EVALUATION OF INNOVATIVE PROJECTS IN CONTROLLING SYSTEM*

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Implementation of the controlling system onto the high-tech enterprises requires the development of specific tools for their evaluation. The models of projects estimation are offered on the article on the basis of the methods of factor analysis, linear regression analysis and fuzzy logic of Mamdani's algorithm.

Keywords: enterprise, innovative projects, model, estimation.

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ОЦЕНКА ИННОВАЦИОННЫХ ПРОЕКТОВ В СИСТЕМЕ КОНТРОЛЛИНГА

Внедрение системы контроллинга на предприятиях высокотехнологичного комплекса, требует разработки специфического инструментария их оценки. В статье предложены модели оценки данных проектов на основе использования методов факторного анализа, линейного регрессионного анализа и нечеткой логики по алгоритму Э. Мамдани.

Ключевые слова: предприятие, инновационные проекты, модель, оценка.

1. Introduction

Successful implementation of innovative projects is the determining factor in the strategic development of the industry. However, before you turn on a project in the long-term program of development of the enterprise, you must define its priorities. To solve this problem using formal mathematical methods based on accurate and adequate description of the problem situations and their analysis is not always possible [1].

Additional restrictions imposed by this external environment, which is characterized by volatility and uncertainty. Therefore, the inclusion of any innovation project in the program of innovation development of the enterprises of high-tech complex (HTC) must precede the project comparison and selection of the best of them.

2. Methods and tools for assessment of innovative projects in the controlling system of high-tech enterprises

Controlling system in enterprises HTC includes the following main elements: the vertical (functional and operational) controlling; horizontal (project) controlling, controlling external socio-economic environment (Fig. 1).

Functional and operational controlling, should be used, first and foremost, enterprise-wide of HTC, and controlling the project – for each investment or innovation project, implemented by the enterprise [2].

The system parameters of the vertical controlling involves the use of the following major groups of indicators: financial, technical, economic, innovation; human resources. Determining potential of the enterprise of HTC, its competitiveness and future possibilities is using, basically, innovation (the degree of development of innovation infrastructure, the level of innovation of technology and the equipment used, etc.), as well as human resources (expertise, staffing, quality of personnel training, etc.) indicators.

The effectiveness of any innovation project is characterized by a system of indicators that reflect the ratio of its costs and benefits. The structure of costs are included in the project provided for current and non-recurring costs of all its performers. For the valuation of outcomes and costs can be used baseline, world, forecast and target prices. At the same time inflation factor should be taken into account, which can be measured either index of price or the rate of inflation [3].

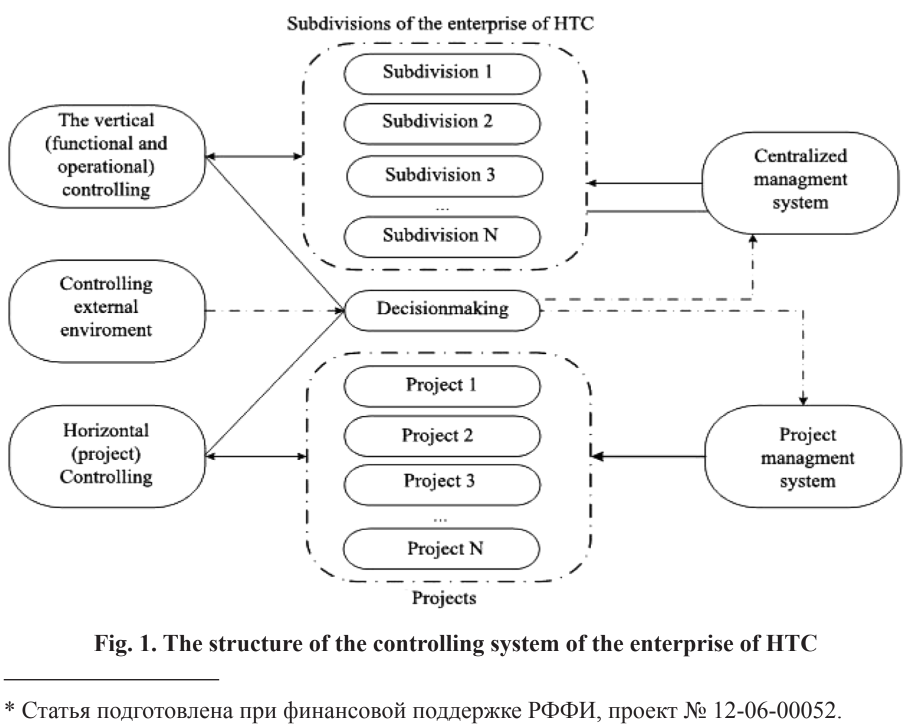

Fig. 1. The structure of the controlling system of the enterprise of HTC

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Since the same magnitude costs incurred by at the different times are not equal cost, when evaluating the comparison of the effectiveness of the innovative project of multi-temporal parameters must be achieved by bringing them to the prices in the initial period by the so-called method of the present value, or discount, that is, bringing the costs and benefits one point in time. Bringing to the reference point in time costs, results and effects it is advisable to produce by multiplying them by a certain standard that every enterprise of HTC sets or at the level of interest rate, or as a standard of profitableness of investment.

Evaluating the effectiveness of the projects is to provide the highest quality selection of them for inclusion in the program of innovative development of enterprise of HTC. When comparing innovative projects must adhere to the principle of system approach and take into account the most important property of economies – the emergence, which makes the cumulative effect of inequality on the implementation of a range of innovative projects and the magnitude of the effects at separate their conduct. An integrated approach to evaluating the effectiveness of the innovative project requires consideration of the effects of the totality of his actions.

Any innovative project is multi-faceted. The effect of its implementation can be shown to improve the quality and increase product lines (product innovation); increasing productivity and improving its conditions (technological innovation); increase the efficiency of management (institutional innovation), improving the quality of life (social innovation).

The concept of the utility of the innovative project is identified in the economic sense in an interconnected analysis of the quality and quantity of produced goods (services) and labor input (works), and changes in production costs and sales – their size and structure, income and other indicators, if implemented. The effectiveness of innovative projects is determined by their ability to save the appropriate amount of work, time and other resources per unit of all the necessary and expected beneficial effects of products and services [4].

Forming a program of innovative development of enterprise of HTC it is necessary to estimate the predicted effect of the implementation of its projects. As predicted effect $Э_t$ on t-th step (stage) an innovative project can be considered the dynamics of its cash flow (budget). In the implementation of the various activities of the project is the influx $П_t(t)$ and outflow $O_t(t)$ of cash. The difference between them (cash flow – ψ) is equal to:

$$\psi_i(t) = П_t(t) - O_t(t), \qquad (1)$$

where: i = 1, 2, 3 ... – measures the innovation project.

Annual effect $Э_Г$ of an innovative project for the year is determined as the excess of the annual revenues of the project ($Д_Г$) over its annual spending ($Р_Г$):

$$Э_Г = Д_Г - Р_Г \qquad (2)$$

The integrated effect $Э_{инт}$ of the implementation of the innovative project is calculated as the sum of the discounted projected annual effects, that is, as the excess of projected revenues integrated project $Д_{инт}$ over its integral costs $Р_{инт}$. In the event that precisely known probabilities of the various conditions of an innovative project, the expected effect of the integral must be calculated according to the formula of the expectation:

$$Э_{ож} = Э_i \times P_i, \qquad (3)$$

where: $Э_{ож}$ – expected the integrated effect of the project; $Э_i$ – the integrated effect at the i-th condition of realization; P_i – the probability of the project.

In general, the calculation of the expected economic impact of the integrated implementation of the innovative project is proposed to implement the following formula:

$$Э_{ож} = \alpha \times Э_{max} + (1 - \alpha) \times Э_{min}, \qquad (4)$$

where: $Э_{max}$ and $Э_{min}$ – the highest and lowest expectations of the integral effect on permissible probability distributions; α – a special standard to account for the effect of the uncertainty that characterizes the system preferences enterprise of HTC under conditions of uncertainty (usually equal to 0.3).

In the formation of the program of innovative development of the enterprise of HTC by incorporating the most effective and innovative projects should take into account that its effectiveness will not be equal to the sum of the efficiencies of the posted projects.

Typically, the effectiveness of an innovative project in the vast majority of cases is measured not by one but by several indicators, which are functionals depending on the values of parameters.

We denote $z_i (i = 1, n)$ the values of the innovative project and define it according to the limits for a limited parameter space, for which the following conditions: $z_{i\max} < z_i < z_{i\min}$, $(i = 1, n)$. If we assume that the structure of the draft set, the performance indicators $Э_j$ can be presented as functions of the parameter z_i, i.e. $Э_j = f(z_1, z_2, ..., z_n)$, $(j = 1, m)$. Accordingly, the set of values $Э_1, Э_2, ..., Э_n$ should be regarded as a system of m size variables defined on a set of options for innovative project.

Given the complexity of the innovation project as a control object, depending on the analytical criteria for performance evaluation of the studied parameters (factors that determine the characteristics of its constituent innovative measures) can be expressed empirically as close relationships, calculated by linear regression analysis. In this case, the analytical expression of the innovation performance of the project will be as follows:

$$Э_j = b_{j0} + \sum_{i=1}^{n} b_{ji} z_i , \qquad (5)$$

where: the coefficients of the analytical model b_{ji} are determined the least squares method on the basis of statistical data or expert.

To compare the different options of the innovative project, the figures obtained should depersonalize by rationing. We define rules to limit the minimized total. For the normalized values of x minimized indicator, the following relations: $x = 1$, if $Э \leq Э_{min}$; $x = 0$, if $Э = Э_{max}$; $x < 0$, if $Э > Э_{max}$; $x_j = x_v$, if $Э_j = Э_V$; $x_j \geq x_v$, if $Э_j < Э_V$. Similarly, the regulation establishes rules for maximized performance: $x = 1$, if $Э \geq Э_{max}$; $x = 0$, if $Э = Э_{min}$; $x < 0$, if $Э < Э_{min}$; $x_j = x_v$, if $Э_j = Э_V$; $x_j \geq x_v$, if $Э_j > Э_V$.

Formalize the problem of determining the effectiveness of the innovation project. Let discussed its variants are characterized by a set of performance indicators $Э_1, Э_2, ..., Э_m$, which are functions of the parameters $z_1, z_2, \ldots, z_n$. To compare different performance variants of the innovative project and selecting the optimal move to the vector of normalized values of parameters $X = \langle x_1, x_2, \ldots x_m \rangle$. Then the effectiveness of each option S will match the values of the normalized vector $X(S)$. Version of the innovative project, planned to implement by enterprise of high-tech complex and satisfying the constraints on the range of permissible values, that is, the conditions:

$$\begin{aligned} &Э_j(z_1, z_2, \ldots, z_n) \geq Э_{j\,min} (j = 1, r), \\ &Э_j(z_1, z_2, \ldots, z_n) \leq Э_{j\,max} (j = r + 1, r + 2, ..., s), \qquad (6) \\ &Э_j(z_1, z_2, \ldots, z_n) = Э_{j0} (j = s + 1, s + 2, ..., m) \end{aligned}$$

called admissible innovative design for its efficacy. It is assumed that under the conditions (6) the first r indices are maximized, the following (s-r) indicators are to be minimized, and the last (m-s) performance – with bilateral restrictions. The normalized parameters can be written as: $x_j(z_1, z_2, ..., z_n)$, $j = 1, m$.

Comparing the options innovative project may be the case that for some version of a performance better than the other, and on the other – is worse. In this case, we propose to use criteria based on the principle of the priority of one over the other performance indicator. It is assumed that the influence of each parameter $Э_j$ on the overall index performance of innovative project depends not only on its normalized value, but also on a weighting factor φ_j characterizing the degree of its importance.

Then a generalized indicator of the effectiveness of the innovative project can be represented as a function of the normalized values of local indicators $Э_j$ and their weights coefficients φ_j. Usually weighting values are selected by expert judgment, subject to conditions $\sum_{j=1}^{m} \varphi_j = 1$. On this basis, as a criterion for evaluating the effectiveness of the generalized innovation project ($Э_{об}$) can be measured by the following:

$$Э_{об} = \sum_{j=1}^{m} Э_j \times \varphi_j \qquad (7)$$

Application of (7) allows you to choose the most efficient version of the innovative project of the enterprise of HTC. The best option would be the one for which the index $Э_{об}$ has a maximum value [3].

The most appropriate solutions to the problem are the models based on the use of fuzzy logic algorithm by E. Mamdani, the use of which is explained by the fact that when using the classical methods of mathematics optimal solution of this problem is very difficult to get, because not always possible to make an acceptable from the point of view accuracy, its analytical description.

Characteristic of a fuzzy set membership function acts (Membership Function). We denote $MF_c(x)$ – a degree of membership to the fuzzy set C, which is a generalization of the concept of the characteristic functions of a conventional set. Then the fuzzy set C is a set of ordered pairs of the form $C = \{MF_c(x) / x\}$ and $MF_c(x)$ [0,1]. The value $MF_c(x) = 0$ means no supplies to the set and the value $MF_c(x) = 1$ – full membership in the given set.

For fuzzy sets are subject to certain logic. The most basic, necessary for the calculations are the operations of union and intersection. The intersection of two fuzzy sets (fuzzy «AND»): $A \cap B$: $MF_{AB}(x) = min(MF_A(x), MF_B(x))$. The union of two fuzzy sets (fuzzy «OR»): $A \cap B$: $MF_{AB}(x) = max(MF_A(x), MF_B(x))$.

In the theory of fuzzy sets developed a general approach to the intersection and union operators. To describe the concepts of fuzzy sets is introducing a concept of fuzzy and linguistic variables. Fuzzy variable is decribing by a set of (N, X, A), where N – is the name of a variable, X – a universal set (domain reasoning), A – fuzzy set on X. Linguistic variable values can be fuzzy variables, i.e. linguistic variable is at a higher level than the fuzzy variable.

Linguistic variables consist of a set of names and their meanings, they are called the basic term set T. The elements of a basic term-set are: the name of fuzzy variables, a universal set X; syntactic rule G, which are generated by the new terms by using the natural or formal language, semantic rule P, which each value of the linguistic variable assigns a fuzzy subset of X.

Used in various types of expertise and control systems, fuzzy inference mechanism is basically using the knowledge base formed by domain specialists in the form of a set of fuzzy predicate rules of the form: $П_1$: if x is A_1, then z is B_1; $П_2$: if x is A_2, then z is B_2; $П_n$: if x is A_n, then z is B_n, where: x – input variable (name known data values), z – variable output (the name for the data values to be calculated), A_i and B_i – fuzzy sets defined respectively by X and Z using the membership functions $\mu_{Ai}(x)$ и $\mu_{Bi}(z)$.

The mechanism of fuzzy inference in the approximation of a function z (x) can be represented by the above fuzzy predicate rules. It allows you to set the following relationship: Fact: x is A; consequence: z is B.

This output in the form of E. Mamdani algorithm can be described mathematically as follows:

1. The introduction of fuzziness (fuzzification). To this end, for a given (clear) the value of the argument $x = x_0$ are the prerequisites for the degree of truth for each rule $a_i = \mu_{Ai}(x_0)$.

2. Fuzzy inference on each rule, i.e. are "truncated" membership function for the output variable:

$$\mu_{Bi}^*(z) = \min Z[a_i, \mu_{Bi}(z)] \qquad (8)$$

The collection of innovative projects selected for the evaluation of priority

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Definition of a set of criteria for the prioritization of projects:
– Profitability of the project;
– The degree of riskiness of the project;
– The share of innovative products in total manufactured products.

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The assessment of priority projects

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Stage 1 – Processing of criteria:
– Verbal determination of levels for each criterion;
– Determination of criteria weights on the results of expert survey;
– Analysis of the results of the expert survey;
– Analysis of the consistency of the expert estimates.

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Stage 2 – Processing of fuzzy rules:
– Determination of the degree of accessories input data fuzzy subsets;
– Modification of fuzzy subsets according of their membership;
– The union of subsets of modified;
– The transition from fuzzy subsets to scalar values.

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Stage 3 – Settlement and processing of results
– Settlement with the software;
– Processing and analysis of the results;
– Decision-making.

Fig. 2. Multi-criteria evaluation model of priority innovative projects

3. Composition: with the use of MAXIMUM operation (max) that is joined to found the truncated functions, resulting in a final fuzzy subset of the output variable with membership function:

$$\mu_\Sigma(z) = \mu_B(z) = \\ = \max Z\,[\mu_{B1}^*(z), \mu_{B2}^*(z), \ldots, \mu_{Bn}^*(z)] \quad (9)$$

4. Bringing to clarity (defuzzification) to find $z_0 = F(x_0)$: usually held centroid method, i.e. precise value of the output variable is defined as the center of gravity of the curve $\mu_\Sigma(z)$:

$$z_0 = (z \times \mu_\Sigma(z)dz) : \mu_\Sigma(z)dz, \quad (10)$$

$$z_0 = \frac{\int_\Omega z \times \mu_\Sigma(z)dz}{\int_\Omega \mu_\Sigma(z)dz} \quad (11)$$

The order of selection of the innovative project is the following. Need to know: $X^* = (x_1^*, x_2^*, \ldots, x_n^*)$ – a variety of options, which are subject to multiple criteria analysis; $Y = (y_1, y_2, \ldots, y_n)$ – the set of criteria that are evaluated options. The objective is to streamline the elements of X^* on criteria set Y. Fuzzy inference algorithm by E. Mamdani performed on fuzzy knowledge base, in which the values of input and output variables are defined by fuzzy sets:

$$\bigcup_{p=1}^{k_j}\left(\bigcap_{i=1}^{n} x_i = a_{i,jp} \text{ with the weight } w_{jp}\right) \to y = d_{j,}\, j = \overline{1,m}, \quad (12)$$

where: W – domain $\mu_\Sigma(z)$.

The structure of economic-mathematical model for assessing the priority of innovative projects in the high-tech sector, is presented in Figure 2.

To describe this model, you can use the following notation: $\mu_{jp}(x_i)$ – membership function of the fuzzy set input xi to the fuzzy set $a_{i,jp}$:

$$a_{i,jp} = \int_{\underline{x_i}}^{\overline{x_i}} \mu_{jp}(x_i)/x_i,\ x_i \in \left|\overline{x_i}, \underline{x_i}\right| \quad (13)$$

Then:

$$d_j = \int_{\underline{y}}^{\overline{y}} \mu_{jp}(y)/y,\ y \in \left|\overline{y}, \underline{y}\right|, \quad (14)$$

where: $\mu_{jp}(y)$: output membership function to the fuzzy set d_j. Degrees of accessories input set of options is calculated as follows:

$$\mu_{dj}(X^*) = \bigvee_{p=\overline{1,k_j}} W_{jp} \bigwedge_{i=\overline{1,n}} \left[\mu_{jp}(x_i^*)\right],\ j = \overline{1,m}, \quad (15)$$

where: $\vee(\wedge)$ – the operation of many possible implementations of logical «OR» («AND»).

The most appropriate use of the following: for operation «OR» – finding the maximum, for an operation «AND» – finding the minimum. The result is a fuzzy set $\tilde{y}$ corresponding to the input vector X^*:

$$\tilde{y} = \frac{\mu_{d1}(X^*)}{d_1} + \frac{\mu_{d2}(X^*)}{d_2} + \ldots + \frac{\mu_{dm}(X^*)}{d_m} \quad (16)$$

Numeric (clear) the value of the output parameter y, corresponding to the input vector X^* is determined by dephasification of fuzzy sets $\tilde{y}$. The most commonly dephasification used method of center of gravity:

$$y = \frac{\int_{\underline{y}}^{\overline{y}} y \cdot \mu_{\tilde{y}}(y)dy}{\int_{\underline{y}}^{\overline{y}} \mu_{\tilde{y}}(y)dy} \quad (17)$$

3. Conclusion

The practical application of the methods considered and tools allows to obtain reliable estimates of priority innovation projects, thus reducing the risk of making ineffective decisions that could affect the stability of the innovative development of enterprises. The implementation of the developed instruments conducive to the introduction of a controlling system in enterprises of HTC.

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