FORECASTING OF RESULTS OF THE STATE-LEVEL PROJECTS IMPLEMENTATION

Igor Kononenko
National Technical University "Kharkiv Polytechnical Institute"
61002, Kharkov, Frunze Str., 21, Ukraine
E-mail: igorvkononenko@gmail.com

Igor Babich
National Technical University "Kharkiv Polytechnical Institute"
61002, Kharkov, Frunze Str., 21, Ukraine
E-mail: babich.igor.i@gmail.com

Abstract

The problem of modeling the impact of the state-level projects implementation on introduction of the newest technologies is considered in this paper. To solve this problem the simulation model of scientific and technological development of economic activity types of Ukraine is developed. This model is proposed for optimization of development plans of a particular branch of industry. It is proposed to perform optimization with the help of the developed mathematical model in which the simulation model is used for estimating the values of some parameters of the mathematical model included in the objective functions and constraints. Technique for simulating the impact of the introduction of the newest technologies in the thematic direction "Energy and Energy Efficiency" on the state of Ukrainian industry is developed.

Key words: simulation model, branch of industry, optimization model, simulation technique, the newest technologies.

JEL Classificiation: C63 - Computational Techniques; Simulation Modeling

1. INTRODUCTION

The course for the innovative development of the country's economy chosen by the government of Ukraine makes it necessary to identify priority areas for scientific and technological development of various types of economic activity. In each priority area of scientific and technological development a certain set of new technologies can be identified. The actual problem is to simulate and forecast the impact of the implementation of state-level projects, concerning the introduction of new technologies. To solve this problem the following two approaches are now widely used: Technology Foresight (Miles, 2009) and the traditional UNIDO technique for evaluation of the economic efficiency of investments (UNIDO, 1986). Despite their widespread use to predict the effect of the introduction of innovative industrial projects, these approaches have several drawbacks. For example, Foresight approach allows receiving an expert (heuristic) evaluation of the project impact, and depends largely on the experts' viewpoint in this field. This approach gives good quality estimates, but not quantitative. Different methods for evaluation of the innovative projects efficiency based on the UNIDO technique devoid this disadvantage. However, they do not incorporate the impact of project implementation in education sphere, research and development sphere, the influence of one branch of industry on another and in the end represent the impact as a set of different financial and economic indicators.

Solving the problem of adequate simulation and forecasting of the impact of the critical technologies introduction on the state of industry, education, R&D, and other requires a qualitatively different approach which is deprived of the above drawbacks. In this regard, the purpose of this work is to develop the complex technique of modeling and forecasting the impact of the critical technologies introduction, using a simulation model. Simulation model usage is explained by the complex structure of the processes relationship occurring in the real economy and will consider various aspects of the critical technologies impact on the sphere of production, employment, education, research and development, etc.

2. MATHEMATICAL MODELS FOR FORECASTING AND OPTIMIZATION OF INDUSTRY DEVELOPMENT PLANS

2.1. Simulation model of scientific and technological development of economic activity types of Ukraine

To solve this problem the simulation model of scientific and technological development of economic activity types of Ukraine (Kononenko, 2006) which was created within the State program of forecasting scientific and technological development of Ukraine is proposed to use. The model allows simulating 11 types of economic activity of Ukraine, united in the following branches of industry: Power industry; Mechanical engineering; Metallurgy; Food industry.

This simulation model contains over 2000 variables and parameters and provides a medium-term change forecast of the following parameters for any of the simulated economic activity: the volume of completed research engineering; the volume of completed development activities; the amount of fixed assets; the amount of working capital; the amount of intangible assets; the number of staff involved in production; the level of the staff shortage in production; net profit, and many others.

The whole model is built in accordance with the J. Forrester's system dynamics methodology. The structure of the simulation model is a set of blocks connected by a number of closed information flows. These flows contain data about finances, quality and quantity of staff, the structure of fixed assets and working capital, the level of applied techniques, products, and intangible assets for the main blocks of the model.

The main blocks of the simulation model include: Types of economic activity; Sphere of research engineering; Sphere of development activities; Education sphere; Trade sphere.

The providing blocks of the simulation model include: Block of the investments distribution; Block of the economic condition definition of country's economic activity type; Block that describes the demographic situation in the country; Block that simulates the budgets of all levels of the country.

Let us consider the model structure in more details. Based on the information that comes from the block of the economic condition definition of country's economic activity type, the investment policy is formed. Its essence consists in revealing the volume of investments into the country's economic activity types, sphere of development activities and sphere of research engineering, as well as in determining the share of investments in production of innovative products. It is the investments that ensure the existence and development of the mentioned institutions. Investments are directed for providing the given spheres with additional fixed assets, intangible assets and working capital. Sphere of research engineering at financing at the expense of external customers, as well as budget funds on an exit transfers scientific products to the sphere of development activities. In the sphere of development activities the scientific products with sufficient financing turn into techniques and projects which arrive in the form of intangible assets at the block which models the main economic activity types of the country. The information on functioning of economic activity type arrives at the block of the economic condition definition of country's economic activity type in which a number of financial and economic indicators are calculated. These indicators are used further for definition of an investment policy.

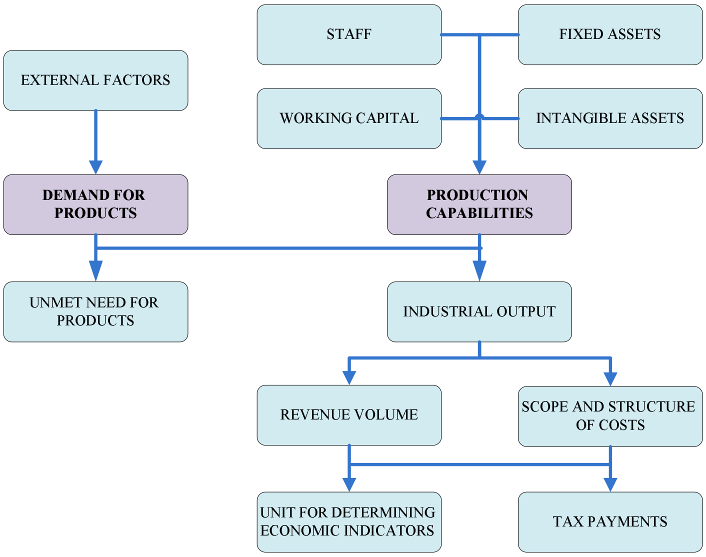
The chain described above is the main in simulation model of scientific and technological development of the country's main economic activity types. Briefly it can be described as follows: investments → research → technology → industrial products → financial indicators → investment policy formation → investments.

Another chain provides a simulation of the educational process. From the block, which describes, in particular, the age structure of the population, information about the number of people who fill up the education system is received. As a result of the education system operation, the prepared professionals are employed in economic activity types, as well as in spheres of R&D. Their work provides normal functioning of the spheres that finally affects the increase of budget funds, which are received for education system support.

Country's economic activity types are the main consumers of new techniques, projects and investments. Financial results from the operation of economic activity types are distributed according to the established priorities that determine the investment policy and expectations. Input parameters for each economic activity type are investments (private, state, local governments, internal and external - foreign), including those in the form of working capital, as well as staff, which comes from the education sphere, and intangible assets which result from the operation of R&D sphere. As a result of each economic activity type operation the industrial products, which come to the open markets of the country and abroad, are manufactured. After the sale of manufactured goods money are returned to investors. As a result of economic activity types functioning the budgets of all levels are replenished.

Let us consider the content of a standard economic activity type in the model. All types of economic activity are built on the same principle. They differ only by the configuration data. Figure 1 shows the model structure of a standard country's economic activity type.

Figure-1: Structure of a standard economic activity type in the simulation model



The most important variables that characterize the economic activity type are the "Production capabilities" and "Demand for products". Economic activity type products are divided into two groups:

- Innovative products which meet the requirements of the world market in the next 3-5 years;
- "Ordinary" products on which during the considered period of time the demand within the country is high enough but which will give way to the market of innovative products in the next 3-5 years.

The volume of demand for economic activity type products is the initial data, for which it is necessary to make the forecast for all forecasting interval before modeling beginning. For forecasting of demand for economic activity type products it is suggested to use the method developed by I.V. Kononenko and B.I. Derevjanchenko (Kononenko, 1999).

Production capabilities of economic activity type depend on four major factors: people who work in the given economic activity type, the total amount of fixed assets, the availability of working capital and intangible assets. Production capabilities represent function from these arguments. As such function it is offered to use the multiplicative Cobb-Douglas production function. Production capabilities are calculated for each product type with its own production function.

The simulation model is configured based on the official statistics and experts' data for 2000-2005. Adequacy test and verification of the simulation model is performed on the data for 2006-2007. As a criterion for estimating the accuracy of the forecast the MAPE (mean absolute percentage error) indicator was used. The average value of this indicator calculated for all the major variables in the model, equaled to 5.77%, which is a sufficiently high rate of forecast accuracy.

On the basis of experiments with the simulation model forecasting and analytical research were carried out and proposals concerning the development of scientific, technological and staff support of 11 economic activity types of Ukraine were formulated. Different development scenarios of these economic activity types were designed and simulated and key indicators forecasts of their functioning were obtained (Kononenko, 2010).

2.2. Mathematical model for development plans optimization of a branch of industry

This simulation model is proposed to use for optimization of development plans of a particular branch of industry. It is proposed to perform optimization with the help of the developed mathematical model (Kononenko, 2010) in which the simulation model is used for estimating the values of some parameters of the mathematical model included in the objective functions and constraints.

For industry development Θ measures can be used, which in a combination from one to δ create development variants, realization of each of them can be carried out in year t of the planning period. In total M development variants are analyzed.

As the measures directed to the development of the branch of industry, it is suggested to consider the state projects on introduction of the newest technologies. Thus for each measure the following parameters should be set: ω_r^i – lump-sum costs in year r from the beginning of measure i implementation ($i=\overline{1,\Theta}$); C_r^i – change of current costs in year r from the beginning of measure i implementation; K_r^i – residual value of fixed assets, which are eliminated in connection with the measure i implementation in year r.

The developed mathematical model has the following form:

1) Objective function (criterion – branch of industry profit maximization)

$$L_1=\sum_{t=1}^{T}\sum_{h=1}^{H}\alpha_t(\mathrm{V}_{1t}^{(h)}+\mathrm{V}_{2t}^{(h)})-\sum_{t=1}^{t_n}\sum_{j=1}^{\grave{I}}\sum_{r=1}^{l}\omega_{jr}\alpha_{t+r-1}\beta'_{t+r-1}x_{jt}+\sum_{t=1}^{t_n}\sum_{j=1}^{\grave{I}}\sum_{r=1}^{l}K_{jr}\alpha_{t+r-1}\beta''_{t+r-1}x_{jt}-$$

$$-\sum_{k=1}^{T} C_k\alpha_k\beta_k''' - \sum_{j=1}^{\text{ì}}\left(\sum_{r=1}^{g} C_{jr}\sum_{k=r}^{T}\alpha_k\beta_k'''\tilde{o}_{j1} + \sum_{r=1}^{g}C_{jr}\sum_{k=r+1}^{T}\alpha_k\beta_k'''\tilde{o}_{j2} + \right.$$

$$\left. + \ldots + \sum_{r=1}^{\min\{g,T-t_n+1\}} C_{jr}\sum_{k=t_n+r-1}^{T}\alpha_k\beta_k'''\tilde{o}_{jt_n}\right) - \omega_{prev} + K_{prev} - C_{prev} \to \max_{x_{jt}}, \qquad (1)$$

Objective function (criterion - minimization of the general costs of an industry on production of ordinary and innovative products)

$$L_2 = \sum_{t=1}^{t_n}\sum_{j=1}^{\text{ì}}\sum_{r=1}^{l}\omega_{jr}\alpha_{t+r-1}\beta'_{t+r-1}x_{jt} - \sum_{t=1}^{t_n}\sum_{j=1}^{\text{ì}}\sum_{r=1}^{l}K_{jr}\alpha_{t+r-1}\beta''_{t+r-1}x_{jt} + \sum_{k=1}^{T}C_k\alpha_k\beta_k''' +$$

$$+\sum_{j=1}^{\text{ì}}\left(\sum_{r=1}^{g}C_{jr}\sum_{k=r}^{T}\alpha_k\beta_k'''\tilde{o}_{j1} + \sum_{r=1}^{g}C_{jr}\sum_{k=r+1}^{T}\alpha_k\beta_k'''\tilde{o}_{j2} + \ldots + \sum_{r=1}^{\min\{g,T-t_n+1\}}C_{jr}\sum_{k=t_n+r-1}^{T}\alpha_k\beta_k'''\tilde{o}_{jt_n}\right) +$$

$$+\omega_{prev} - K_{prev} + C_{prev} \to \min_{x_{jt}}, \qquad (2)$$

Objective function (criterion - maximization of innovative products output by the branch of industry)

$$L_3 = \sum_{t=1}^{T}\sum_{h=1}^{H}\alpha_t V_{2t}^{(h)} \to \max_{x_{jt}}, \qquad (3)$$

where T – duration of the planning period of the branch of industry functioning, years; H – number of country's economic activity types, that belong to the considered branch of industry; $\alpha_t = (1+E_n)^{t_e-t}$, E_n – standard of reduction of costs and results different in time, t_e – estimated year; $V_{1t}^{(h)}$, $V_{2t}^{(h)}$ – real output estimates of ordinary and innovative products by the economic activity type of industry h in year t, based on demand. These values are defined algorithmically in the following form

$$V_{1t}^{(h)} = \begin{cases} A_{1t}^{(h)}, & if \ A_{1t}^{(h)} \le D_{1t}^{(h)}, \\ D_{1t}^{(h)}, & if \ A_{1t}^{(h)} > D_{1t}^{(h)} \end{cases} \qquad V_{2t}^{(h)} = \begin{cases} A_{2t}^{(h)}, & if \ A_{2t}^{(h)} \le D_{2t}^{(h)}, \\ D_{2t}^{(h)}, & if \ A_{2t}^{(h)} > D_{2t}^{(h)} \end{cases}$$

where $A_{1t}^{(h)}$, $A_{2t}^{(h)}$ – production capacity of economic activity type of industry h for the production of ordinary and innovative products, respectively, in year t of the planning period, monetary units, ($t=\overline{1,T}$, $h=\overline{1,H}$); $D_{1t}^{(h)}$, $D_{2t}^{(h)}$ – demand on ordinary and accordingly innovative products of economic activity type of industry h in year t of the planning period, monetary units.

Estimates of real output by the economic activity type of industry h of ordinary $V_{1t}^{(h)}$ and innovative $V_{2t}^{(h)}$ products in year t are defined with the help of the previously described simulation model. Use of the simulation model is caused by the algorithmic dependence of real output volume of branch of industry on the current system structure and the parameter values of its structural elements. The value of the current estimate of the real output volume of products is a function of the previous value of this estimate and the variants of development accepted in (g - 1) past years and in year t

$$V_{1t}^{(h)} = \Phi_1(V_{1,t-1}^{(h)},\ x_{jp}),\quad V_{2t}^{(h)} = \Phi_2(V_{2,t-1}^{(h)},\ x_{jp}),\quad (\ j = \overline{1,M}\ ,\ p = \overline{t+1-g,t}\ ),$$

where g - the maximum number of years during which the development variant j can be carried out.

t_n – start time of the last development variant realization, $t_n \leq T$; β_t', β_t'', β_t''' – coefficients that take into account the changes in year t, versus year 0 of lump-sum costs, residual cost of fixed assets and current costs, respectively, due to the changes in prices; $l = 1-t+min(t+g-1,T)$ – the last year during which the development variant j can be carried out; $\omega_{jr} = \sum_{i\in\Omega_j}\omega_r^i$ – costs for realization of the development variant j in year r from the beginning of its realization, where Ω_j – set of measures' numbers that form the development variant j; $C_{jr} = \sum_{i\in\Omega_j} C_r^i$ – change of current costs in connection with realization of the development variant j in year r from the beginning of its realization; $K_{jr} = \sum_{i\in\Omega_j} K_r^i$ – residual value of fixed assets which are eliminated in connection with realization of the development variant j in year r from the beginning of its realization;

ω_{prev} - lump-sum costs which must be incurred in the planning period in connection with the development variants accepted during the years preceding the year t=1

$$\omega_{prev} = \sum_{j=1}^{\grave{i}}\sum_{k=1}^{g-1}\alpha_k\beta_k' \sum_{p=-g+1+k}^{0}\omega_{j,-p+1+k}\tilde{o}_{jp}\ ;$$

K_{prev} - residual value of fixed assets which are eliminated in the planning period in connection with the development variants accepted during the period preceding the year t=1

$$K_{prev} = \sum_{j=1}^{\grave{i}}\sum_{k=1}^{g-1}\alpha_k\beta_k'' \sum_{p=-g+1+k}^{0}K_{j,-p+1+k}\tilde{o}_{jp}\ ;$$

C_{prev} - change of current costs in the planning period in connection with the development variants initialed in the preceding period

$$C_{prev} = \sum_{j=1}^{\grave{i}}\left(\sum_{\mu=1}^{g-1}\sum_{k=\mu}^{T}\alpha_k\beta_k''' \sum_{p=-g+1+\mu}^{0}C_{j,-p+1+\mu}\tilde{o}_{jp}\right).$$

2) Conditions of the state order execution for ordinary and innovative products of economic activity type h in all years of the planning period

$$\begin{cases} \grave{A}_{1t}^{(h)} \geq B_{1t}^{(h)} \\ \grave{A}_{2t}^{(h)} \geq B_{2t}^{(h)} \end{cases} \quad t=\overline{1,\grave{O}}, \quad h=\overline{1,H}, \tag{4}$$

where $B_{1t}^{(h)}$, $B_{2t}^{(h)}$ – the state order for ordinary and accordingly innovative products of economic activity type h in year t of the planning period.

3) Restrictions on sequence of development variants realization

$$x_{jt} cardL_j - \sum_{l \in L_j} \sum_{m=1}^{t-1} \tilde{o}_{lm} \leq 0, \quad j=\overline{1,\grave{I}}, \quad \forall t \in \{2,3,...,t_n\}, \tag{5}$$

$$x_{jt} \sum_{l \in \grave{I}_j} \sum_{m=1}^{t-1} \tilde{o}_{lm} = 0, \quad j=\overline{1,\grave{I}}, \quad \forall t \in \{2,3,...,t_n\}. \tag{6}$$

where L_j – set of development variants which should be realized before the implementation of the development variant j; M_j – set of development variants after which the development variant j cannot be implemented.

4) Restriction on number of the realized variants in each year t of the planning period

$$\sum_{j=1}^{\grave{I}} x_{jt} \leq 1, \quad t=\overline{1,t_n}. \tag{7}$$

Thus, the resulted mathematical model of development plans optimization of branch of industry of Ukraine is described by the dynamic non-Markov model (1) - (7) with algorithmic (1), (3) and analytical (2) objective functions, with algorithmic (4) and analytical (7) constraints, with Boolean variables

$$x_{jt} \in \{0,1\}, \quad j=\overline{1,M}, \quad t=\overline{1,t_n}, \tag{8}$$

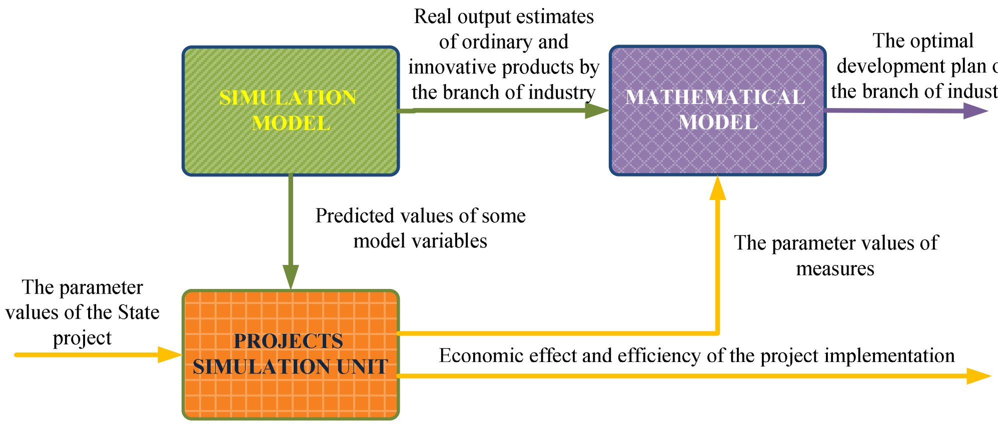
where x_{jt} =1 means that in year t the realization of the development variant j has begun; x_{jt}=0 means the opposite action.

Non-Markov character is expressed in the fact that the decision about the implementation of any development variant in year t, will have an impact on the state of the system in years t, t+1, t+2, …, t+g–1.

2.3. Simulation technique of the newest technologies introduction impact

For an estimation of numerical values of parameters of one or another measure, i.e. the state project on introduction of the newest technology, it is suggested to use the simulation technique developed by authors. This technique allows simulating the impact of the introduction of the newest technologies in the thematic direction “Energy and Energy Efficiency” on the state of Ukrainian industry. It makes it possible to predict the following impact indicators of the introduction of new technologies in the power industry and other affected industries: real output of innovative products; amount of production costs reduction due to the introduction of the newest technology; amount of the net profit increase for economic activity types affected by the implementation of the newest technology; economic efficiency of the implementation of the state project, and others. This technique is implemented as a separate unit in the simulation model. The enlarged structural diagram of the integration of simulation technique for the state projects concerning the implementation of the new technologies with the previously described simulation and mathematical model is presented in Figure 2. The arrows indicate the main streams of input and output information transmitted between the diagram elements.

Figure-2: The interaction diagram of the projects simulation unit with simulation and mathematical model



It should be noticed that in this paper, the implementation of one or another state project on introduction of the newest technology in the thematic direction “Energy and Energy Efficiency” is considered as the manufacturing process of the new technological equipment by branch-manufacturer (in this case it is mechanical engineering) for branch-customer (power industry), with the subsequent implementation of this equipment as the basic production assets by the branch-customer.

Implementation of any project is proposed to be considered as a sequence of following stages: $[t_0, t_1]$ – stage of fundamental and applied scientific research with the duration of $\tau_1=t_1-t_0$ years; $[t_1, t_2]$ – stage of the prototype development and the technology of its serial production with the duration of $\tau_2=t_2-t_1$ years; $[t_2, t_3]$ – stage of technological preparation of the industrial production of innovative products with the duration of $\tau_3=t_3-t_2$ years; $[t_3,T]$ – stage of the industrial production of the newest products with the duration of $\tau_4=T-t_3$ years; $[t_3+\Delta t,T]$ – stage of the introduction of the produced newest products into the branch of industry.

Let us consider the developed projects simulation technique for a case of a single project. It consists of the following main steps:

Step 1. Assignment of the numerical values to the parameters of the project considered: initial year of the project realization – t_0; duration of the planning period – T, years; duration of the research engineering stage – τ_1, years; duration of the development activities stage – τ_2, years; duration of the pre-production stage – τ_3, years; amount of expenses on research engineering – W_1, monetary units; amount of expenses on development activities – W_2, monetary units; lump-sum costs on production creation – W_3, monetary units; volume of demand for the given newest products by years – D_i, monetary units; per-unit cost of the newest products by year – Z_i, monetary units; amount of the total costs to produce one unit of the newest products in year i – C_i, monetary units; planned investments into production capacities of branch-manufacturer by years – Inv_k, monetary units; number of innovative human resources necessary to produce a unit of the newest products – L_0, people; productivity of the new assets – FP, product conv. units per year; the extent of the new assets workload in year r – β_r; the amount of the per-unit production variable costs in year j with the use of the new assets – $\overline{C}^{\,new\,A}_{\,j}$, monetary units; labour intensity of per-unit production with the use of the new production assets – η, people.

Step 2. Calculation of the branch-manufacturer production capacities using the equation

$$A_i = A_0 + \sum_{k=t_3+1}^{i-1} \frac{Inv_k}{\grave{I}_k} \qquad (i = \overline{t_3 + 2, T}), \tag{9}$$

where A_0 – nominal capacity of the created industry production in branch-manufacturer by means of costs W_3; Inv_k – volume of investments (monetary units) in the branch-manufacturer production capacities in year k ($k = \overline{t_3 + 1, T - 1}$); M_k – amount of money needed to increase production capacity by one unit in year k.

Step 3. Calculation of the innovative products output using the following expression

$$Q_i = \begin{cases} A_i\,, & if \;\; A_i \le D_i\,, \\ D_i\,, & if \;\; A_i > D_i \end{cases}. \tag{10}$$

Step 4. Determination of the required number of staff needed for the output of the newest products by means of the equation

$$L_i = L_0 Q_i \qquad (i = \overline{t_3 + 1, T}). \tag{11}$$

Step 5. Determination of the output rate of the newest products, taking into account the availability of staff, using the expression

$$Q_i = \begin{cases} \dfrac{-\hat{L}_i}{L_0}, & if \quad \hat{L}_i < 0 \quad and \quad L_i > -\hat{L}_i, \\ 0, & if \quad \hat{L}_i \geq 0, \\ \begin{cases} A_i, & if \ A_i \leq D_i, \\ D_i, & if \ A_i > D_i \end{cases}, & if \quad \hat{L}_i < 0 \quad and \quad L_i \leq -\hat{L}_i \end{cases} . \qquad (12)$$

where $\hat{L}_i$ - staff shortage in the field of the innovative production of the branch-manufacturer in year *i*, defined by means of the simulation model.

Step 6. Determination of the number of borrowed staff L_i^{borrow}, needed for the production of Q_i units of the newest products in year *i*, regardless of the availability of staff

$$L_i^{borrow} = \begin{cases} L_i = L_0 Q_i, & if \quad \hat{L}_i \geq 0, \\ L_i + \hat{L}_i, & if \quad \hat{L}_i < 0 \quad and \quad L_i > -\hat{L}_i, \cdot \\ 0, & if \quad \hat{L}_i < 0 \quad and \quad L_i \leq -\hat{L} \end{cases} \qquad (13)$$

Step 7. Calculation of the potentially unproduced volume of products by the branch-manufacturer in year *i*

$$Q_i^- = \frac{L_i^{borrow}}{N_i}, \qquad (14)$$

where N_i – labour intensity of per unit production of innovative products in the branch-manufacturer’s innovative production sphere in year *i*. This parameter can either acquire a constant value, i.e. N_i=const or change in time, i.e. be considered as time function $N_i=N(t_i)$, which values are calculated by means of following expression

$$N_i = \frac{L_i^{PF}}{V_i^{PF}}, \qquad (15)$$

where L_i^{PF} – the total number of staff involved in the branch-manufacturer’s innovative production sphere in year *i*; V_i^{PF} – the potential rate of the production output in natural expression in the branch-manufacturer’s innovative production sphere in year *i*. These two values are defined using the simulation model.

Step 8. Calculation of the economic benefits for the branch-manufacturer from the introduction of the newest technology

$$EFFECT = \sum_{i=t_3+1}^{T} Z_i Q_i - \left(\sum_{i=t_3+1}^{T} Q_i C_i + \sum_{j=1}^{3} W_j + \sum_{k=t_3+1}^{T-1} Inv_k \right) - \sum_{i=t_3+1}^{T} Z_i^* Q_i^-, \qquad (16)$$

where Z_i^* – the price for the branch-manufacturer innovative products in year *i* (monetary units). This parameter value is transferred from the simulation model.

Step 9. Definition of the cumulative productivity of the new assets provided their full load

$$\overline{Q}_j^{new} = FP \cdot Q_{j-\Delta t} \qquad (j = \overline{t_3 + \Delta t + 1, T}), \tag{17}$$

where Δt – time required to the implementation of the acquired in year *i* assets Q_i, number of years, $\Delta t \in [0, T - t_3 - 1]$, $\Delta t \in Z_0$.

Step 10. Calculation of the eliminated assets cost of the branch-customer in connection with the introduction of the new ones. Here the tree cases are possible: 1) Introduction of the new assets results in outflow of equivalent in cumulative productivity volume of assets used. In this case, the cost of the fixed assets eliminated in year *j* will be equal to

$$\overline{K}_j^e = \frac{\overline{Q}_j^{new}}{\overline{FP}_j}, \tag{18}$$

where $\overline{FP}_j$ – productivity of the used production assets in the branch-customer in year *j*, i.e. the number of products conv. units that are produced by per unit cost of production assets. This value is defined by means of the following expression

$$\overline{FP}_j = \frac{\overline{V}_j^{PF}}{\overline{K}_j^{PF}}, \tag{19}$$

where $\overline{V}_j^{PF}$ – the potential production output rate in natural expression in the branch-customer's innovative production sphere in year *j*. This value is defined with use of the simulation model on the basis of three-factor production function; $\overline{K}_j^{PF}$ – value of the production assets in monetary terms, used in the branch-customer's innovative production sphere in year *j*. This value does not consider the volume of the new assets that are being introduced and is also defined with use of the simulation model.

2) Available in branch-customer production assets are not eliminated in connection with the introduction of the new assets. In this case $\overline{K}_j^e = 0$;

3) Introduction of the new production assets results in outflow of smaller in cumulative productivity volume of assets used. Some variants are therefore possible:

3a) each year *j* of the planning period the volume of assets, cumulative productivity of which is proportional to the total productivity of the assets introduced is eliminated. Then

$$\overline{K}_j^e = k \cdot \frac{\overline{Q}_j^{new}}{\overline{FP}_j}, \tag{20}$$

where k – proportionality factor, $k = const \ \forall j = \overline{t_3 + \Delta t + 1, T}$, $k \in (0;1)$.

3b) each year j the volume of assets with fixed (constant) cumulative productivity is eliminated. In this case

$$\overline{K}^{e}_{j} = \frac{\overline{Q}^{fixed}_{j}}{\overline{\overline{FP}}_{j}} \ , \tag{21}$$

where $\overline{Q}^{fixed}_{j}$ – cumulative productivity of assets which are eliminated in year j, $\overline{Q}^{fixed}_{j} = const$ and $\overline{Q}^{fixed}_{j} < \overline{Q}^{new}_{j} \ \forall j = \overline{t_3 + \Delta t + 1, T}$.

3c) each year j the volume of production assets with various cumulative productivity is eliminated. In this case the cost of eliminated production assets is also calculated by means of expression (21), only provided that $\overline{Q}^{fixed}_{j} \neq const$, $\overline{Q}^{fixed}_{j} \in (0;\overline{Q}^{new}_{j})$.

Step 11. Definition of the branch-customer production costs reduction by means of the following expression

$$\Delta\overline{COSTS} = \sum_{j=t_3+\Delta t+1}^{T} (\overline{C}^{A}_{j} - \overline{C^{new}}^{A}_{j})\overline{Q''_{j}} , \tag{22}$$

where $\overline{C}^{A}_{j}$, $\overline{C^{new}}^{A}_{j}$ – variable per-unit production costs in year j with the use of the available "old" production assets and already introduced newest assets respectively; $\overline{Q''_{j}}$ – number of branch-customer products produced in year j with the use of already introduced newest assets. This value is defined as

$$\overline{Q''_{j}} = \sum_{r=t_3+\Delta t+1}^{j} \beta_r \overline{Q}^{new}_{r} \ , \tag{23}$$

where β_r – supposed production capability of the newest production assets being used in year r, $\beta_r \in [0;1] \ \forall r = \overline{t_3 + \Delta t + 1, j}$, $j = \overline{t_3 + \Delta t + 1, T}$

Step 12. Definition of the branch-customer rate of the production output increase by means of the following expression

$$\Delta\overline{Q}_{j} = \overline{Q}^{N}_{j} - \overline{Q}_{j} , \tag{24}$$

where $\overline{Q}_{j}$ – estimate of the real output volume of products in natural expression in the branch-customer's innovative production sphere in year j which is defined by means of the simulation model; $\overline{Q}^{N}_{j}$ – estimate of the real output volume of products in natural expression in the branch-customer's innovative production sphere in year j which considers the volume of the new assets that have been introduced. It is defined as

$$\overline{Q_j^N} = \begin{cases} \overline{V}_j^{new}, & if\ \overline{V}_j^{new} \le \overline{D}_j, \\ \overline{D}_j, & if\ \overline{V}_j^{new} > \overline{D}_j \end{cases}, \qquad (25)$$

where $\overline{D}_j$ – demand on innovative products of branch-customer in year *j*. This parameter value is transferred from the simulation model; $\overline{V}_j^{new}$ – the potential rate of the production output in natural expression in the branch-customer's innovative production sphere in year *j* which considers the volume of the new assets that have been introduced. This value is defined as

$$\overline{V}_j^{new} = \overline{Q'_j} + \overline{Q''_j},$$

where $\overline{Q'_j}$ – number of branch-customer products produced in year *j* with the use of the available "old" production assets. This value is calculated with the use of

$$\overline{Q'_j} = A \cdot (\overline{L}_j^{PF} - \sum_{r=t_3+\Delta t+1}^{j} \overline{L}_r^b)^{\alpha_1} \cdot (\overline{K}_j^{PF} - \sum_{r=t_3+\Delta t+1}^{j} \overline{K}_r^e)^{\alpha_2} \cdot (\overline{I}_j^{PF})^{\alpha_3}, \qquad (26)$$

where $\overline{L}_j^{PF}$, $\overline{I}_j^{PF}$ – the total number of staff and the amount of intangible assets respectively that are used in the branch-customer's innovative production sphere in year *j*. This parameter values as well as coefficient values A, α_1, α_2, α_3 are transferred from the simulation model; $\overline{L}_r^b = \eta \cdot \overline{Q''_j}$ – number of staff manufacturing products in the branch-customer's innovative production sphere in year *r* with the use of the new assets.

Step 13. Calculation of the economic benefits for the branch-customer from the introduction of the advanced technology with the help of

$$\overline{EFFECT} = \Delta\overline{INCOME} + \Delta\overline{COSTS} + \overline{K}^e - \overline{K}^{new}, \qquad (27)$$

where $\Delta\overline{INCOME} = \sum_{j=t_3+\Delta t+1}^{T} \overline{Z}_j^* \Delta\overline{Q_j}$ – additional income of the branch-customer in the planning period due to changes in output rate, where $\overline{Z}_j^*$ – the price for the branch-customer innovative products in year *j* (monetary units). This parameter value is transferred from the simulation model; $\overline{K}^e = \sum_{j=t_3+\Delta t+1}^{T} \overline{K}_j^e$ – value of the fixed production assets of the branch-customer, which are eliminated in the planning period in connection with the introduction of new assets; $\overline{K}^{new} = \sum_{i=t_3+1}^{T} Z_i Q_i$ – the cost of new production assets acquired for the implementation in the planning period.

Step 14. Determination of the effect and efficiency of the newest technology introduction by calculation of the following indicators

$$EFFECT^{\Sigma} = EFFECT + \overline{EFFECT} \quad (28)$$

$$EFFICIENCY = \frac{EFFECT^{\Sigma}}{COSTS + \overline{K}^{new}} \quad (29)$$

where $COSTS = \sum_{i=t_3+1}^{T} Q_i C_i + \sum_{j=1}^{3} W_j + \sum_{k=t_3+1}^{T-1} Inv_k$ – cumulative expenses of the branch-manufacturer in the planning period;

3. CONCLUSION

The considered models developed by the authors are proposed for use in the decision making process at the State level. Joint use of these models and the simulation technique will allow forecasting the results of the State-level projects implementation concerning the introduction of the newest technologies and developing the optimal plan for the growth of Ukraine's industry in medium-term perspective.

BIBLIOGRAPHY

Miles, I., Popper, R., Keenan, M., Georghiou, L., Harper, J.C. (2009), "The Handbook of Technology Foresight: Concepts and Practice", Edward Elgar Publishing Ltd.

Manual for Evaluation of Industrial Project. - UNIDO, Vienna, 1986

Kononenko, Igor, Anton Repin (2006), "The Modeling and Forecasting of the Technological and Innovational Development of a Transition-Economy Country", Sydney, Australia:3rd International Conference on Project Management. – 7 p.

Kononenko, Igor, Boris Derevjanchenko (1999), "Development of demand forecast for products", Kharkov: Kharkov Tecnnologies. – 14 p.

Kononenko, Igor (2010), "The forecast providing of the development programs of Ukraine", Nikolaev: Proceedings of the International Scientific Conference "Project Management: State and Prospects", pp. 146-148.

Kononenko, Igor, Igor Babich (2010), "Optimization model for development plans of Ukraine's branch of industry", *Bulletin of the National Technical University «Kharkiv Polytechnical Institute»*, Vol.67, pp. 161-170.