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SETTING OF CRITERIA IN THE COMMERCIAL POTENTIAL ASSESSMENT METHOD OF INNOVATIVE TECHNOLOGICAL SOLUTIONS

Key words

Innovative technological solution, commercial potential assessment, assessment criteria, AHP method.

Summary

The article presents the *Analytic Hierarchy Process (AHP)* method, used for the development of the commercial potential assessment method (PK) of innovative technological solutions. The need for the development of such a method was stemmed from the *"Innovative Systems of Technical Support for Sustainable Development of Economy"* strategic research programme. The AHP method helps to assign weights to the thematic assessment areas of the commercial potential method and the criteria within the areas. The AHP method is dedicated to supporting the decision making process and to facilitating the assessment with the use of multi-criteria, especially in the case of qualitative criteria subjectively assessed by the experts.

The developed PK method significantly supports the process of knowledge transformation and transfer of advanced technologies in the area of the

development and the maintenance of machines and technical devices. The use of this assessment improves the innovativeness and competitiveness of the economy by increasing of the efficiency and the effectiveness of the commercialisation process of innovative technological solutions.

Introduction

The organisations, which want to have a guaranteed stable position on the market, have to develop innovative technological solutions corresponding to market needs. In order to be up to date with the needs of the society concerning latest technologies, it is necessary to systematically evaluate them at all stages of their development. Such a complex evaluation includes the following stages: the *ex-ante* evaluation (before the start of the development of a product), the *on-going* evaluation (during the development of a product), the *ex-post* evaluation (when the product is already developed), and the *follow-up* evaluation (some years after the development of a product) (see Figure 1).

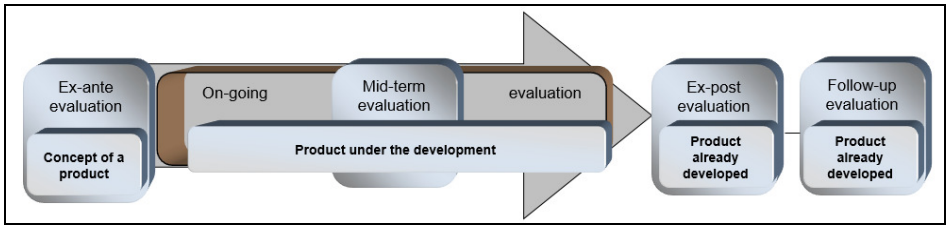

Fig. 1. Assessment of a technological innovation at different stages of the evaluation
Source: Łopacińska L.: Model ewaluacji programów badawczych w obszarze innowacji technicznych (thesis under development), 2013.

There are as many different approaches of how to assess market opportunities of a product as there are evaluators, because there is no single, proper approach. The selection of any approach depends on different circumstances. All known methods boil down to a few principal techniques [1]:

- To start with published information from proprietary sources;
- To extrapolate gathered data in a manner appropriate to the defined new product;
- To ask potential customers whether, and under what circumstances, they would buy the product;
- To estimate the supplier's expanding market share over time; and,
- To conduct a detailed survey of potential customers, distribution channels and competitors using several survey instruments to project the new product's market penetration in each applicable segment.

The state-of-the-art indicates different methods used in the assessment of the commercial potential. One of the most common methods is the Quicklook™ method [2]. It enables one to assess the commercial potential of innovations through the acquirement of general but significant information, which is needed for the preliminary estimation of chances for the commercialisation of innovations. The Quicklook™ method comprises of the following stages: the identification of the potential market for innovations; the identification of potential users; the contact with experts and entrepreneurs; and, the identification of chances and barriers for the development or the implementation of innovations. The extension to the Quicklook™ method is the In-Depth method, which enables one to acquire information on the commercial potential of innovations through the conduction of a detailed expertise.

The technology evaluation tools have also been developed at the University of Missouri. One of the tools serves to assess technologies for potential technology transfer [3]. This method includes the following steps: the identification of potential commercial applications of a technology, the identification of potential markets for commercial applications of a technology, the identification of potential technology acquirers, the estimation of commercialisation related costs, the price of a technology, and the development of a business plan for the commercial assessment of a technology.

Several models have also been developed to determine commercial potential of innovations, especially technologies. These models assess several factors influencing successful commercialisation of a technology. However, the principle problem, including the synthesis of individual aspects, quantifying them and calculating the overall commercial potential of technology, has remained unanswered [4–8].

Bandarian [9] proposes a method that aids the decision makers to select those early stage technologies that have the potential to be successfully transferred to marketplace. The method is based on a decision of experts and the use of fuzzy logic to measure and quantify commercial potential for a candidate technology for development.

The commercial potential can also be measured with the use of multi-criteria decision-making methods. This article is focused on the AHP method, because it stimulates the correct development of the elements, which are included in the method of commercial potential assessment.

1. The Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process developed by Saaty [10, 11] is a method that enables the ranking of multiple criteria and supports the decision making process. The wide applicability of the AHP method is caused by its simplicity, flexibility, and possibility to integrate with other methods used for solving

advanced and very complex multi-criteria decision problems. A wide application area of the AHP method has been studied in a number of papers. The complexity of the literature review of the AHP applications was presented in Ho and Vaidya publications [12, 13].

To make a decision in a systematic way, the analytic process is decomposed into the following basic steps:

1. Defining the problem,
2. Structuring the problem in a hierarchy of levels constituting the goal, criteria and alternatives,
3. Constructing a set of paired comparison matrices and comparing each element in the corresponding level by using the comparison scale,
4. Doing calculations to find the priority vector,
5. Checking the consistency of the matrix, and
6. Calculating final ratings.

The scale to use in judgment making by paired comparisons among the elements is given in Table 1. The paired comparisons are carried out for all elements to be considered.

Table. 1. Scale for paired comparisons

Intensity of importanc(a_{ij})	Definition	Explanation
1	Equal importance	A_i and A_j elements are equally important
3	Weak importance	A_i is slightly more important than A_j
5	Strong importance	A_i is strongly more important than A_j
7	Very strong importance	A_i is very strongly more important than A_j
9	Extreme importance	A_i is extremely preferred than A_j
2, 4, 6, 8	Intermediate values	Used when compromise is needed between two adjacent judgments
Reciprocals: 1/2, 1/3, …, 1/9	If A_j element is favoured in comparison with A_i then the reciprocal value is used	

Source: Authors.

The quality and the reliability of the judgment process and final results are expressed by the matrix consistency. The consistency ratio (CR) is used to check consistency of the matrix:

$$CR = \frac{CI}{RI} \tag{1}$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{2}$$

where:

n – dimension of the matrix,
CI – consistency index,
RI – random index (that depends on matrix dimension),
λ_{max} – maximum eigenvalue (calculated for a given matrix).

The matrix is consistent if the CR value is less than 0.10. If the consistency ratio exceeds 0.10, the matrix is inconsistent and then the judgment process must be revised.

2. The commercial potential assessment method

The commercial potential assessment method (PK),[1] developed at the Institute for Sustainable Technologies – National Research Institute in Radom, enables to test the level of the commercial potential of innovative technological solutions at different stages of their development and to make comparative analysis of the assessment results at the previous stages of the development of a solution.

The assessment concerns the innovative technological solutions, which belong to the following categories: devices, technologies, systems, and materials. Moreover, the assessment concerns four areas: technological, market, economic and legal, and organisational (see Figure 2) [14].

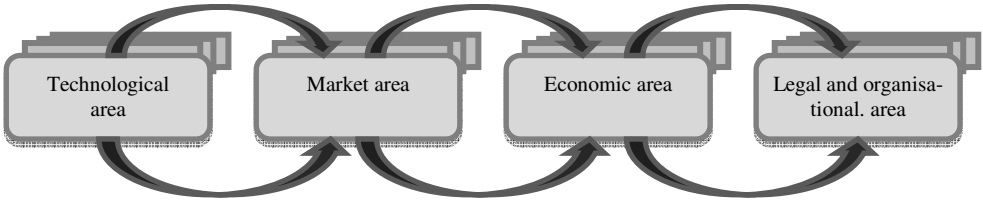

Fig. 2. Areas of the commercial potential assessment
Source: Authors.

The *technological area* includes, among others, the following criteria: the technological level in comparison to analogous or similar solutions, the uniqueness of the solution, the energy consumption, the technical safety, and the environmental threats.

[1] *Innovative Systems of Technical Support for Sustainable Development of Economy* strategic research programme.

The *market area* includes the criteria concerning the market demand for a solution, the potential scope of application, and the potential scale of application. Moreover, the analysis of existing solutions and the indication if a solution is adequate to the needs of beneficiaries are very important elements of the assessment.

The *economic area* includes the following criteria: the profitability of production, the dissemination / promotion costs, the maintenance costs, the price of the solution comparing to similar solutions, the income after the application of a solution, and the potential profits from a solution.

The *legal and organisation area* includes, among others, the following criteria: the level of protection of legal rights to a solution, the possibilities of imitation of a solution by third parties, and the dependencies between the implementation, and the changes in legal regulations.

In all areas of the commercial potential assessment, the authors proposed 32 criteria altogether.

Due to the diversification of the levels of significance of the areas, and the detailed criteria, the authors, by assigning weights to the individual areas, established the hierarchy of their importance. A very important element of the method is the choice of competent experts with experience in engineering, innovation, knowledge transfer, marketing, commercial, economy, and legal areas. In order to grade the areas and the criteria, the AHP method was used.

The hierarchical structure for the commercial potential assessment of technological innovative solutions is shown in Figure 3. Applying the AHP procedure described in Step 2, the hierarchy of the structure was developed and the following main areas of assessment were identified: the Technological area (T), the Market area (M), the Economic area (E), and the Legal and Organisational area (O). These areas are the main criteria in the assessment system. At the lowest level of the structure, the detailed criteria concerning special aspects of areas are determined (see Table 2). The number of the detailed criteria in the areas is limited to a maximum of ten criteria, which is in accordance with the of the AHP method.

Priorities are determined by executing paired comparisons of criteria at the main criteria level and the detailed criteria level. Judgments are made by the interdisciplinary team of experts. Priority vectors in matrices are determined in the process of computation.

The paired comparison matrix for main criteria is shown in Table 3. Estimated elements of the priority vector present the weights of the main criteria. The ranking of weights revealed the dominant importance of market and economic areas.

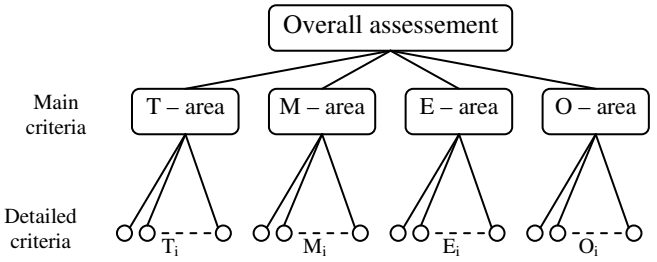

Fig. 3. Hierarchical structure for commercial potential assessment
Source: Authors.

Table 2. Detailed criteria determined in main areas

Technological area (T)	Market area (M)
1. Uniqueness of the solution on the national level 2. Innovative character of the solution on the national level 3. Level of functionality in comparison to analogous or similar solutions 4. Technological level in comparison to analogous or similar solutions 5. Energy consumption 6. Technical safety 7. Environment threats 8. Time needed to complete the project 9. Time within which the innovative character is sustained 10. Perspectives on development and implementation of next generations of a solution	1. Market demand for a solution 2. Potential beneficiaries of a solution 3. Potential scale of application 4. Potential scope of application 5. Competitive solutions on the market 6. Beneficiaries' satisfaction level 7. Access of beneficiaries to a solution 8. Market position of an institution developing a solution 9. Pace at which analogous or similar solutions are implemented on the national level
Economic area (E)	**Legal and Organisational area (O)**
1. Profitability of production 2. Exploitation costs 3. Dissemination / promotion costs 4. Maintenance costs 5. Price of a solution comparing to similar solutions 6. Dependencies between the price of a solution and the costs of materials and energy 7. Income after the application of a solution 8. Profit stemming from the application of a solution	1. Protection of legal rights to a solution 2. Possibilities of imitation of a solution by third parties 3. Dependency between the implementation of a solution and changes in legal rules 4. Servicing 5. Product implementation programme

Source: Authors.

Table 3. Paired comparison matrix for main criteria

	T	M	E	O	Priority vector
T	1	1/2	1/2	4	0.200
M	2	1	1	6	0.371
E	2	1	1	6	0.371
O	¼	1/6	1/6	1	0.058

Consistency ratio: $CR = 0.004 < 0.1$.
Source: Authors.

Paired comparison matrices for the detailed criteria in the main assessment areas are shown (see Tables 4 through 7).

Table 4. Paired comparison matrix for detailed criteria in the Technological area

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	Priority vector
T1	1	1/2	1/2	2	5	5	7	1	2	3	0.151
T2	2	1	1/2	1	7	3	5	1	2	2	0.148
T3	2	2	1	2	4	4	4	2	3	5	0.212
T4	1/2	1	1/2	1	4	4	4	2	3	5	0.150
T5	1/5	1/7	1/4	1/4	1	1/2	1	1/3	1/3	1	0.032
T6	1/5	1/3	1/4	1/4	2	1	1	1/3	1/3	1	0.040
T7	1/7	1/5	1/4	1/4	1	1	1	1/3	1/3	1	0.034
T8	1	1	1/2	1/2	3	3	3	1	1	3	0.109
T9	1/2	1/2	1/3	1/3	3	3	3	1	1	2	0.084
T10	1/3	1/2	1/5	1/5	1	1	1	1/3	1/2	1	0.041

Consistency ratio: $CR = 0.032 < 0.1$.
Source: Authors.

Table 5. Paired comparison matrix for detailed criteria in the Market area

	M1	M2	M3	M4	M5	M6	M7	M8	M9	Priority vector
M1	1	2	2	2	4	5	3	5	5	0.239
M2	½	1	1/2	2	4	5	3	5	5	0.176
M3	½	2	1	2	4	4	3	6	6	0.208
M4	½	1/2	1/2	1	4	4	3	6	6	0.153
M5	¼	1/4	1/4	1/4	1	2	3	2	2	0.065
M6	1/5	1/5	1/4	1/4	1/2	1	2	2	1	0.047
M7	1/3	1/3	1/3	1/3	1/3	1/2	1	1	1/3	0.037
M8	1/5	1/5	1/6	1/6	1/2	1/2	1	1	2	0.037
M9	1/5	1/5	1/6	1/6	1/2	1	3	1/2	1	0.038

Consistency ratio: $CR = 0.062 < 0.1$.
Source: Authors.

Table 6. Paired comparison matrix for detailed criteria in the Economic area

	E1	E2	E3	E4	E5	E6	E7	E8	Priority vector
E1	1	3	5	3	3	5	2	2	0.250
E2	1/3	1	3	3	1/6	2	1/3	1/3	0.071
E3	1/5	1/3	1	1/3	1/5	1	1/7	1/7	0.029
E4	1/3	1/3	3	1	1/4	2	1/5	1/5	0.050
E5	1/3	6	5	4	1	7	2	2	0.224
E6	1/5	1/2	1	1/2	1/7	1	1/5	1/5	0.034
E7	½	3	7	5	1/2	5	1	1	0.171
E8	½	3	7	5	1/2	5	1	1	0.171

Consistency ratio: $CR = 0.057 < 0.1$.
Source: Authors.

In the Technological area, the criterion 'Level of functionality in comparison to analogous or similar solutions' has the maximum rank (weight 0.212). The following criteria: 'Uniqueness…', 'Innovative character…', and 'Technological level…' have approximately equal weights (about 0.150). In the Market area, the top criteria are the criterion 'Market demand for a solution' (weight 0.239) and the criterion 'Potential scale of application' (weight 0.208). In the Economic area, among the criteria, the 'Profitability of production' (weight 0.250) and the 'Price of a solution…' (weight 0.224) are crucial in the assessment of innovative solutions. In the Legal and Organisational area, the criterion concerning problems of 'Product implementation programme' is dominant (weight 0.484) (see Figure 4).

Table 7. Paired comparison matrix for detailed criteria in the Legal and Organisational area

	O1	O2	O3	O4	O5	Priority vector
O1	1	1	3	3	1/3	0.190
O2	1	1	3	3	1/3	0.190
O3	1/3	1/3	1	1/2	1/5	0.062
O4	1/3	1/3	2	1	1/7	0.076
O5	3	3	5	7	1	0.482

Consistency ratio: $CR = 0.026 < 0.1$.
Source: Authors.

The overall assessment of the commercial potential (V_{Comm}) of an innovative solution is given by the following equation:

$$V_{Comm} = W_T \cdot \sum_{i=1}^{10} w_i^T \cdot a_i^T + W_M \cdot \sum_{i=1}^{9} w_i^M \cdot a_i^M + \\ + W_E \cdot \sum_{i=1}^{8} w_i^E \cdot a_i^E + W_O \cdot \sum_{i=1}^{5} w_i^O \cdot a_i^O \tag{3}$$

where:

W_T, W_M, W_E, W_O – weights of the following areas: Technological, Market, Economic, and Legal and Organisational (see Table 3);
$w_i^T, w_i^M, w_i^E, w_i^O$ – weights of i-criterion in the corresponding area (Table 4 through 7);
$a_i^T, a_i^M\ a_i^E,\ a_i^O$ – assessment value with respect to the i-criterion in the corresponding area.

The use of the AHP method for the hierarchization of the criteria of commercial potential assessment revealed that some of the criteria had very low weights (in white colour in Figure 4). Therefore, the possibility of removing them from the list of criteria should be considered, since they do not have a significant impact on the final result of the assessment.

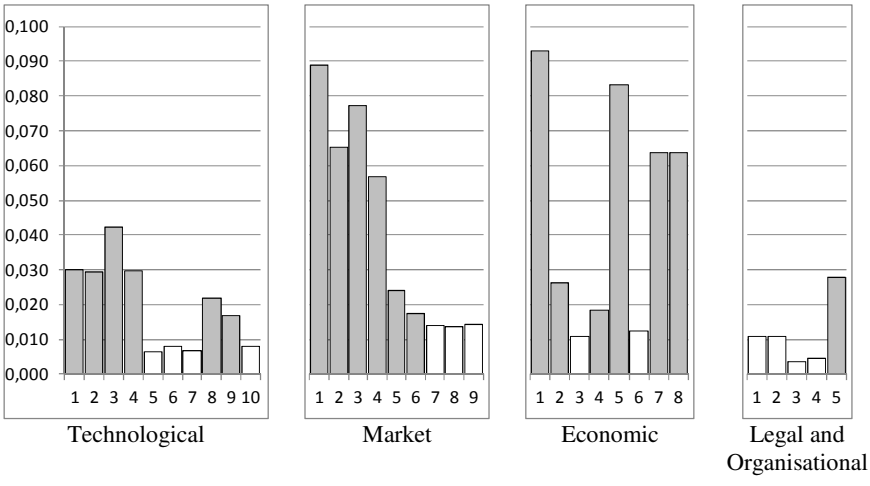

Fig. 4. Comparison of criteria weights
Source: Authors.

3. An empirical application of the assessment method

The developed hierarchical set of criteria was applied in the commercial potential assessment method of innovative technological solutions, which are the results of the *'Innovative Systems of Technical Support for Sustainable Development of Economy'* strategic research programme. The assessment of the innovative technological solution is conducted with the use of the IT system [15, 16], which enables automatic calculation of the final score of the assessment according to the dependency presented in Equation (3). The assessment sheet for innovative solutions presents the structure of the assessment system applied in the developed method (see Figure 5).

COMMERCIAL POTENTIAL ASSESSMENT 23/09/2013

III.5.3_U_1_1	**Technological device for the execution of hydro- and solvothermal syntheses with a PTFE chamber with no high-pressure valves**

Research task III.5.3. **Advanced technologies for microwave hydrothermal synthesis of nanoparticles**

NO.	CRITERION	QUALITATIVE ASSESSMENT	WEIGHT (1-5)	QUANTITATIVE ASSESSMENT	SCORE
	TECHNOLOGICAL AREA				
1	Uniqueness of the solution on the national level	Low	4	0	36
		Average		3	
		High		6	
		Very high		9	
2	Innovativeness character of the solution on the national level	Low	4	0	36
		Average		3	
		High		6	
		Very high		9	
3	Level of functionality in comparison to analogous or similar solutions	Lower	5	0	45
		Equal		3	
		Higher		6	
		Dominant		9	
4	Technological level in comparison to analogous or similar solutions	Low	4	0	36
		Average		3	
		High		6	
		Critical		9	
7	Energy consumption	Very high	1	0	9
		High		3	
		Average		6	
		Low		9	
6	Technical safety	Low	1	1	9
		Average		2	
		High		3	
		Very high		4	
7	Environmental threats	Significant	1	1	6
		Average		2	
		Low		3	
		None		4	

Fig. 5. Sheet of the commercial potential assessment (excerpt)
Source: Authors.

The AHP method was successfully applied for the assessment of the commercial potential assessment of innovative solutions in the Strategic Programme *'Innovative Systems of Technical Support for Sustainable Development of Economy'*. In the assessment process, a determined set of criteria was used. The developed procedure of assessment was very useful for the ranking of c.a. 170 technological innovative solutions.

Conclusions

During the development of the method of the commercial potential assessment, four thematic areas were identified, which include a total of 32 criteria. The AHP method helped to establish weights for the thematic areas and criteria. The market and the economic areas received the highest weights, while the legal and organisational area had very low weights, which shows that this area has little or no significance in the overall assessment of the innovative solutions.

The authors confirmed the usability of the AHP method as a research tool enabling the verification of the assessment results as the identification of the coherence of the assessment results achieved was helpful in eliminating mistakes and contradictions in partial assessments.

The case studies of practical application of the method demonstrated the correctness of the operations.

Based on the analysis of the results, the authors stated that some of the criteria with the lowest values of weights could be eliminated.

Further research on the improvement of the method of commercial potential assessment of innovative technological solutions aims at the development of the IT system, which will facilitate their automatic assessment.

Scientific work executed within the Strategic Programme 'Innovative Systems of Technical Support for Sustainable Development of Economy' within Innovative Economy Operational Programme.

References

1. Kalinowski J.J.: Assessing commercial opportunities for new products. Trilogy Associates.
2. Gwarda-Gruszczyńska E. (2010): Quicklook™ jako metoda oceny potencjału komercyjnego innowacji i technologii Acta Universitatis Lodziensis Folia Oeconomica 234.
3. Myers D.: Technology evaluation tools: assessing technologies for potential technology transfer www.netl.doe.gov/publications/proceedings/02/transpartner/13 [access: 10.10.2013].

4. Kathleen A.R. (2003): Bringing New Technology to Market, Prentice Hall, New Jersey.
5. Martyniuk A.O. (2002): Market opportunity analyses and technology transfer, International Journal of Technology Transfer and Commercialisation – Vol. 1, No.4 pp. 385–404.
6. Martyniuk A.O., Jain R.K., Stone H.J. (2003): Critical success factors and barriers to technology transfer: case studies and implications, International Journal of Technology Transfer and Commercialisation – Vol. 2, No. 3, pp. 306–327.
7. Martino J.P. (1995): R&D Project Selection, John Wiley & Sons.
8. Triandis H.C. (1990): Management of Research and development organizations, John Wiley & Sons.
9. Bandarian R.: Evaluation of commercial potential of a new technology at the early stage of development with fuzzy logic. Journal of Technology Management & Innovation 2007, Volume 2, Issue 4, pp. 73–85.
10. Saaty T.L. (1980): The Analytic Hierarchy Process. New York: McGraw Hill. New York.
11. Saaty T.L. (2008): Decision making with the analytic hierarchy process. Int. J. Services Sciences. Vol. 1. No 1, pp. 83–97.
12. Ho W. (2008): Integrated analytic hierarchy process and its applications – A literature review. European Journal of Operational Research 186, pp. 211–228.
13. Vaidya O.S., Kumar S. (2006): Analytic hierarchy process: An overview of applications. European Journal of Operational Research 169, pp. 1–29.
14. Belina B., Łopacińska L., Karsznia W.: Commercial potential oriented evalutaion of innovative products. Maintenance Problems 4/2012, pp. 23––32.
15. Mazurkiewicz A., Karsznia W., Giesko T., Belina B.: System operacyjny oceny stopnia dojrzałości wdrożeniowej innowacyjnych rozwiązań w zakresie usług. Problemy Eksploatacji 3/2011, s. 61–73.
16. Mazurkiewicz A., Poteralska B.: System of a complex assessment of technological innovative solutions. Maintenance Problems 4/2012, pp. 5–22.

Dobór kryteriów w metodzie oceny potencjału komercyjnego rozwiązań innowacyjnych

Słowa kluczowe

Rozwiązanie innowacyjne, ocena potencjału komercyjnego, kryteria oceny, metoda AHP.

Streszczenie

W artykule zaprezentowano metodę hierarchicznej analizy problemu (Analytic Hierarchy Process – AHP) w zastosowaniu do opracowania metody oceny potencjału komercyjnego (PK) innowacyjnych rozwiązań technicznych, w tym opracowanych w ramach Programu Strategicznego pn. „Innowacyjne systemy wspomagania technicznego zrównoważonego rozwoju gospodarki" (w zakresie wyznaczania wag obszarów problemowych oraz poszczególnych kryteriów w ramach obszarów). Metoda AHP jest dedykowana głównie do wspomagania wyboru wariantów decyzyjnych, ale także do dokonywania oceny diagnostycznej lub porównawczej w ujęciu wielokryterialnym, szczególnie w przypadku występowania kryteriów jakościowych oraz subiektywnym charakterze dokonywanych przez ekspertów ocen.

Opracowana metoda oceny potencjału komercyjnego (PK) stanowi istotny element wspomagania procesów transformacji wiedzy i transferu zaawansowanych technologii procesowych i produktowych w obszarze wytwarzania oraz eksploatacji maszyn i urządzeń technicznych. Wykorzystanie metody do oceny powstających rozwiązań przyczynia się do wzrostu innowacyjności i konkurencyjności gospodarki poprzez zwiększenie efektywności i skuteczności procesu komercjalizacji innowacyjnych.