumes, unprofitable products, projects with negative net discounted income (*NPV*) can be included in the plan. Given that in market conditions the criterion for maximizing company value is more preferable, the *NPV* indicator is more suitable for solving the problems of long-term planning. For this, in the model such an indicator should be calculated. For the planned periods, we calculate net cash flows:

$$\sum_Z -E_{z\lambda} y_{z\nu} - I_{2t} - \Delta Q_t + A_t + P_{\text{чп},t} + B(-,t) - B(+,t) = 0,$$
$$t = 1, 2, \ldots, T;\ \lambda = t - \nu + 1, \nu = t_{zj} - \lambda_z^*, \ldots, t_{zj} - 1, t_{zj}, t_{zj} + 1, \quad (22)$$

where $B(-,t)$ – negative cash flow;

$B(+,t)$ – positive cash flow.

If $d_t = 1/(1 + \eta_t + r)^{t-1}$ denotes the discount coefficients, r - the level of risk of the innovative activity of the enterprise, then the net discounted income from the activity of the enterprise can be calculated as follows:

$$NPV = \sum_t d_t\,(-B(-,t) + B(+,t)). \quad (23)$$

Objective function: *NPV* → maximum.

If you fix the *NPV* cumulative total by years, you can determine the payback period of the entire innovation programme, taking into account the systemic (synergistic) effect. The evaluation of one project can be carried out by calculations without this project and with it.

The optimization task allows us to evaluate the effectiveness of not only investment projects, innovations, but also any other organizational and technical measures aimed at changing technical, economic and financial indicators, achieving their desired values.

The replacement of product j by j_* is carried out by investment strategy options. Variants of strategies are determined by the volume and rate of investment, the nature of the process of investing in R&D, the speed of increasing production to the project level and the payback time of the product. The replacement strategy is the amount of investment for each year, up to the year of the beginning of mass production.

The investment strategy of the innovation project is formally defined as the sum of two functions - financing innovative capacity and financing the innovation process:

$$S = F(S_\gamma) + F(S_\eta) \qquad (24)$$

where $F(S_\gamma)$ is the investment strategy for innovation potential;

$F(S_\eta)$ - investment strategy for the stages of the innovation process.

Then the investment strategy S_k can be specified in the following form:

$$S_k = \{I_n, M_\gamma M_\eta\}, k = 1,2 \dots K \qquad (25)$$

where S_k is the investment strategy;

I_n - the volume of invested capital;

M_γ - matrix of investment of innovative potential;

M_η - the matrix of financing the stages of the innovation process;

k is the number of strategies.

There are several options for implementing the innovation process. Then each option can be specified by the investment strategy and determine the corresponding set of matrices (Table 2).

Table 2. **Financing options for the stages of the innovation process** (the table was developed by the authors)

year t	**Number of the work performed and stages**									
	Stages of R&D									
	1.		2.			3.	4.			6.
	1	2	3	4	5	6	7	8	….	*N*
t_1	15								….	
t_2	5	25							….	
t_3		70	7	23					….	
t_4				20	20	20	5		….	
t_5						40			….	
t_6							5	15	….	
t_7							30	70	….	
t_8									….	
t_9									….	40
…..									….	…
T_n									….	40

An company can begin an innovative process from any stage: from fundamental or applied research, or, for example, by purchasing a patent, from the development of a concept product. Strategically, decision makers on innovation have a dilemma - to carry out research at the earliest stage with a large volume of projected investments for the project, to form core competencies and routines in this area and to obtain additional income (rent) or to save on investment, but to lose rents, because competitors will also produce this product.

Such parameters of the innovative project as the complexity of the product and the depth of the innovation process increase the volume of investments, while the high innovative potential contributes to their reduction. Therefore, the financing of innovation processes should focus not only on the cost of work, but also on programmes for changing the quality of assets, i.e. innovative potential of the corporation.

Conclusions

The solution of the presented task of planning the company activity for the future can be considered as optimization of planning of the company's operational and innovative activity, technical and economic and financial planning, analysis of the financial and economic state of the enterprise in dynamics with calculation of all key indicators in the model and outside it.

Such a task is of great importance both for scientific research on the development of a methodology for the sustainable development of an enterprise and for the practice of managing it. Systematic technical and economic and financial management of the company allows us to justify the prospects for its development, economically assess the options for such development, justify the magnitude of the stochastic reserve of sales, profit and other strategic indicators in order to ensure the implementation of planned key indicators.

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