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Development of Method and Models for Assessing Innovativeness and Competitiveness of Scientific - Innovative Projects

Galim Mutanov and Zhanna Yessengaliyeva
Department of Mechanics and Mathematics, Al-Farabi Kazakh National University, Almaty, Kazakhstan

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Abstract: In order to improve the quality of appraisal of scientific-innovative projects method and graphical model of project assessment are developed in this article. Criteria of innovativeness and competitiveness are developed, along with a graphic model allowing visualization of project assessment in the coordinate scale of the matrix model. This method allows prioritizing projects on such key indicators as innovativeness and competitiveness. The method is designed to be utilized by expert commissions responsible for venture funds, development institutes and other potential investors needing to select appropriate scientific-innovation projects.

Key words: Scientific-innovative project · Competitiveness · Innovativeness · Expert estimates · Innovation management · Ranking

INTRODUCTION

Scientific-innovative project (SIP) as a subject of analysis and appraisal. SIP are long-term investment projects characterized by a high degree of uncertainty as to their future outcomes and by the need to commit significant material and financial resources in the course of their implementation.

Any innovation is characterized by its alternative nature, uncertainty and availability of many options at all phases. Therefore it is quite a challenge to forecast innovation behavior, since this task entails assessing the integral performance index, projected future competitiveness and adaptation to the market.

In the literature on innovation, a very extensive consensus currently exists on the importance of "openness" to new ideas and solutions. Because organizing for innovation with an "open" approach is a delicate process, several studies in this research area have explored how the presence of relationships, networks, alliances and other different forms of interaction with external sources of knowledge could be crucial for innovation success ([1] and[2]). Knowledge creation is regarded as the precursor of innovation ([3] and [4]). Understanding fundamentals and life cycle of innovation process is decisive for developing appropriate frameworks that aim to improve success of innovation process [5].

Any scientific-innovative project is a complex system of actions that are interdependent but are interconnected by resources, time and performers and are aimed at achieving specific targets in priority areas of development of science and technology.

SIP must be considered as a complex of interrelated goals and objectives, each with an implementation plan and it is therefore necessary that a more detailed analysis be carried out of all project stages including operational management and that strict control be exercised over its implementation. New innovation assessment skills that permit firms to assess and implement the most appropriate technology according to their need to keep their competitiveness [6].

Innovation is "the overall process whereby an invention is transformed into a commercial product that can be sold profitably" [7]. In Schumpeter's [8] studies, discusses how economic development is driven by innovation, through dynamic processes of 'creative destruction' in which new technologies replace existing ones. Under this view, Schumpeter proposed the following forms of innovation: introduction of new goods; introduction of new forms of production; discovery of a new source of raw materials; opening of a new market; and creating new market structures in an industry.

SIP has become a prime source for gaining a competitive edge in the market. Although a large body of

Corresponding Author: Mutanov, Department of Mechanics and Mathematics, Al-Farabi Kazakh National University, Almaty, Kazakhstan.

research has addressed the question of how to successfully manage individual innovative projects, the management of a firm's new product portfolio has received comparably less research attention [9]. Developing and providing appropriate infrastructures and support systems should be focused matters in order to be efficient and effective in innovation [5].

Cooperative new product development is increasing because, within the networks of companies and organizations, innovation will be promoted through a higher availability of knowledge sharing, knowledge transfer and knowledge application [10-13]. Product program performance refers to the success of the entire portfolio of innovative projects in which a firm is involved in a certain period of time (Calantone & Rubera).

Innovation activities can hold a wide spectrum of potential opportunities for significantly improving of innovative performance [14].

Early studies such as Chandler [15] and, more recently, Mol & Birkinshaw [16] clearly show how management innovation may not only change an organization and bring potential benefits to it, but also redefine an industry by influencing the spread of new ideas.

The Essence of Innovativeness and Competitiveness. At the present stage of the global economy one of the key elements of national economic safety is to ensure "global" competitiveness, which combines competitiveness of business entities at all levels including enterprises, industries and the region's economy as a whole.

On a larger scale, overall interpretation of the term "competitiveness" refers to the ability of the system to achieve and maintain an advantageous position in a changing environment. This formulation leads to the assumption that to sustain competitiveness in the changing environment, changes in the system – innovations – are required.

Leaders may impact management innovation by reducing uncertainty and complexity associated with its pursuit [17] by communicating a shared vision, supporting change and developing a certain type of organizational culture.

A specific feature of innovation processes that result in innovation programs and projects is that they are characterized by the highest investment risk – risk that furthermore is quite difficult to assess due to the lack of effective assessment methods.

The study proceeds as follows. In the next section, we present the method and graphical model for assessing innovativeness and competitiveness of innovative projects.

MATERIALS AND METHODS

Appraisal of a SIP is an important and challenging procedure at the research and development stage. It is a continuous process that implies a possible suspension or termination of a project at any point of time when new information is obtained. Such appraisal requires a clear, formal foundation including the following components:

- Identification of factors relevant to the project;
- Assessment of project proposals as per these factors using quantitative information or expert reviews;
- Acceptance or rejection of project proposals based on the estimates obtained;
- Identification of areas that require additional information and allocation of resources needed for obtaining new information;
- Comparison of the new data with the data used in the initial appraisal;
- Assessment of how new variables will affect the project;
- Decision on whether the project will be continued or suspended/terminated.

Main factors to be taken into account in the appraisal procedure include:

- Financial results of the project implementation;
- Impact of the project in question on other projects included in the company's R&D project portfolio;
- Influence of the project on the economy of an enterprise as a whole, if it is a success.

The relationship between competitiveness and innovativeness originates from definitions of these concepts. Competitiveness can be understood as the ability of countries or companies to produce goods and services that can compete successfully on the world market. In turn, innovativeness can be understood as introduction of a new or significantly improved idea, product, service, process, or practice designed to produce a useful result. The quality of innovation is determined by the effect of its commercialization, the level of which can be determined by assessing the competitiveness of products.

There is a certain relationship between competitiveness and innovativeness. SIP being objects of two interacting segments – science and business – are formalized as two-dimensional objects with the dependence.

K=f(I),

where K is competitiveness and I is innovativeness. In a certain sense, innovative relations are the result of competitiveness, which enables us to consider competitiveness as a function of innovation. Innovativeness and competitiveness are the most meaningful indicators for the scientific-innovation project appraisal process.

Innovativeness Criteria for Innovative Projects. In the wide context, innovation is related to both development of new techniques and technology transfer. In practice these contribute to the competitiveness of the product and/or the enterprise as a whole.

Project innovativeness has to do with the “advanced nature” of technologies and solutions used, including how relevant their application is for the enterprise, region, country. High product innovativeness is associated with high technology and/or marketing discontinuity as well as high uncertainty. Perceived uncertainty is one of the most relevant characteristics of the business environment, where managers may be uncertain about the direction of future technologies and consumer preferences and may be motivated to explore new knowledge ([18, 19]). The effects of technological innovativeness are decomposed as its influence on the market, the innovating firm and the firm's environment is considered [20].

At the project level, we can say that innovativeness is the extent of demand for innovative products, subject to certain criteria. Innovation frequency, the quality of a new product is assumed to be determined by the length of the R&D process [21]. To evaluate an innovative project at the R&D stage, the following basic innovativeness criteria are suggested in Table 1:

Competitiveness determines the ability to withstand competition in comparison to similar objects in this market. Recent research on management innovation, i.e. new managerial processes, practices, or structures that change the nature of managerial work, suggests it can be an important source of competitive advantage [22].

The leading role of innovation within the structure of competitiveness factors has been acknowledged by Porter who made a significant contribution to the scientific understanding of international competition patterns [23]. Firms achieve competitive advantage by finding new ways to compete in their area of activity and bringing them to the market by producing innovations (use of new materials, new technologies, improving the means and methods of organizing the production activity) [23]. Since the outcome of a SIP is a specific product of certain type (consumer goods, services, information) to be assessed by competitiveness indicators, then in order to achieve this goal it will be necessary to define the components of product competitiveness.

Based on the data available on competitiveness components, the competitiveness criteria can be schematically presented as follows indicators in the Table 2.

Such set of criteria makes it possible to conduct an initial assessment of scientific- innovative project.

We propose a method of assessment of SIP referred to the scientific, technical and industrial sector, with a system of target indicators.

In developing the method we used a methodological approach based on expert assessment of innovation and competitiveness indicators for SIPs, accompanied by a graphic model of project innovativeness and competitiveness assessment.

Adequacy of the criteria for the complex index is determined by assigning weights to each criterion and using an additive–multiplicative method of calculation.

SIP assessment, based on the graphic model for assessing project innovativeness and competitiveness, should be carried out in three stages: a) selecting optimal criteria, b) determining weight coefficients and c) positioning projects in the McKinsey matrix [24].

The main distinctive feature of these developed indicators is that they are considered as an assessment of project viability and attractiveness to investors and depend on numerous criteria. To calculate these criteria, we propose the following method. The way to solve this task is related to determination of the average expert values for each innovativeness and competitiveness criterion. Common values of innovation and competitiveness criteria are defined as follows:

$$I_j = \sum_{i=1}^{n} x_i f_{ij}, \sum_{i=1}^{n} x_i = 1 \quad (1)$$

$$K_j = \sum_{k=1}^{m} y_k g_{kj}, \sum_{k=1}^{m} y_k = 1 \quad (2)$$

$$I_{\min} \le I_j \le I_{\max}, K_{\min} \le K_j \le K_{\max}, \quad (3)$$

Table 1: Criteria of innovativeness

##	Innovativeness criteria
1	Compliance of a project with the priority areas of industrial and innovation strategy.
2	Relevance of research and product uniqueness (no analogues).
3	Scientific originality of the solutions proposed within the project.
4	Technological level of the project (technology transfer, new technology).
5	Advantages of the project in comparison with analogues existing in the world.
6	Economic feasibility of the project.

Table 2: Criteria of competitiveness

##	Competitiveness criteria
1	Availability of markets and opportunities to commercialize the proposed project results
2	Level of competitive advantages of R&D results and opportunities to retain them in the long-run
3	Consistency with the existing sale outlets (distribution channels)
4	Patentability (possibility to defend the project by using the patent)
5	Availability of proprietary articles
6	Availability of scientific and technical potential of the project
7	Technical feasibility of the project
8	Project costs
9	Degree of project readiness
10	Availability of a team and experience in project implementation
11	Opportunities to involve private capital (investment attractiveness)
12	Scientific and technical level of project

where,

f_{ij} - Is the value of

i - Th criterion of the

j - Th project for the innovativeness indicator;

x_i – Value of weighting coefficient of i-th criterion for the innovativeness indicator;

n – Number of criteria for the innovativeness indicator;

g_{kj} – Value of the k-th criterion of j-th object (project) for the competitiveness indicator;

y_k – Value of weighting coefficient of the k-th factor for the competitiveness indicator;

m – Number of criteria for the competitiveness indicator;

$j=1,J$ – With J being the number of objects (projects);

I_{min}, I_{max}, K_{min}, K_{max} – minimum and maximum values of the innovativeness and competitiveness indicators.

In the graphic model for assessing project innovativeness and competitiveness, the range of indicators is split into 9 sectors.

In this case, in order to position each project, it is required to define I and K parameters, which are the coordinates of these projects in the matrix. To determine the coordinates in the model we use weighted average factors (criteria). It is recommended that the values for each factor be assessed using the expert approach (from 1 to 9); in the presence of several experts, the values are averaged.

To formalize the criteria rating, expert estimates are the most suitable tool because they contain a complex of logic, mathematical and statistical procedures and are based on knowledge of professionals.

To determine the weighting coefficients for each criterion and their ranking we used the ranking method.

While ranking, the initial ranks are transformed as following: each rank equal to quantity of criteria dividing to initial rank. Then totals are calculated by these transformed ranks:

$$R_J = \sum_{K=1}^{M} R_{JK} \div M, \quad (4)$$

where

R_J = The average of the ranks converted across all the experts for j-th factor;

R_{JK} = Converted rank assigned by k-th expert to j-th factor; and

M = Number of experts.

Next, the weights of criteria are calculated:

$$W_J = R_J \div \sum_{J=1}^{N} R_J, \quad (5)$$

where

W_J – Is the average weight of criterion across all the experts;

N – Is the number of criteria.

Consistency of expert assessments by criteria was verified by calculating the coefficients of factor variations, which are the analogous to dispersion and represented in the following formula:

$$S = \sum_{i=1}^{n} \left\{ \sum_{j=1}^{m} x_{ij} - \frac{1}{2} m(n+1) \right\}^2 , \quad (6)$$

where
S is the factor variation coefficient;
x_{ij} - the rank of i-factor assigned by j-expert;
m - number of experts; n - number of criteria.

Since experts come from various entities or groups, there is a need to identify homogeneity of these groups. To solve this problem across various criteria, derived from experts, the consistency of their views is determined by using concordance coefficient. W concordance coefficient is calculated by using the formula proposed by Kendall:

$$W = \frac{12 \cdot S}{m^2 \cdot \left(n^3 - n\right)}, \quad (7)$$

where S - the sum of squared differences (deviations); m - number of experts; n - number of criteria.

In the case where any expert fails to identify the rating value between several related factors and assigns the same rank, the concordance coefficient is calculated by using the following formula:

$$W = \frac{S}{\frac{1}{12} m^2 (n^3 - n) - m \sum_{j=1}^{m} T_j}, \quad (10)$$

where,

$$T_j = \frac{1}{12} \sum_{t_j} (t_{j^3} - t_j), \quad (9)$$

t_j is the number of equal ranks in the series j.

RESULTS

Based on the above, to calculate criteria values the questioning of 22 experts was undertaken. In qualitative terms, the experts were managers, specialists of scientific research and innovation managers.

The questionnaire was compiled based on the two sets of criteria outlined above. The total number of questionnaires was 22.

Criteria ranking was quite simple: By assigning the highest ranking to the criterion of the lowest value, in their opinion. Importance (rank) of each criterion is determined by the average estimated value and the sum of ranks of expert assessments.

The expert evaluation results make it possible to obtain weighting coefficients to determine positioning of SIP in the matrix.

Weights are demonstrate the importance of each criterion. These data indicate that expert evaluations for each group of the criteria differ by their significance.

For innovativeness indicators these weights are calculated and presented in the Table 3:

For competitiveness indicators, weight coefficient values are as follows: 0.277, 0.119, 0.033, 0.060, 0.067, 0.067, 0.040, 0.037, 0.041, 0.142, 0.057 and 0.061. Within this group, the criteria are the following: the first one is availability of the market and opportunities to commercialize the proposed project results; the second, availability of a team of qualified specialists having experience in project implementation; the third, level of competitive advantages of R&D results and potential to retain them in the long-run; the fourth, availability of proprietary articles; and the fifth criterion is availability of scientific and technological potential, etc.

W-Kendall concordance coefficient equal 0.69, that means good degree of coherence of rankings.

The next stage involves positioning of projects within the graphic model of innovativeness and competitiveness of SIP.

As an example, two projects have been chosen for further assessment by experts by the criteria of innovativeness and competitiveness. The assessments of innovativeness and competitiveness indicators averaged across five experts.

Based on these averaged assessments and weighting coefficients, SIPs were positioned in the graphical model for innovativeness and competitiveness of SIPs. The obtained weights and assessment criteria are presented in Tables 4 and 5.

The resulting matrix allows positioning each SIP based on the criteria of innovativeness and competitiveness indicators in a certain sector. Matrix boundaries are the maximum and minimum possible values from 1 to 9, respectively.

Three groups are highlighted in this matrix (Figure 1): 1) “leader”; 2) the “outsider”; and 3) the ”border.”

Table 3: Calculation of weight coefficients and definition of ranks of estimation of SIP

##	Criteria	Average of ranks	Weights	Rank
1	Compliance of a project with the priority areas of industrial and innovation strategy.	3,35	0,228	3
2	Relevance of research and product uniqueness (no analogues).	3,70	0,252	1
3	Scientific originality of the solutions proposed within the project.	1,50	0,102	5
4	Technological level of the project (technology transfer, new technology).	1,54	0,105	4
5	Advantages of the project in comparison with analogues existing in the world.	1,02	0,069	6
6	Economic feasibility of the project.	3,59	0,244	2

Table 4: Utility estimate for Projects 1 and 2 based on the innovativeness indicators

Criteria	Criteria weights	Criteria values (averaged assessment) Project #1	Criteria values (averaged assessments) Project #2	Normalized estimate of priority vector, Project #1	Normalized estimate of priority vector, Project #2
1) Compliance of project with the priority directions of industrial and innovation strategy	0.228	3.6	4.2	1.56	1.96
2) Research novelty and project uniqueness (no analogues)	0.252	3.6	3.6	1.27	2.12
3) Scientific novelty of the solutions proposed within the project	0.102	4	3.8	0.44	0.90
4) Project technological level (new technology)	0.105	3.8	3.2	0.38	0.88
5) Project advantages as compared with the existing comparables in the world	0.069	3	3.2	0.22	0.57
6) Economic feasibility of the project	0.244	2	3.8	1.67	2.10
Total	1	20	21.8	5.54	8.52

Table 5: Utility estimate for Projects 1 and 2 based on competitiveness indicators

Criteria	Criteria weights	Criteria values (averaged assessment), Project 1	Criteria values (averaged assessments), Project 2	Normalized estimate of priority vector, Project 1	Normalized estimate of priority vector, Project 2
1) Availability of market and opportunities to commercialize the proposed project results	0.277	3	4.2	1.59	2.21
2) Level of competitive advantages of R&D results and possibility for their continuous preservation	0.119	3	3.4	0.47	0.93
3) Consistency with the existing distribution channels	0.033	3.4	3.4	0.10	0.25
4)Patentability (opportunities to defend the project by using the patent)	0.060	3.4	3.4	0.26	0.44
5) Availability of the object of intellectual property	0.067	3.2	3.8	0.24	0.55
6) Availability of scientific and technical potential of the project	0.067	3.6	3.6	0.29	0.52
7) Technical feasibility of the project	0.040	3.8	3.8	0.16	0.30
8) Project costs	0.037	3	3.2	0.24	0.31
9) Degree of project readiness	0.041	3.8	3.4	0.19	0.33
10)Availability of qualified specialists and experience in project implementation	0.142	4.6	4.4	0.71	1.19
11) Opportunities to involve private capital (investment attractiveness)	0.057	3.2	3.6	0.20	0.48
12) Scientific and technical level of project	0.061	3.8	3	0.18	0.41
Total	1	41.8	43.2	4.63	7.92

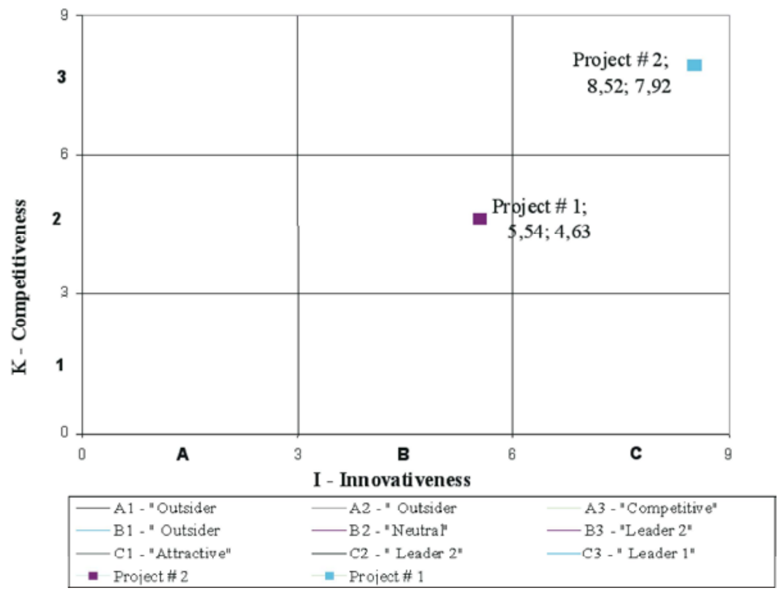

Fig. 1: Example of projects positioning in graphic model

Projects that fall into group of “leaders” have the highest values of innovativeness and competitiveness indicators as compared with the other two groups; they are the absolute priority to be implemented at the earliest possible time.

Projects that fall into the three sections in the lower left corner of the matrix (“outsiders”) have low values based on many criteria. These projects are problematic as they have more weaknesses than strengths.

The three sections located along the main diagonal, going from lower left to upper right edge of the matrix have the classical name of “border”: these include the competitive sector (at low attractiveness), attractive (at low competitiveness) and neutral. These projects are promising and require finalization work.

DISCUSSION

To achieve competitive advantage, firms must find new ways to compete in their niche to enter the market in the only possible way: through innovation. Innovations in the broadest sense include use of new materials, introduction of new technologies and improving means and methods of production activities. Thus innovation equally includes R&D results of production purposes and results geared at improving the organizational structure of production. Any innovation activity requires, above all, investments in various production factors: production infrastructure and marketing, training of personnel and development of their skills and knowledge in technology, including research developments.

Our results also suggest that R&D efforts play an important role in affecting product innovation.

As a solution, this method and graphical model let us select the project whose normalized estimates of priority vectors by value occupy the “Leader 1” section. Such an alternative is Project #2, which according to experts is a priority and ready for implementation.

Project #1 is neutral in the matrix; it is promising, but has some shortcomings that need to be worked on.

In this way, this method allows prioritizing projects on such key indicators as innovativeness and competitiveness.

CONCLUSION

Innovative activity is a critical determinant of competitive advantage [25]. The study of the conceptual framework of innovativeness and competitiveness has brought us to the following conclusions:

- Competitiveness is an estimated parameter; therefore, it presupposes the availability of a subject (who estimates) and an object (which is estimated), as well as objectives (criteria) of estimation. Competitiveness is the key indicator characterizing significance of an object;
- Innovation is the key factor affecting competitiveness;

- Various parameters (criteria) of competitiveness assessment are used when assessing competitiveness of a specific object, depending on the level of its hierarchy (product, company, region, country).
- Project innovativeness has to do with the "advanced nature" of technologies and solutions used, including how relevant their application is for the enterprise, region, country, etc. At the project level, we can say that innovativeness is the extent of demand for innovative products, subject to certain criteria.

The method given here for assessing SIPs makes it possible to improve existing procedures of project analysis, both for commercial and strategically specified objectives.

The process of introducing a novelty product into the market is one of the key steps of any innovative process, which results in an implemented/realized change or innovation.

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