Optimal Method Selection for Assessing the Prospects and Readiness for Market Commercialization of Scientific Researches and Development

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Abstract: The article is devoted to the issues of justifying the method selection for the prospects and readiness assessing for market commercialization of the results of research activities of universities. A review of modern methods for assessing the commercial potential of the intellectual activity results with the identification of their strengths and weaknesses is carried out. The criteria selection for assessing the prospects of using various methods to assess the prospects and readiness for market commercialization of scientific research and development taking into account the practicality of using the methods is substantiated. Based on Kemeny's median method, these methods were ranged, which made it possible to determine the most optimal method for assessing the prospects and readiness for market commercialization of research and development, as well as assessing their commercial potential, which is the TPRL methodology.

1 INTRODUCTION

The current stage of economic development in the world is characterized by active development and implementation of innovations in production. An integral and important part of any innovation is the process of commercializing the results of intellectual activity (Azatbek et al, 2019; Ablaev, 2018). This process allows you to distribute the results of research (project) to a wide range of customers, to investigate the effectiveness of the implementation of these results, to provide the necessary income for researchers for the further circulation of intellectual processes (Zharinova, 2011). Despite the importance of commercializing the results of intellectual property, this issue is not fully understood. So there is no unified approach to the applied terminology and methods of assessing the commercial potential of sciential and scientific and technical results. The latter, as practice reveals, leads researchers to erroneous results.

In this connection, the economic and mathematical justification of sciential and scientific and technical results selected from a variety of methods for assessing the commercial potential of scientific and technical results is one of the most important and urgent scientific issues, the solution of which will allow at the early stages of design (development) to select the most promising areas of research and discard deliberately unrealizable and unpromising developments.

2 THE PURPOSE AND OBJECTIVES OF THE STUDY

The aforementioned gives grounds to formulate the purpose of this work, which incorporates the economic and mathematical substantiation of the selection of the most adequate method for assessing the readiness for market commercialization of research and development.

To achieve this goal, the following tasks were set and solved:

- a review of widely used methods for assessing the commercial potential of research and

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development, as well as their readiness for market commercialization, was carried out;

- selection and justification of criteria for ranging methods for assessing readiness for market commercialization of research and development;

- using the Kemeny median method to range the methods for assessing the readiness for the market commercialization of research and development and to justify the selection of the most optimal method.

3 METHODOLOGICAL STUDY

The methodological basis of this study is the provisions of classical economic theory, theory of innovation, theory and practice of project management, as well as fundamental and applied developments of foreign and domestic scientists in specified areas.

The dialectical method predetermining the study of phenomena in development and interrelation is used. The methods of systemic, logical and economic analysis, as well as methods and techniques of multivariate analysis using expert assessments are applied in the study. The Kemeny median method as a mathematical model that allows ranging the methods for assessing commercial readiness and the implementation of scientific developments was employed.

4 RESEARCH RESULTS

Commercialization of sciential and (or) scientific and technical results is the activity to involve sciential and (or) scientific and technical results in the economic circulation (Federal Law No. 127-FZ, 1996). Part 4 of Art. 16.4 of the Federal Law "On Science and State Scientific and Technical Policy" (Federal Law No. 127-FZ, 1996) with state support for innovative activities of universities provides a procedure for determining the permissible level of risks including financial, and basic criteria for managing them. An important place in this process is taken by the assessment of the prospects for the commercialization of innovation and (or) sciential and (or) scientific and technical products of an innovative project.

It should be noted that at present, a sufficient number of methods have been developed for assessing the prospects and readiness for market commercialization of scientific research and development. They differ in levels of complexity, reliability, conditions of use, which actualizes the problem of choosing those of them that would best reflect the organization needs.

Among the methods that can be applied to assess the readiness for the market commercialization of research and development are:

1. Methods for assessing readiness for market commercialization of scientific developments, based on the assessment of the innovative potential of the organization (Claver-Cortés et al, 2018; Argyres and Porter, 1998; Justel et al, 2007; Verena, 2005; Sabadka, 2012; Aiman-Smith et al, 2005). Assessment of innovative potential is a necessary stage in the study of readiness for market commercialization of research projects. This group of methods is based on the assessment of the organization's potential in terms of resource, financial, personnel and managerial, production and innovation capabilities of the organization itself. For each component, a limited list of indicators is assessed, whereas marketing indicators and an assessment of the potential market for innovative developments, the life cycle of scientific developments, cooperation between participants in the process of commercializing developments, along with legal aspects of supporting the creation of innovations are not taken into account. The innovative potential of an organization can be assessed from two positions: an assessment of the organization's readiness to develop and implement a specific innovative project; assessment of the current state of the organization in relation to all or a group of projects already being implemented.

2. Optional model (Morozov, 2012; Huixia and Tao, 2010). The essence of the method is to calculate the expected commercial value of the project, which takes into account the discounted future revenues of development, the probability of commercial success in case of successful technical implementation, investments in the commercialization of the project, the likelihood of the technical implementation of the project and investments in development. The basis for this model usage is the results of a quantitative and qualitative assessment of the development itself, as well as the potential market, which are tasks with a low level of assessment criteria formalization due to the large number of indicators that affect the final result. In this connection, this method does not allow an objective assessment of the actual level of project commercialization.

3. Hierarchy analysis method (Balykhin, 2016; Reichert et al, 2013; Stummer et al, 2009; Subramanian and Ramanathan, 2012; Chen and Kocaoglu, 2008; Ishizaka and Labib, 2011). The hierarchy analysis method is based on multi-criteria

compilation of ratings of alternative options, which makes it possible to choose the most rational solution that satisfies a number of criteria. The advantage of the method is the possibility of using it with insufficient empirical data. However, comparison and assessment of alternative options is carried out using an expert approach, which leads to a significant influence of subjective factors and can lead to an erroneous decision about the prospects for commercializing a particular project.

4. The LIFT (Linking Innovation, Finance and Technology) methodology (Kvashnin, 2006; Tikhonov, 2012; Assesiing Yoyr Venture, 2021) was developed within the framework of the fifth framework program of the European Union for research and technological development (FP5 - Fifth Framework Program of the European Community for Research, Technological Development and Demonstration Activities), conducted from 1998 to 2002. The LIFT methodology has become widespread in assessing the relevance to the market commercialization of research and development. The LIFT technology audit is an expert method for selecting innovation commercialization projects for funding. The assessment is carried out according to the classical scheme: collection of information (interview) - analysis - drawing up a report. All the information received is recorded and evaluated by experts (in points on a scale from 1 to 5) according to the approved indicators characterizing the project. Indicators are divided into two categories - project attractiveness and risk indicators.

5. The TAME (Technology and Market Evaluation) methodology (Kvashnin, 2006; Tikhonov, 2012) was developed by Lambic Innovation Ltd. The difference between TAME and LIFT methodologies is that the first focuses on assessing potential sales markets for an innovative product. Technology audit according to the TAME methodology is based on a systematic approach to assessing innovative products and their commercial potential, and includes five sections of assessment: strengths and breadth of market applications of an innovative product; the essence of the new technology used in the product; existing problems of an innovative product commercialization; existing problems of facilitating an innovative product commercialization process; other commercial matters. Each section is assessed on the basis of questionnaires. All answers to questions are scored on a five-point scale, but unlike the LIFT methodology, where points are assigned only to sections (indicators) of the assessment based on all answers to questions in a section, in the TAME methodology each question in a section is scored.

6. TRL methodology (Technology Readiness Level) (Technology Management in the DOD's ATD, 2002; Forsman, 2013) is a method for assessing the level of technology readiness for commercialization and use in the commercial sphere, developed by the US National Aerospace Agency NASA in the 1970s. The levels are determined according to established rules, taking into account, inter alia, the concept of technology, technological requirements, demonstration of the technological capabilities of the product. The TRL score is expressed in natural numbers from 1 to 9, with 9 being the highest level corresponding to the start of commercial production of the product. The levels have the following characteristics: TRL 1 - Basic principles; TRL 2 - Technological concept; TRL 3 - Experimental Proof of Concept; TRL 4 - Laboratory verification in the laboratory; TRL 5 - Validation of Technology in an Industry Significant Environment; TRL 6 - Technology Demonstrated in a Relevant Environment; TRL 7 - Demonstration of a prototype system in an operating environment; TRL 8 - System completed and qualified; TRL 9 - Actual system tested in an operating environment (competitive manufacturing in the case of key assistive technologies). The methodology is used by such large companies as United Engine Corporation, United Aircraft Corporation, Siemens, Airbus, Boeing; US National Aeronautics and Space Administration, etc. The literature presents dozens of different practical applications of the TRL methodology for various organizations, industrial companies, government departments, national and international foundations, which indicates the flexibility and ability to adapt the methodology to a specific product. Despite the fact that the TRL does not cover many aspects that should be taken into account when assessing the project as a whole, in practice, approaches based on the TRL scale are used, but also describing other levels of preparedness.

7. The TPRL (Technology Project Readiness Level) methodology based on the TRL methodology was developed (Petrov et al, 2016), taking into account such project values as: Technological readiness (TRL); Manufacturing Readiness (MRL); Engineering Readiness (ERL); Organizational Readiness (ORL); System Readiness (SRL); Benefits and Risks (BRL); Market Readiness and Commercialization (CRL) Levels. Quantitative assessments of the TRL of a project, obtained using the model, can be used to make various management decisions, for example, to develop a work schedule, a

financing plan, including determining the ratio of the shares of budgetary and extrabudgetary funding within the framework of programs implemented by various support institutions, as well as other solutions.

8. The commercial potential of research and development can also be assessed using classical economic methods for evaluating the effectiveness of investments: the Net Present Value method; Profit ability Index method, PI; Internal rate of return method, IRR; weighted average cost of capital, WACC; MIRR method (modified internal rate of return); PP method (payback period of innovation); ARR method (innovation efficiency ratio); Break-Even Point Analysis method (break-even point analysis). Despite the fact that these methods qualitatively reflect the effectiveness of an innovative project, their disadvantage, in our opinion, is the concentration exclusively on the financial parameters of the project without taking into account the technological and technical features of research and development.

Thus, a system analysis should be a tool for studying commercial potential. The use of various mathematical methods makes it possible to identify the prospects for further research, assess the level of commercial readiness, and predict positive effects in various fields.

To range methods for assessing readiness for market commercialization of research and development, it is proposed to use a number of criteria, namely:

- initial data specification record: the method used should take into account the most important properties of the initial information used to calculate the performance indicators (the random nature of changes over time in the technical and economic indicators of developments, the timing of costs and future income, the presence of non-commercial effects in various areas);
- validity: the assessment method should be strictly justified, logical, it should not contain contradictions of a substantive and formal nature (economic, mathematical, technical, etc.);
- unambiguous results: the method should provide an unambiguous interpretation of the results of the application, not allow conditional transitions;
- informative content: one of the most important requirements for methods. The higher the informative content level, the lower is the likelihood of an erroneous decision, the lower is the risk of the need for additional research;
- accuracy: the criterion is primarily important for methods that do not give a qualitative assessment of the possibility of market commercialization, but provide quantitative information for decision making;
- simplicity: the complexity of the method used should be related to the expected results;
- information accessibility: the main problem in assessing the readiness for the market commercialization of research and development is the lack of information or the difficulty of obtaining it. This is primarily about the effect (income part) of investments. In many cases, it is practically impossible to determine it precisely, while it is necessary at the initial justification stages of the commercialization possibility;
- implementation costs: the complexity of the assessment, the need for additional financial costs when applying certain methods of assessing the readiness for market commercialization of research and development.

Thus, it is proposed to compare the tools available to the organization for assessing the commercial potential of research and development according to the following criteria: initial data specification record, validity, unambiguous results, informative content, accuracy, simplicity, information accessibility, implementation costs.

According to the proposed criteria and objects (methods), a survey of experts was carried out, in the capacity of which, in the course of the analysis, were experts in the field of assessing the effectiveness of innovations. Namely, PhDs of four higher educational institutions of the Russian Federation: 2 doctors of technical sciences, 12 candidates of economic sciences. Moreover, IT managers of four domestic enterprises took part in the survey. A total of 20 people were interviewed (the minimum allowable sample size).

The results of the survey of experts are presented in table 1.

Table 1: Results of the survey of experts.

Criterion	Objects (methods)							
	1. Assessment of organization innovative potential	2. Optional model.	3.Hierarchy analysis method	4. LIFT	5. TAME	6. TRL	7. TPRL	8.Standard methods
initial data specification record: considers (1) — does not consider (5)	5	3	2	2	2	1	1	4
validity: high (1) — low (5)	4	2	3	1	1	2	1	2
unambiguous results: high (1) — low (5)	5	2	3	2	1	1	1	1
informative content: high (1) — low (5)	4	3	3	3	2	2	1	3
accuracy: high (1) — low (5)	5	4	3	2	1	2	1	3
simplicity: high (1) — low (5)	1	3	3	3	4	4	5	3
information accessibility: full (1) — partial (5)	1	3	2	3	4	4	5	2
implementation cost: high (1) — low (5)	1	4	3	4	4	4	5	3

The numerical values in the table are essentially objects of a non-numerical nature, since they only reflect the attitudes of experts such as "good", "normal", "bad". An expert, putting down a score, compares objects, but the ratio between the scores does not answer the question "How much better / worse? » So A. I. Orlov notes that «A common misconception is that experts try to consider the answers as numbers, they are engaged in 'digitizing' their opinions, attributing numerical values to these opinions - points, which are then processed using the methods of applied statistics as the results of ordinary physical and technical measurements. In the case of arbitrariness of "digitization", the conclusions obtained as a result of data processing may not be relevant to reality» (Orlov, 2002).

In general, on the basis of the expert assessment data, the task is to compose the average ordering, which is the closest to the true one, based on the data set by the ordering experts. To do this, we will use the Kemeny-Snell median. The choice of the median for the analysis is based on the fact that the Kemeny median is the only resultant strict ranging that is neutral, consistent, and condorcet.

$\|r_{ij}\|$In the algebraic approach, the main task is to determine the distance between two permutations, for example, $A и B$ - d (A, B). For each permutation, a matrix is determined, whose elements are the numbers +1 or 0. The element of the matrix with number (i, j) is +1 if the range of object i is less than the range of object j, that is, if object i comes in ordering before object j. Otherwise, this element is equal to 0. The diagonal elements of the matrix can be omitted. Let us denote $\|a_{ij}\|$ such a matrix constructed from the permutation A, $\|b_{ij}\|$ - by the permutation B. Now the distance d (A, B) introduced by Kemeny and Snell is:

$$d\,(A, B) = \frac{1}{2}\sum_{i \neq j} \left| a_{ij} - b_{ij} \right| \tag{1}$$

Using this distance, it is possible to determine something like the "center" of all the opinions expressed, choosing as such a permutation, the sum of the distances from which to all expert permutations $A_1, \dots, A_m$ is the smallest. This permutation A_0 is called the Kemeny-Snell median. So, a permutation A_0 is called the Kemeny-Snell median of the set of permutations $A_1, \dots, A_m$ if:

$$\sum_{i=1}^{m} d\,(A_0, A_i) = \min_{A} \sum_{i=1}^{m} d\,(A, A_i) \tag{2}$$

Calculation A_0 in the case of large m, n can present certain difficulties.

The algorithm for evaluating methods includes the following steps:

1. Based on the set goal of asessing the methods, we select a set of informative quality indicators {k_1, k_2, ..., k_m}, which will be used to evaluate the quality of each object from the set OB_j = ⟨Ob_1, Ob_2, ..., Ob_n)

In other words, we need to assess the 8 methods discussed above by eight indicators: k1 - initial data specification record; k2 - validity; etc. All indicators were evaluated in points on a scale from 1 to 5. At the same time, 1 indicates the best value of the indicator, whereas 5 - the worst.

2. We range the objects for each line corresponding to one of the indicators. Each j-th indicator will give its own vector of preferences $k_j = (k_{j1}, k_{j2}, \ldots, k_{jn}), j = \overline{1, m}$, where k_{ji} is the ordinal number of the object occupying the i-th place in the ranпing according to the j-th indicator.

The initial data of a survey of experts for analysis using the Kemeny median are presented in Table 1.

3. Let's predetermine all assessments of objects in an ordinal scale and find out whether preference can be expressed by ranges. In each ranging, the first place is occupied by the most attractive, from the point of view of the considered indicator, the object, and then in descending order. Then, each vector kj is associated with a vector $\pi_j = (\pi_{j1}, \pi_{j2}, \ldots, \pi_{jn})$ formed according to the rule: coordinate π_{ji} is the number of directions, which, according to the j-th particular indicator, are more preferable than the direction with the ordinal number i (Tikhonov, 2012; Mitus and Katsko, 2015). The results are summarized in Table 2.

Table 2: Assessments of objects in an ordinal scale.

Criteria	OB_1	OB_2	OB_3	OB_4	OB_5	OB_6	OB_7	OB_8
Initial data specificatio n record	7	5	2	2	2	0	0	6
Validity	7	3	6	0	0	3	0	3
Unambiguo us results	7	4	6	4	0	0	0	0
Informative content	7	3	3	3	1	1	0	3
Accuracy	7	6	4	2	0	2	0	4
Simplicity	0	1	1	1	5	5	7	1
Information accessibility	0	3	1	3	5	5	7	1
Implementa tion cost	0	2	1	2	2	2	7	1

4. Search for group ranging that will best represent individual preferences. As such, the Kemeny median will be considered, defined as follows:

$$\pi^* = \min_{\pi} \sum_{j=1}^{m} d(\pi, \pi^j) \quad (3)$$

where $d(\pi, \pi^j)$ is the distance between the two rangings, determined by the formula:

$$d(\pi, \pi^j) = \sum_{i=1}^{n} |\pi_i - \pi_i^j| \quad (4)$$

5. Next, we build a loss matrix $R = \{r_{pq}\}$: we consider vectors in which the direction with a number $i (i \in \{1, 2, \ldots., n\})$ is located sequentially from the 1st to the nth place: $\pi = (\pi_1, \pi_2, \ldots., \pi_p, \ldots., \pi_n)$ - ranging, in which the p-th indicator is in the q-th place $\pi_p = q - 1$ (i.e.), then :

$$r_{pq} = \sum_{j=1}^{m} |\pi_p - \pi_p^j| \quad (5)$$

For our data, we get the matrix of losses in Table 3.

Table 3: Loss matrix R.

35	33	31	29	27	25	23	21
27	19	13	9	11	15	21	29
24	16	14	14	16	20	24	32
17	11	7	9	15	23	31	39
15	13	13	17	21	25	33	41
18	14	12	14	18	22	30	38
21	23	25	27	29	31	33	35
19	13	13	13	17	23	29	37

Obtained by the author based on the research results.

6. By minimizing the functional, we solve the assignment problem:

$$\begin{cases} \sum_{p=1}^{n} \sum_{q=1}^{n} r_{pq} * x_{pq} \to \min \\ \sum_{p=1}^{n} x_{pq} = 1, \ p = \overline{1, n} \\ \sum_{q=1}^{n} x_{pq} = 1, \ q = \overline{1, n} \\ x_{pq} \geq 0, \end{cases} \quad (6)$$

where X is a binary matrix of values: $x_{pq} = 1$ if the pth alternative is assigned to the qth place and xpq = 0, otherwise.

When conditions (6) are met, the matrix $X = \{x_{pq}\}$ corresponds to some ranging.

We get the assignment matrix in the form (Table 4):

Table 4: Assignment matrix.

0	0	0	0	0	0	0	1
0	0	0	0	0	1	0	0
0	0	0	0	0	0	1	0
0	0	0	1	0	0	0	0
0	1	0	0	0	0	0	0
0	0	1	0	0	0	0	0
1	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0

Using the matrix $X^* = \{x^*_{pq}\}$, we restore the vector of group preference K *, analyzing the matrix row by row: if, then in the vector K * we put. In our case: $x_{17} = 1; x_{25} = 1; x_{36} = 1; x_{44} = 1; x_{58} = 1; x_{62} = 1$; $x_{73} = 1$; $x_{81} = 1;$; hence, $P^* = (7,5,6,4,8,2,3,1)$.

5 DISCUSSION

Kemeny's median method made it possible to range the methods for assessing the readiness for the market commercialization of research and development. The calculation results gave grounds to prioritize the use of the methods:

1. TPRL Methodology.
2. Methodology TAME.
3. TRL Methodology.
4. LIFT Methodology.
5. Economic methods for assessing the effectiveness of investments.
6. Optional model.
7. Hierarchy analysis method.
8. Methods for assessing readiness for market commercialization of scientific developments, based on the assessment of the innovative potential of the organization.

As the results of our research have shown, the TPRL methodology is the most optimal method for assessing the readiness for market commercialization of research and development, as well as assessing their commercial potential. Despite the priority of this method, in our opinion, it requires additional labor, since many factors in the proposed model are subjective, which ultimately can distort the results of evaluating the commercialization of scientific developments and reject promising developments at the initial stages.

Therefore, the prospect for further research is the modernization of the classic TPRL model, which will cover the main factors and criteria inherent in the scientific development of universities.

6 CONCLUSIONS

Analysis of modern methods for assessing the prospects and readiness for market commercialization of research and development of universities, taking into account these projects specifications, allowed us to reasonably select the main criteria for ranging them in order of importance.

On the basis of Kemeny's median method, these methods were ranged, which made it possible to determine the most optimal method for assessing the readiness for market commercialization of research and development, as well as assessing their commercial potential, which is the TPRL methodology, however, in our opinion, it requires additional modernization, because it does not sufficiently take into account the main factors and criteria inherent in the scientific development of universities, which is a prospect for future research.

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