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Calculation and analytical instrumentarium for estimating the economic efficiency of the digital technologies development process

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Abstract. Development of digital technologies which has ultimately transformed the world economy requires a reasonable methodology for estimating economic efficiency. In this study, we tried to create methodological tools on the basis of a calculation and analytical base. Calculation-analytical algorithms of absolute and relative efficiency have been interpreted. High-priority economical (internal rate of return, discounted net profit and expenses) and program-target (coefficients of significance and efficiency) indicators have been studied. Advantages and disadvantages of the algorithm for evaluating the digital technologies efficiency in the context of the digital economy development in Russia were critically reconsidered. Economic components which reflect ROI in the process of implementing digital technologies and program-target components which characterize economic efficiency of distributing investments within the framework of the scientific-production program have been studied. Comparative analysis has been carried out in relation to the following: main goals which correspond to final results of the development process of digital technologies of industrial economic entities; secondary goals which reflect the methods of achieving main goals; and also scientific-production measures which provide implementation of secondary goals of the digital technologies development program of industrial economic entities. The advantages of the collegial decision-making technique in the sphere of development of digital technologies of industrial-production companies have been substantiated: creative thinking of qualified corporate authors, confrontation of polar scientific views, business mutual influence of experts, overcoming conformity of personal opinions and achieving scientific objectivity and validity of the scientific-production decision being made. Advantages of the functional-cost tools in digital economy have been identified: accounting of dynamics of cost flows variability for all periods of a digital technology “life cycle”, influence of stochastic market-institutional factors, neutralizing the destructive process of the capital sub-optimization for solving local business problems, stimulation of efficiency of the scientific-technical policy of the Russian Federation.

1. Timeliness of estimating the efficiency of the digital technologies development process
Managing expenses in the digital era is on the brink of serious shocks. Many foreign companies have implemented new approaches to this managing function: management on the basis of estimating the
activity, delivery capacity accounting, controlling target costs and a balanced system of indices. The efficiency of the digital technologies process development is a multi-criteria instrument-methodological category which equally integrates both finance and investment priorities and priorities of social significance of the production and business activity of modern business entities [1]. In this regard, the substantial essence of the decision can be determined by means of the following: with the help of absolute and relative indices – studying not only economical but also social, sociopolitical, cultural and historical, mental and other aspects of the programs, implemented on the alternative basis, for development of digital technologies of business entities; interpreting them by means of monetary equivalents and, thus, unifying the function-and-cost procedure of setting maximum effective variants of capital investments in modern digital economy [2].

The subject matter of the function-and-cost analysis is expressed in searching for reserves which exclude unreasonable expenses and, thereby, stimulate economic efficiency of the scientific-production program which is extremely important now as “today, enterprises are again facing significant challenges that will prove very disruptive” [3]. The function-and-cost analysis can be applied in the process of production and business activity of industrial enterprises for studying the efficiency of [4]:

1) scientific-research, design and experimental, planning and surveying and other projects;
2) innovation digital technologies used in enterprises;
3) complex target programs which are being implemented in the industrial economy and related to developing, producing and implementing high-technology science-based production.

Development of digital technologies has become the reason of growth of the compared items of expenditure which require operational accounting and analysis in real-time mode. Thus, for example, like it is in aeronautics: besides the complexity of the final product itself, one should take into account several millions of components required for producing airplanes (for comparison, about 10,000 details are required for producing an automobile in mechanical engineering) [5]. Comparative analysis of raw materials, semi-finished products and components nomenclature can potentially be very time-consuming. Besides, one should also take into account constant upgrading and improving of these details, changing of their cost. In this regard, the “calculation of cost” function is the key characteristics of competitive ability. Digital technologies have changed not only evaluation of the economic efficiency of management decisions but also the complexity of socio-economic estimation. It is connected with stiffening of regulatory requirements in the field of corporate management, with consequences of the global financial crisis which has influenced the systems of managing costs and financial control. The main peculiarity of applying the method of function-and-cost analysis of the process of developing digital technologies of industrial business entities consists in the fact that efficiency estimation is performed in two directions:

1) according to the indices of economic efficiency which reflect the payback of operational expenses;
2) according to the indices of program-target or socio-economic efficiency which characterize the effectiveness of distributing costs on the basis of final results of the process of developing digital technologies of industrial enterprises.

In all the cases of applying the function-and-cost analysis, the program is presented in the form of a functional and structural model with subsequent estimation of the efficiency of costs according to different elements and functions of this model.

2. Main calculation and analytical principles
The efficiency of the process of developing digital technologies of industrial business entities is a system concept which includes two general instrument-methodological components:

1. Economic component which reflects payback of investments in the process of implementing a scientific-production program;
2. Program-target component which characterizes socio-economic efficiency of distributing investments within the framework of the scientific-production program.
In order to characterize the economic efficiency, absolute and relative indices are applied, which are determined during the life cycle of the production and business program, – the time period from the beginning of designing and implementing the scientific and technical event till the end of beneficial use of its results [6].

Net profit value for the life cycle of a scientific and production innovation, reduced to the initial instant, is an absolute index of economic efficiency. As a relative index, it is recommended to use the internal rate of return of the innovation, equal to the interest rate able to provide equivalent size of net profit value [7].

The program-target efficiency is determined based on the structure of the program for developing digital technologies of a business entity and the importance of its final scientific-and-production results.

The program structure is presented in the form of a hierarchy system which includes three basic calculation and analytical levels:
1. The main goals which correspond to the final results of the process of developing digital technologies of industrial business entities;
2. Secondary goals which reflect the ways of achieving the main production and business goals;
3. Scientific-production events which provide implementation of secondary goals of the program.

Connections between the main and secondary scientific and production goals and also between the secondary goals and events are characterized by the following calculation and analytical parameters [8]:
1. Coefficients of relative importance which determine the relative contribution of elements of the lowest level into implementation of the upper level element.
2. Load coefficients which reflect the degree of support of different upper level elements by the element of the lowest level.

The following calculation and analytical indices are used as the indicators of program-target or socio-economic efficiency of the program for developing digital technologies of an enterprise:
1. Coefficients of socio-economic significance which characterize the contribution of scientific-production events and secondary goals into the main goals of the digital technologies development program.
2. Coefficients of socio-economic efficiency which determine the correlation: “contribution in achieving main scientific and production goals – investment expenditures”.

Indicators of the economical and program-target efficiency are determined at the level of events of the program for developing the digital technologies of an enterprise, secondary and main goals [9].

The analysis of efficiency of scientific and production events of the digital technologies development program is carried out in the following sequence:
1. Determining the structure of the digital technologies development program;
2. Calculation of indices of economic efficiency according to the program elements;
3. Calculation of program-target (socio-economical) efficiency according to the program elements;
4. General analysis of the obtained results.

3. Stages of calculating the indices of economic efficiency

Calculation of the indices of economic efficiency of the program of development of digital technologies in industrial business entities is performed in the following sequence:
1. The program events;
2. Secondary goals of the program;
3. Main goals.

At that, the indices of absolute and relative efficiency are determined at the level of scientific-production events, and at the level of secondary and main goals of the program only absolute efficiency is indicated [10].
Besides the enumerated characteristics, the values of reduced costs are determined for all the levels of the program of developing digital technologies of industrial business entities, and later they are used for analyzing socio-economic efficiency [11].

The net profit value, reduced to the initial instant, is used as an index of absolute efficiency of the suggested production and business innovations. The innovation is accepted as economically efficient if the reduced net profit value is greater than zero [12].

Discounting of the net value is performed on the basis of data on dynamics of costs and gross profit for each scientific and production event and also time parameters of its life cycle (implementation terms and beneficial use of resources).

In the case if the gross profit values and current expenditures values are constant in time, and the event implementation time is not equal to zero, then calculation of the net profit (NP) is performed in the following way:

\[
NP = \left[ (W - I)(1 - H) + A \cdot H \right] \left( \frac{1 + P}{1 + P} \right)^{T_f} - \frac{\sum_{t=1}^{T_s} K_t - L_t}{(1 + P)^{T_s}} \text{ [rub.]} \tag{1}
\]

\( W, I, A \) – correspondingly, the values of gross profit, current expenditures and amortization deductions, rub.;
\( K_t, L_t \) – the values of capital investments for the goals of implementing digital technologies and tax privileges connected with these capital investments (per year \( t \)), rub.;
\( T_s, T_f \) – correspondingly, the time for carrying out a scientific-production event and beneficial use of its results, years;
\( H \) – tax rate for profit;
\( P \) – discounting normative standard

If the period of implementation of the scientific-production innovation can be disregarded, then calculation of the net profit value gets simpler:

\[
NP = \left[ (W - I)(1 - H) + A \cdot H \right] \left( \frac{1 + P}{1 + P} \right)^{T_f} - K + L \text{ [rub.]} \tag{2}
\]

\( K \) and \( L \)– correspondingly, general values of capital investments and tax privileges, rub.

The internal rate of return (IRR) is a relative index of economic efficiency; it is recommended to use its calculation for the estimation of profitability of attracting loan funds for investing in scientific and production innovations related to the development of digital technologies, – the credit is profitable if the loan charge doesn’t exceed IRR [13].

If the cost flows are constant, capital investments are one-time and in the case if the implementation period for digital technologies must be taken into account, the following equation is used for calculating IRR:

\[
f (\omega) = \left[ (W - I)(1 - H) + A \cdot H \right] \left( \frac{1 + \omega}{1 + \omega} \right)^{T_f} - \frac{\sum_{t=1}^{T_s} K_t - L_t}{(1 + \omega)^{T_s}} \tag{3}
\]

\( \omega \)– reference values of IRR, determined by expertise

If the \( T_R \) value can be disregarded, the equation will be simplified and take the form:

\[
f (\omega) = \left[ (W - I)(1 - H) + A \cdot H \right] \left( \frac{1 + \omega}{1 + \omega} \right)^{T_f} - K + L \tag{4}
\]

The method of successive iterations is used for calculating the internal rate of return:
\[ \omega_{k,1} = \omega_k - (\omega_k - \omega_{k-1}) \cdot \frac{f(\omega_k)}{f(\omega_k) - f(\omega_{k-1})} \]  
(5)

\( \omega_k \) and \( \omega_{k,1} \) – the internal rate of return values obtained, correspondingly, at the \( k \) and \( (k-1) \) calculation step;

\( f(\omega_k) \) and \( f(\omega_{k-1}) \) – the function values determined at the \( k \) and \( (k-1) \) calculation step

Determining reduced costs indices if the cost flows are constant, capital investments are one-time and the condition \( T_R \neq 0 \) is fulfilled, which is carried out in the following way:

\[
Z = \frac{I(1-H)+(W-A)\cdot H}{P(1+P)^{T_f}-(1+P)^{T_s}} \left[ (1+P)^{T_f} - 1 \right] - \sum_{r=1}^{2} \frac{K_s - L_s}{(1+P)^{T_s}} [\text{rub.}] 
\]  
(6)

If the period of implementation of the scientific and production event can be accepted as equal to zero, calculation of the reduced costs is carried out according to the following formula:

\[
Z = \frac{I(1-H)+(W-A)\cdot H}{P(1+P)^{T_f}} \left[ (1+P)^{T_f} - 1 \right] + K - L [\text{rub.}] 
\]  
(7)

When analyzing economic efficiency it is recommended to determine the indices of the reduced net value and reduced costs for secondary and main goals of the program for development of digital technologies of industrial business entities. “One of the main objectives of the costing function is to define target costs for purchasing and manufacturing” [14].

Calculations of the reduced net profit and reduced costs for secondary goals of the program are carried out according to the following formulas:

\[
NP = \sum_{j=1}^{m} d_{jl} NP_j, j=1...m [\text{rub.}] 
\]  
(8)

\[
Z'_j = \sum_{i=1}^{n} d_{ij} Z_i, j=1...m [\text{rub.}] 
\]  
(9)

\( NP_j \) and \( Z'_j \) – correspondingly, the reduced values of net profit and costs related to the following \( j \) and secondary goal, rub.;

\( NP_i \) and \( Z_i \) – reduced net profit and costs for the \( l \) event which supports the \( j \) secondary goal, rub.;

\( d_{jl} \) – the load coefficient of the connection between the \( l \) event and the \( j \) secondary goal

Calculation of the reduced values of net profit and costs for main goals of the program of development of digital technologies are carried out in the following way:

\[
N_i'' = \sum_{j=1}^{m} b_{ij} NP'_j, i=1...k [\text{rub.}] 
\]  
(10)

\[
Z''_i = \sum_{j=1}^{m} b_{ij} Z'_j, i=1...k [\text{rub.}] 
\]  
(11)

\( N_i'' \) and \( Z''_i \) – reduced values of net profit and costs related to the \( i \) main goal, rub.;
$NP'_j$ and $Z'_j$ – reduced net profit and costs for the $j$ subgoal which supports the $i$ main scientific and production goal, rub.;

$b_{ij}$ – the load coefficient of the connection between the $j$ secondary and the $i$ main goals

4. Stages of calculating the indices of program-target efficiency

Calculation of the indices of program-target (socio-economic) efficiency of the program of development of digital technologies in industrial business entities is performed in the following sequence:

1. Main goals of the program;
2. Secondary goals;
3. Scientific and production events of the program.

Coefficients of the socio-economic significance and efficiency are used as the program-target efficiency indices. All the characteristics are interpreted for each program level. The socio-economic significance coefficients are generalizing indicators of importance of certain elements of the program for the development of digital technologies of an industrial enterprise from the point of view of priority of its main goals [15]. The significance coefficients at the level of main socio-economic goals coincide with the values of coefficients of the relative importance of these goals determined on the basis of expert estimations.

The coefficients of significance of secondary goals and events of the program are determined in the following way:

$$R'_j = \sum_{i=1}^{k} R'^*_i \cdot a_{ij}, j = 1...m$$

$$R'_l = \sum_{j=1}^{m} R'_j \cdot c_{jl}, l = 1...n$$

$R'_j$ and $R'_l$ – coefficients of significance, correspondingly, of the $j$ secondary goal and the $l$ event;

$a_{ij}$ and $c_{jl}$ – coefficients of relative importance of the connection between, correspondingly, the $i$ main and $j$ secondary goals or the $j$ subgoal and the $l$ event

Coefficients of efficiency are determined by the relation of coefficients of significance and reduced costs of individual elements of the program to the total amount of its expenditures. The higher the value of the efficiency coefficient is, the higher the socio-economic productivity of distribution of costs in this program element is.

Coefficients of efficiency of different elements of the program for the development of digital technologies – the main scientific and production goals, sub-goals and events – can be determined by means of the following formulas:

$$E'^*_i = \frac{R'^*_i \cdot Z}{Z'^*_i}, i = 1...k;$$

$$E'^*_j = \frac{R'_j \cdot Z}{Z'_j}, j = 1...m$$

$$E'_l = \frac{R'_l \cdot Z}{Z'_l}, l = 1...n$$
\( E_i^* \), \( E_j \) and \( E_l \) – coefficients of efficiency, correspondingly, of the \( i \) main and the \( j \) secondary goals and the \( l \) event of the program;
\( R_i^* \), \( R_j \) and \( R_l \) – coefficients of significance, correspondingly, of the \( i \) main and the \( j \) secondary goals and the \( l \) event;
\( Z_i^* \), \( Z_j \) and \( Z_l \) – the values of reduced costs, correspondingly, according to the goals and event of the program, rub.;

\( Z \) – the total amount of the reduced costs for the program in general, rub.

Thus, the suggested instrument-methodological solution represents a multipurpose calculation-analytical algorithm which contains both generally acknowledged finance and investment criteria (discounted net profit and costs and also internal rate of return of digital technologies), and representational socio-economic indicators (coefficients of significance and efficiency).

Practical application of the suggested calculation-analytical algorithm presupposes creating a highly qualified expert team of specialists with various scientific and production interests who are able to study the engineering and technology, investment, social and other peculiarities of modern digital technologies and make a conclusion whether it is reasonable to use each of them. As a result of such teams' activity, expert estimations of digital technologies are worked out, based on the use of professional experience, intuition, scientific potential of workers, and which represent a multipurpose method of solving problems that can't be formalized (those are the problems of digital economy).

5. Conclusions
The socio-economic coefficients of significance and efficiency, presented in the authorial instrument-methodological variant, will be based on creative innovation thinking of the competent corporate authors, confrontation of polar scientific views, business mutual influence of experts, which overcomes conformity of personal opinions and guarantees scientific objectivity, validity and significance of the scientific-production decision made with their help [15].

Absolute calculation and analytical indices of efficiency – discounted net profit and costs, – copying the fundamental patterns of digital economy, are warrantors of achieving authentic characteristics of processes of implementation of scientific-technical innovations. The internal rate of return is identical to the discount rate which equalizes profit and expenses of the programs of digital technologies development, whereby it represents a mandatory condition and attribute of their socio-economic analysis.

Applying a complex of the above-mentioned calculation and analytical characteristics – discounted profit and expenses, internal rate of return, coefficients of efficiency and significance – allows estimating economic consequences and prospects of implementation of digital technologies, present them in monetary measurement and elaborating an efficient program of their development, as applied to particular conditions of an industrial business entity. “The information generated from such activities may generate some value for the project team but is lost for longer term, strategic applications”. Calculation and analytical advantages of the suggested instrument-methodological solution in digital economy are indisputable, as the function-and-cost methodology allows to take into account the dynamics of varying cost flows of all periods of the digital technology “life cycle” in consequence of the stochastic factors’ influence, avoid the process of sub-optimization of the capital for solving local production and business problems and, thereby, stimulate efficiency of the scientific-technical policy of Russia.

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