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Expert evaluation of innovation projects of mining enterprises on the basis of methods of system analysis and fuzzy logics

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Abstract. This paper presents the multipurpose approach to evaluation of research and innovation projects based on the method of analysis of hierarchies and fuzzy logics for the mining industry. The approach, implemented as part of a decision support system, can reduce the degree of subjectivity during examinations by taking into account both quantitative and qualitative characteristics of the compared innovative alternatives; it does not depend on specific conditions of examination and allows engagement of experts of various fields of knowledge. The system includes the mechanism of coordination of several experts' views. Using of fuzzy logics allows evaluating the qualitative characteristics of innovations in the form of formalized logical conclusions.

1 Introduction

The strategy of innovative development of the Russian Federation for the period until 2020 and the long-term program for the development of the Russian coal industry for the period until 2030 indicates the need to develop the innovative potential of coal-mining enterprises. In 2016, Kuzbass produced 227.4 million tons of coal, which is 5.4% more than in 2015. At the same time, according to expert estimates, the total area of disturbed lands covers already about 100 thousand hectares, and the area of uncultivated land has sharply increased over the past ten years. Coal mining companies require sound scientific support, new technological solutions are needed. In this regard, the actual task is to evaluate the potential of innovative projects [1].

The infrastructure of coal-mining enterprises is based on the integrated functioning of structural units in various fields of activity. Managers constantly face multidirectional tasks, decisions on which cannot be made using the same factors and models (comparison of enterprises by the level of investment attractiveness, evaluation of the effectiveness of mines, open-pit mines, coal processing plants, comparison of the competitiveness of coal grades and products of processing, comparison of the ecological state of the areas of mining operations, comparison of the technical level of mining machines and equipment, selection and evaluation of engineering and technical workers in the coal industry) [2]. The persons

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making decision on these tasks periodically face the need for an integrated assessment of the potential of innovative projects. When carrying out such an examination, a large number of functional indicators [3, 4] (mining-geological, technological, technical, economic, ecological, social) must be taken into account, which may have a different nature - quantitative and qualitative. Thus, an important task is the formation of methods and algorithms for evaluating innovation projects of mining enterprises which allow taking into account the maximum possible number of factors associated with the implementation of innovation with minimal time, labor costs and a low proportion of subjectivity.

2 Expert evaluation of innovation projects

2.1 Existing techniques of innovation projects selection and evaluation

In the Russian Federation, a system of financial support for enterprises and research teams involved in the innovative development of a particular industry is widely developed. On the territory of the Russian Federation there are various systems for competitive selection of projects and their funding: federal scientific and technical programs based on government contracts; support of initiative projects in the field of humanities and social sciences by the Russian Humanitarian Scientific Foundation (RGNF) and the Russian Foundation for Basic Research (RFFI); Support of young innovators by the Foundation for Promoting the Development of Small Forms of Enterprises in the Scientific and Technical Sphere (UMNIK), and others. As a rule, in such competitions the evaluation of innovations is carried out only on the basis of the score-expert method [5, 6], and in this connection quite often the decisions made are subjective in nature.

There are three main approaches to the examination of innovative projects, which are based on various methods: *descriptive, comparing the positions "before" and "after", and comparative*. Pros and cons of various methods result in their combined application by expert structures. But at present, there is no universal formalized methodology that would allow a qualitative and effective evaluation of projects. In addition, the analysis of existing methods of innovation management shows that there is no unified approach to the formation of the composition of the criteria for assessing their commercial potential.

2.2 Specifics of evaluation of innovation projects

Since an innovation project by its the content is an investment project aimed at modernization of any type of goods, works or services, in Russia, expert questionnaires developed on the basis of "Methodological recommendations for assessing the effectiveness of investment projects and their selection for financing" (approved by a joint decision of the State Construction Committee, the Ministry of Economy, the Ministry of Finance and the State Committee for Industry of Russia on March 31, 1994, No. 7 - 12/47) are used, as a rule, to assess innovations. At the same time, the main indicators of the effectiveness of the project are commercial efficiency, budget efficiency and economic efficiency. However, innovation projects have certain specificity in terms of assessing their efficiency, in connection with which it is necessary to take into account their difference from investment projects: the need to create objects of intellectual property, increased costs during introduction of new equipment; specific and sufficiently significant risks; use of specific forms of financing (budget, venture, etc.). Therefore, it would be wrong to fully project the methods of investment projects evaluation on the system for assessing the effectiveness of innovation. Thus, there is a need to develop an expert system for assessing the innovative potential of an enterprise, which, under uncertainty, would allow an unlimited number of criteria to be used for evaluation in comparing available alternatives, and in addition would make it possible to assess on the basis of criteria having a different nature.

It should be noted that for the evaluation of innovation projects it is advisable to use not only numerical methods of data processing [7, 8], but also to carry out a purely qualitative assessment of the situation on the basis of logical conclusions, presenting the obtained quantitative values of variables as some linguistic parameters. The advantages of using this approach include the possibility of using the expert's experience. As one of the tools for supporting decision-making in a condition of uncertainty, one can use the apparatus of the theory of fuzzy sets. The basis of the theory of fuzzy sets is the production of fuzzy logical inferences, that is, the derivation of conclusions in the form of a fuzzy set, which corresponds to the current input values using a fuzzy knowledge base and fuzzy operations [9, 10].

3 Expert evaluation of innovations using the methods of system analysis and fuzzy logics

The authors are working to create an information support system for decision-making (Figure 1) on the basis of methods of system analysis and elements of fuzzy logic.

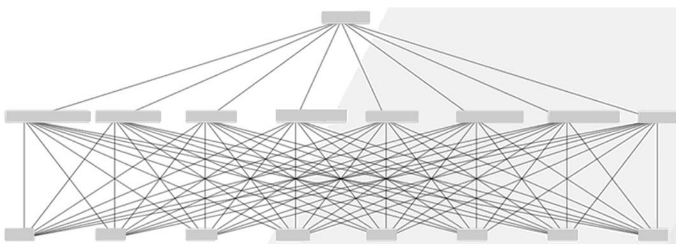

Fig. 1. Information system interface

As a result of the study, the database of characteristics and criteria for project evaluation was determined. As statistical data for filling the test information base, the project evaluation criteria were used which had been used earlier by experts at the following scientific events: competition of the Foundation for Assistance to Small Innovative Enterprises in Science and Technology - UMNIK (2015, Kemerovo), “RFFI. Regional competition SIBERIA” (RFFI - Kuzbass) (2015, Kemerovo). The results of the research showed that in most cases for the preliminary selection of projects by expert structures the following six groups of indicators were used in different combinations.

1) *Scientific and technical level of development*. This group of indicators includes evaluation of the commercial potential of development, patent protection, the relevance of the idea, the authors' awareness of the current state of the problem in this field of activity, the volume and nature of the product market.

2) *Economic efficiency of the project*: the possibility of commercialization of the results of operations, the availability of a business plan for the implementation of the project, the compliance of the volume of declared investments with the objectives of the project, the time to reach the break-even point, the projected average annual profit, the net present value, the internal rate of return, the payback period, presence of distribution risks, potential customers, increase in labor productivity.

3) *Production criteria*: the need in equipment and raw materials, the need in staff, the project's compliance with available fixed assets, the availability of a pilot sample, the degree of development of project documentation, the possibility of approbation of the results of work.

4) *Social significance*: compliance of the project with priority areas of the Russian economy development, possibility of creating new jobs, the use of labor of social categories of citizens, improving the quality of labor, developing social infrastructure, improving the level of labor safety, compliance with environmental standards and safety standards.

5) *Authors' team*: the author's initiative, assessment of capacities of the project leader and its team, scientific contribution of each team member in the problem.

6) *Project demonstration*: assessment of the quality of the prepared presentation of the results of the work / project, the extent to which the author was aware of the issues related to the project during its defense.

The methodology was developed for a comparative expertise of innovative projects, which is based on obtaining a numerical assessment of the potential of innovation projects by defining a linguistic variable for each of the above comparison criteria.

The proposed methodology using the method of analysis of hierarchies and the fuzzy logics apparatus consists of 4 stages.

Stage 1. Elimination of apparent unpromising projects.

Stage 2. Application of the method of analysis of hierarchies (MAI) T. Saati. The method consists in decomposing the problem into simpler parts and stepwise setting the priorities of the components using paired comparisons (Figure 2).

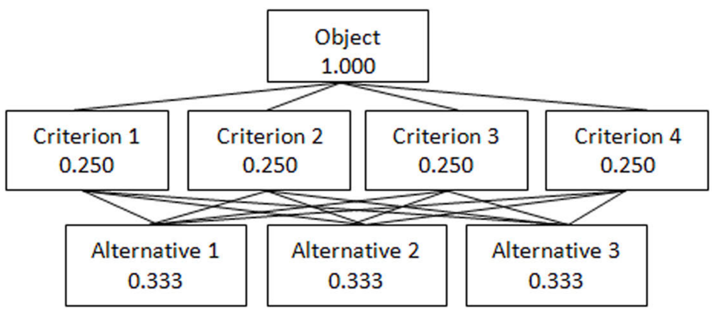

Figure 2. Hierarchy problem presentation

The method of analyzing hierarchies involves implementation of 11 stages [11, 12]:

1) Determination of the list of experts involved in the procedure of evaluating alternatives and taking decisions;
2) Decomposition of the problem in the task hierarchy;
3) Identification of the task solution evaluation criteria;
4) Construction of matrix of paired comparisons of criteria (priorities are set to each criterion based on opinion of each expert);
5) Construction of matrix of pared comparisons of alternatives with consideration of the set level of criteria importance for each decision-maker;
6) Calculation of priorities;
7) Synthesis of priorities;
8) Conformance testing;
9) Calculation of the global vector of priorities by all the levels of the hierarchy;
10) alternate selection of each of the experts for the examination in this project;
11) calculation of the final priority vector taking into account the opinion of all experts who participated in the assessment.

Stage 3. Consideration of criteria as fuzzy sets, which are given on universal sets of variants with the help of membership function in the form of triangular or trapezoidal fuzzy numbers.

Stage 4. Ranking of variants on the basis of intersection of fuzzy set-criteria, which correspond to Bellman-Zadeh scheme known in decision-making theory. When assessing indicators, experts set the lower estimates - pessimistic and the upper estimates – optimistic. Further processing of fuzzy formulated opinions of experts is proposed to be carried out by dephasing of the obtained fuzzy partial estimates and their further processing in a de-phased form [13-15].

Thus, the task of decision making under the given technique is as follows.

There is $V = \{v_1, v_2, \ldots, v_n\}$ – a set of innovative projects that are subject to multicriteria analysis;

$C = \{c_1, c_2, \ldots, c_m\}$ – a set of quantitative and qualitative criteria by which alternatives are evaluated;

$B = \{b_1, b_2, \ldots, b_k\}$ – competence of estimates k of experts conducting experts' assessment.

The problem is to arrange the elements of the set V by the criteria from the set C, taking into account the competence B of the expert estimates. For example, in the role of qualitative criteria for comparing alternatives, we will use the relevance of the idea (K1), the possibility of commercialization (K2), the stage of project elaboration (K3), the expected effective demand for products based on the use of the project (K4); evaluation of the authors' team (K5); scientific novelty (K6). In accordance with the above list of criteria, one can distinguish linguistic variables Xij, where i is the number of the alternative; j is the criterion number. We define the range for all linguistic variables as Ui = [0, 1] for i = 1, 2, 3, 4; J = 1, 2, 3, 4, 5, 6.

The sets of values of linguistic variables (term sets) for each of the criteria are formulated as follows:

$T(X_{i1})$ = the idea is not new + the project has some unique features that create unobvious technological or operational advantages + a significant part of the development is new + the proposed idea is absolutely new.

$T(X_{i2})$ = there are no prospects for the commercial implementation of the product + the market analysis is superficial, the prospects are not well grounded or are questionable + the market analysis is detailed, but the rationale for the commercial feasibility is questionable + the market analysis is detailed, the rationale for the commercial implementation is clear, the rationale for project risks and measures to reduce them don't admit of doubt;

$T(X_{i3})$ = the project is not worked out + the project is not well developed + the project is medium-developed + the project is sufficiently developed + the project is fully developed;

$T(X_{i4})$ = extremely low + low + average + high + extremely high;

$T(X_{i5})$= great experience of the authors of the project, there is a scientific capacity for the project + there is a scientific capacity for the project, but there is no experience with the authors + there is experience of research with the authors, but there is no scientific capacity for the project + there is no scientific experience with the authors of the project and scientific capacity.

Further, the following stages of the examination are expected:

- Fuzzy variables of each term set are used as qualitative estimates of alternatives according to one of the criteria;
- To obtain evaluation of the alternatives under review, the method of expert evaluation is applied and survey of the expert group is conducted;
- Using average estimates of alternatives for each of the criteria, a matrix of average estimates is formed;
- In view of the fact that the criteria have different degrees of importance, their coefficients of relative importance are determined using the hierarchy analysis method, then

the Eigen values of the matrix are calculated and the coefficients of the relative importance of the criteria are calculated;

- A fuzzy set of estimates of the criteria given by experts is modified by raising to a power corresponding to the coefficient of relative importance of the criterion;
- Calculation is made of set D needed for selection of the preferred alternative based on the Savage criterion (max (min)). To do this, select the maximum value of the indicator from the minimum for each alternative. The alternative thus obtained is given preference in selecting a project for implementation [16].

Thus, the decision-making procedure takes a clear formalized form, excluding possible subjectivity when taking into account the views of various experts.

4 Conclusion

The developed methods and algorithms were implemented as part of a decision support system that allows to take into account an unlimited number of criteria for evaluating available alternatives, to obtain an estimate based on criteria having a different nature - quantitative and qualitative by using the scales of relative comparisons of T. Saati, and it also takes into account the opinions of several experts who participate in evaluation of projects.

The use of the software reduces intellectual and time costs in the examination of available alternative scientific developments in deciding on implementation of innovation regardless of the specific field of application, the nature of the indicators, the complexity of the project being evaluated and the number of experts that will make decision making comfortable, technological, and, what is most important, effective.

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