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METHODOLOGY TO EVALUATE THE INNOVATIVE CAPACITY OF BUSINESS ENTITIES

The paper argues that the most effective model to evaluate the enterprise innovative capacity subject to an uncertainty factor is the model based on the fuzzy sets theory. The model has obvious advantages in comparison with the expert and statistical methods of evaluation, since it allows minimizing the evaluation errors.

Keywords: *research organizations; innovations; scientific activity; innovative potential; expert evaluation methods; fuzzy sets.*

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МЕТОДИКА ОЦІНЮВАННЯ ІННОВАЦІЙНОГО ПОТЕНЦІАЛУ СУБ'ЄКТІВ ГОСПОДАРЮВАННЯ

У статті доведено, що найбільш ефективною моделлю оцінювання інноваційного потенціалу підприємства з урахуванням чинників невизначеності є модель, заснована на теорії нечітких множин. Розроблена модель має явні переваги у порівнянні з експертними та статистичними методами оцінювання та дозволяє мінімізувати погрішність отримуваних оцінок.

Ключові слова: *наукові організації; інновації; наукова діяльність; інноваційний потенціал; експертні методи оцінювання; нечіткі множини.*

Форм. 3. Рис. 1. Табл. 6. Літ. 10.

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МЕТОДИКА ОЦЕНКИ ИННОВАЦИОННОГО ПОТЕНЦИАЛА СУБЪЕКТОВ ХОЗЯЙСТВОВАНИЯ

В статье обосновано, что наиболее эффективной моделью оценки инновационного потенциала предприятия с учетом фактора неопределенности является модель, основанная на теории нечетких множеств. Разработанная модель обладает явными преимуществами по сравнению с экспертными и статистическими методами оценки, позволяя минимизировать погрешность получаемых оценок.

Ключевые слова: *научные организации; инновации; научная деятельность; инновационный потенциал; экспертные методы оценки; нечеткие множества.*

Introduction. The effective use of innovative potential makes possible the transition of an economic system into a qualitatively new state. Such a potential of business entities is transformed into a discrete form during the innovative process ensured by subjects' activity.

One of the factors raising the scientific substantiation of innovative activity management is the evaluation of innovative potential.

Studying and evaluation of the level and trends of development of innovative potential in various sectors of national innovative system allows to identify a set of the factors and conditions necessary for steady economic development of the economy as a whole.

Development of the evaluation techniques of the innovative component in the new and developing sectors of the economy becomes more and more urgent. In practice great attention is dedicated to the evaluation of innovations and innovative activity.

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Among the existing methods it is necessary to point out the technique of a uniform statistical investigation of scientific research and development – Frascati Manual (by the Organization of Economic Cooperation and Development, OECD), the method for evaluation of the scientific and technical potential, as a component of the integrated indicator of the country's competitiveness (for the experts of the World Economic Forum, WEF), method for evaluation of the development of the innovative activity of European Union (EU), used by the experts of the Commission of the European Communities (CEC), methods of national associations of automated trade, and various factor-indicative methods, which, as a rule, are based on the generalization of statistical and analytical data, obtained from enterprises' inspections.

The usual sequence of actions in the analysis includes the following stages: problem statement; object analysis; selection of a method; elaboration process; analysis of the development results.

From the point of view of the analysis of the evaluation tools the most essential stages are the selection of an evaluation method and the process of evaluation itself.

New classifications for the evaluation of innovative potential continue to emerge. The main reason behind this is the complexity of the subject under evaluation and the indivisibility of innovative potential into independent components. The boundaries between the components are fuzzy, and frequently it is difficult to find "a dividing line". Therefore we believe, it would be correct to classify the methods, which are the basic for the evaluation of the systems of any complexity and acting as a basis for construction of the existing methodolody.

System of evaluation of the level of innovative development of business entities based on the use of heuristics and fuzzy measures of similarity. A specific feature of the proposed approach is a combination of a situational approach to decision-making, heuristic methods and algorithms based on the fuzzy sets theory. Decision-making is one of the basic components of any management process. Despite its seeming simplicity a decision-making process is not simple at all.

There are features common for any decision-making process, no matter, where it is carried out. It is a uniform core, which forms the technology for elaboration and adoption of decisions, employed in any organization. This is the common foundation, on which the decision-making theory is based. One of the specific features of such theory is the availability of the methods, allowing us process quantitative and qualitative information.

In a number of cases in the process of decision-making we have to resort to the use of an expert evaluation and fuzzy logic, intended for operation with quantitative and qualitative information.

The main aim of the expert technologies is to enhance professionalism and efficiency of the adopted administrative decisions (Malyshev and Shestakov, 2012). Today many works are devoted to the problems connected with the adoption of administrative decisions. Here we will discuss the key stages of elaboration and adoption of decisions used in organizations management.

There are different ways to present the decision-making process, on the basis of which the approaches to management are varied: systemic, quantitative, situational, and other.

As a number of authors point out (Goncharenko, 2007), the situational approach reflects more fully the problems arising in the result of an administrative activity, it is a universal approach and, in fact, it includes the basic methods connected with the adoption of management decisions contained in other approaches.

Decisions are prepared on the basis of all the available information concerning the situation, its careful analysis and evaluation.

Solving of the above tasks demands carrying out the following procedures (Zubov, 2012):

1. Proceeding from the analysis of the management objectives, a number of attributes or parameters are singled out, by which the level of an innovative development of a subject is determined.

2. For each of the above attributes an indicator is assigned corresponding to it, for example, with the values: $\alpha 1$ = "high", $\alpha 2$ = "medium", $\alpha 3$ = "low".

3. Innovative development indicators $\alpha 1$, $\alpha 2$, $\alpha 3$ together with the families of their values form a multidimensional space. During the evaluation of such a category as "innovative development of subjects", the signs are set in a hierarchy. Formation of a hierarchy begins with breaking of the system of innovative development indicators into groups of uniform indices. Such a group is called a *criterion* – all the indicators are divided into two classes – indicators and criteria. Indicators of all the hierarchal levels are placed into corresponding basic scales $\{X, Y, \ldots, Z\}$, which form a base of multidimensional space indexes, each point of which $(x0, y0, \ldots, z0)$ characterizes a certain level of innovative development of a subject.

4. The number of the levels of innovative development of a subject necessary for efficient control is determined.

5. The space of innovative development indicators is divided into reference classes, which in a general case are fuzzy. With each of these classes certain levels of such development are bound, for example, $U1$ = "high", $U2$ = "medium" and $U3$ = "low".

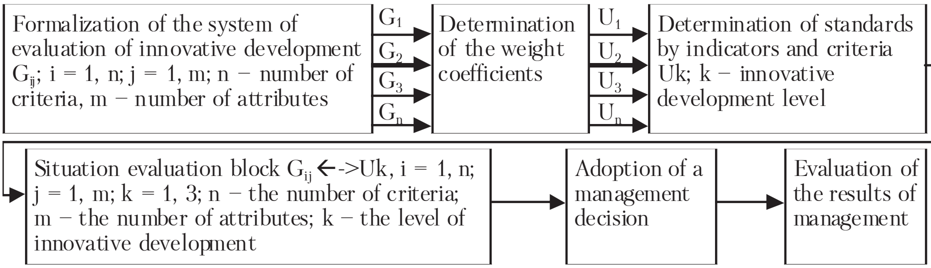
6. A qualitative structure of the model of innovative development levels is formed, for example, in the form of a decision table. In each line, in the first n columns of the table there is one of the possible sets of parameters of innovative development, and the last column contains the level of innovative development corresponding to the set.

7. Values of the parameters of a situation of management are evaluated, the set of which $(x0, y0, \ldots, z0)$ determines its position in the space of innovative development parameters.

There is, in a certain predetermined sense, the nearest to the point $(x0, y0, \ldots, z0)$ reference class, by the level of which the innovative development level is defined. Implementation of the stage demands setting in the space of innovative development parameters of the metrics or affinity measures, through which the "nearest" reference class is defined.

8. In accordance with the results and "configuration" of the parameters' values the relevant decision is made.

Multifactor model of a complex evaluation of innovative potential of business entities. The abovestated order of adoption of a management decision can be presented in a form of a block-scheme for the factorial analysis of subjects. We will divide factors by n criteria.



G_{ij} – indicators; G_i – criteria; Uk – security level decision adopted.

Figure 1. **Scheme of decision-making,** *authors development*

Elaboration of the system of balanced indicators for evaluation of the level of innovative potential and determination of their interrelation within the framework of such a model was done with the use of the determined factorial analysis, and was logically predetermined by the essence of innovative activity of the scientific-technological complex of economic zones.

n criterion of factors (groups) (G) is singled out and a scale is developed for the evaluation of every model's element, a correlation is done of the indicators' values with the corresponding values of the level of innovative potential ($G - G_{ij}$), where i is the number of criteria $i = 1, n$; j is the number of indicators $j = 1, m$ (Table 1).

The opinions found as a result of processing the expert data were averaged with the use of arithmetic mean.

$$\overline{G_i} = \frac{\sum_{i=1}^{k} G_i}{k}, \qquad (1)$$

where G_i – is a weight of a factor for i-expert; k – is the number of experts.

Table 1. **Factors for evaluation of the innovative potential component of the scientific-technological complex of economic zones**

Numbers	Groups	Indices	Indicators
G_1	Educational level	3	$G_{a1i}, i = \overline{1,3}$
G_2	Standard of well-being	2	$G_{a2i}, i = \overline{1,2}$
G_3	Level of infrastructure elements in a region	1	$G_{a4i}, i = \overline{1,1}$
G_4	Level of economic development of a region	2	$G_{a5i}, i = \overline{1,2}$

The ranged list consisting of 4 groups has 3 levels of mutual preferences (Table 2).

Table 2. **Ranged number of groups of factors by the method of direct arrangement**

Group number	Names of the factors groups	Factor rank in the list
G_1	Educational level	3
G_2	Standard of well-being	2
G_3	Level of infrastructure elements in a region	1
G_4	Level of innovation development of a region	3

Weighting factors of the list ranged by Fishbern rule with the use of a recursive scale were determined. The condition of priority of the first two groups over each other and over the third group, and an alternative of indifference of the second and the third groups is characterized by the following relation: $G_3 > G_2 > G_1 \approx G_4$.

Determination of criteria by the Fishbern Scale:

$$W_i = \frac{2\times(n-i+1)}{(n+1)\times n}, \tag{2}$$

where W_i – the value coefficient of i-indicator; i – the number of a criterion; n – the number of criteria, $i = 1, 2, ..., n$. In our case $n = 4$ (Table 3). If the indicators have equal value:

$$W_i = \frac{1}{n}. \tag{3}$$

Ranging of the investigated groups of factors is done by weighting coefficients (Table 3).

Table 3. **Weighting coefficients of the ranged groups of factors**

Group of factors	Weighting coefficients
G_1	0.25(25%)
G_2	0.30 (30%)
G_3	0.20 (20%)
G_4	0.25(25%)
Total:	1.00 (100%)

The proposed technique for a complex evaluation of an innovative potential, constructed with the use of the fuzzy sets theory, was not previously applied to the evaluation of an innovative potential for **a factorial analysis of social and economic environment** of the scientific-technological complex of economic zones.

For evaluation of the level of an innovative potential two linguistic variables are set. The first variable with the corresponding terms-subsets is introduced for the evaluation of each model element. Evaluation of each indicator is done according to the standard 3-level scale, where linguistic descriptions: low, medium and high correspond to the set intervals of the indicators values.

The above indicators have a diverse character, but, since the value of any quantity indicator is within the interval from 0 to 1, all the quantitative evaluations are bound with a linguistic variable. At that, the zero value of a fuzzy criterion is estimated as the worst of possible values, and unity – as the best. The second variable with a corresponding term-set is appropriated on the basis of data evaluation for each indicator (G) corresponding to the levels of innovative potential (LIP) by the given indicators.

It should be pointed out that in the scientific-technological complex of economic zones positive growth rates of financial and economic indices are observed. Calculations were done of the indicators' values included in the model of a complex evaluation of innovative potential of such a scientific-technological complex. For the description of factorial characteristics a standard was developed for the evaluation of factorial component of innovative potential.

Application of the method of the factorial analysis of development of RSTC during the evaluation of innovative potential (Table 4) also provides an opportunity to identify invariantly innovative products.

Table 4. **Standards for the evaluation of the indicators of the index of innovative potential**

Linguistic variable	Standard
Low (IC)	< 10%
Medium (IC)	10–75%
High (IC)	> 75%

In the course of monitoring innovative activity information about the subject of innovative potential is taken into account.

For the purpose of finding out the opportunities and effective ways for increasing the innovative potential of subjects an analysis and evaluation were carried out of innovative potential for scientific-technological complex of economic zones.

The basic directions of innovative development were determined. Statistics of the factors of scientific-technological complex of economic zones were revealed.

Table 5. **Index of Factors**

#	Economic zones	Index			
		Innovation	Education	Well-being	Infrastructure
1.	Quba-Khachmaz	0.1353314	0.01552	0.150648	0.23982595
2.	Shaki-Zaqatala	0.1552562	0.032513	0.165321	0.26793471
3.	Lankaran	0.1619498	0.04267	0.176193	0.26698667
4.	Yukhari-Karabakh	0.1659169	0.030055	0.134221	0.33347475
5.	Aran	0.1839129	0.025665	0.166893	0.35918047
6.	Ganja-Qazakh	0.2595628	0.191951	0.253392	0.33334487
7.	Nakhichevan	0.2817092	0.237058	0.198661	0.40940835
8.	Absheron	0.4974446	0.283127	0.209206	1
9.	City of Baku	0.9176619	1	1	0.7529858

The work also included the monitoring of the level of innovative potential of the scientific-technological complex of economic zones (Table 6).

Table 6. **The indicators of innovative potential of the scientific-technological complex of economic zones**

Number	Name of the group of factors	Quba-Khachmaz	Shaki-Zaqatala	Lankaran	Daglig-Shirvan	Aran	Ganja-Qazakh	Nakhichevan	Absheron	City of Baku
G_1	Educational level	Low	Low	Low	Low	Low	Medium	Medium	Medium	High
G_2	Standard of well-being	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High
G_3	Level of infrastructure elements in a region	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	High
G_4	Innovative level	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	High
Total		Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	High

This method can also be applied for the evaluation of innovative potential of various subjects.

Thus, the results of the implemented research allow us carry out the monitoring of innovative potential of business entities, which, in the long run makes it possible to control their efficiency and make reasonable strategic decisions.

Conclusions. The methods proposed in the work for a complex evaluation of innovative potential of business entities on the basis of the theory of fuzzy sets meet the requirements for obtaining reliable results under the conditions of uncertainty.

The proposed technique allows us establish a correlation between the numerical values of the indicators and the level of innovative potential, connecting them with the evaluations of linguistic variables. By means of the given technique it is possible to implement a quantitative interpretation of qualitative factors expressed in the terms of a natural language.

The methods developed for a complex evaluation of innovative potential allow us apply them to different subjects, and also carry out monitoring of its level, which makes it possible to implement control over enterprises' activity and to improve their management system to ensure their effective innovative development.

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