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INNOVATIVE MANUFACTURING PLANNING BASED ON INTEGRATED METHODOLOGY OF RATIONAL ALTERNATIVE SELECTION

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Introduction. Innovation is one of the major factors of economic growth in modern economy on the macrolevel, and a prominent contributor to an enterprise's profit increase at microlevel. Nevertheless, innovation activity is accompanied by a high level of risk and may cause significant losses. Thus, the problem of limiting the risk by developing rational methods of decision making is relevant.

Aim and tasks. The article aims at development of integrated methodology for taking a decision as to selection of rational innovative production alternative based on the usage of a group of decision making methods in dependency on conditions under which the decision is being taken.

Results. The article analyses decision making process in the context of system approach and defines stages of decision making. Criteria of effective decision are described and classified. Methods of decision making are observed and classified according to the conditions of decision making. The necessary components of integrated methodology of selection of rational innovative production alternative are defined. The formation principles and general structure of the integrated methodology of selection of rational innovative production alternative are described.

Conclusions. The task of decision effectiveness assessment is complicated by simultaneous existence of number of performance goals with different suitability for formal evaluation, negative correlation between speed and accuracy of decision making, and temporal distance between decision making process and goal achievement, which requires employment of discounting methods. The above-mentioned factors determine the necessity for an integrated criterion, which includes economic efficiency indicators but is not reduced to them. Thus, integrated methodology of selection of rational innovative production alternative consists of multicriteria decision making solution, assessment of sufficient range of alternatives, allowance for uncertainty as to input information about criteria, inclusion of different types of criteria measurement, provision of possibility to use alternative information at all stages of decision making process.

Keywords: innovative production, management decision making, manufacture organization, mathematical methods in management.

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ПЛАНУВАННЯ ІННОВАЦІЙНОГО ВИРОБНИЦТВА НА ОСНОВІ КОМПЛЕКСНОЇ МЕТОДИКИ ВИБОРУ РАЦІОНАЛЬНОЇ АЛЬТЕРНАТИВИ

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Вступ. Інновації є одним з основних факторів економічного зростання в сучасній економіці на макрорівні та істотним фактором збільшення прибутку підприємства на мікрорівні. Проте, інноваційна діяльність супроводжується високим рівнем ризику і може призвести до значних збитків. Таким чином, актуальною є проблема обмеження ризику шляхом розробки раціональних методів прийняття рішень.

Мета і завдання. Метою статті є розробка комплексної методології прийняття рішення про вибір раціональної інноваційної виробничої альтернативи на основі використання групи методів прийняття рішень в залежності від умов прийняття рішення.

Результати. У статті проаналізовано процес прийняття рішень у контексті системного підходу та визначено етапи прийняття рішень. Описано та класифіковано критерії ефективного рішення. Досліджено методи прийняття рішень та класифіковано відповідно до умов прийняття рішень. Визначено необхідні компоненти комплексної методології вибору раціональної інноваційної виробничої альтернативи. Описано принципи формування та загальну структуру комплексної методології вибору раціональної інноваційної виробничої альтернативи.

Висновки. Завдання оцінки ефективності рішень ускладнюється одночасним існуванням ряду цілей ефективності з різною придатністю для формальної оцінки, негативною кореляцією між швидкістю і точністю прийняття рішень і віддаленістю у часі між процесом прийняття рішень і досягненням мети, що вимагає застосування методів дисконтування. Перераховані вище фактори визначають необхідність комплексного критерію, який включає показники економічної ефективності, але не зводиться до них. Таким чином, комплексна методологія вибору раціональної інноваційної виробничої альтернативи складається з багатокритеріального рішення для прийняття рішень, оцінки достатнього діапазону альтернатив, обліку невизначеності вхідної інформації про критерії, включення різних видів вимірювання критеріїв, забезпечення можливості використання альтернативної інформації на всіх етапах процесу прийняття рішень.

Ключові слова: інноваційна продукція, прийняття управлінських рішень, організація виробництва, математичні методи в управлінні.

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Introduction. The twenty-first century is characterized by the emergence of significant innovations. In developed countries, a scientific and technological revolution is taking place, leading to the formation of an innovation and investment economy, which is based on the sixth technological paradigm. In such countries as the United States, Japan, and the European Union, national programs and long-term strategies for the development of scientific and technological areas of the sixth technological paradigm are already in place. But in Ukraine, it is still quite common to believe that it is necessary to first master the technologies of the fifth technological paradigm, which condemns the country to follow the strategy of "catching up development", which does not allow the country to bridge the gap in innovation and investment development in comparison with world leaders.

However, world experience shows that in the development of the modern innovation and investment system, the staged nature of technological paradigm is relative, since several technological paradigms are implemented simultaneously on a global scale. Developed countries, such as Japan, sell outdated and no more feasible technologies to developing countries, thus prolonging the technological lag of the latter. A significant part of the countries that have chosen the transition to innovation and investment development as a strategic direction continue to use the technologies of the previous paradigm while introducing the latest ones - the technologies of the fifth and sixth paradigms. To bridge the technological gap, it is necessary to invest in promising areas aiming at leadership in order to be able to achieve a new technological paradigm.

The basis for the development of a new innovation and investment economy is the innovation and investment potential of an industrial enterprise. To mobilize it, it is necessary to use scientific and intellectual potential, attract natural and financial resources and fixed capital, and apply scientifically based management methods. The target direction is to ensure the implementation of innovation cycles and achieve sustainable economic development based on innovations.

Innovative products allow the enterprise, on the one hand, to increase its innovation and investment activity, and on the other hand, they require certain costs for the implementation of innovations. Moreover, as a rule, an increase in innovation and investment activity is achieved as a result of an increase in costs. This consideration leads to the relevance of scientifically justified planning methods of rational production alternative selection.

Analysis of recent research and publications. A number of works looking at general issues of decision making process and describing the specifics of particular method implementation has been published in recent years. Klepikova O. [1] reviews contemporary decision making information systems. Hrubyak S.V. [2] analyses the dominant approaches to decision making and defines stages of decision making in general. Gusarina N.V. [3] looks at modern methods of decision making and offers an algorithm of information support for decision making system. Kabachenko D.V. [4] also describes stages of decision making and offers to assess efficiency of a decision on the basis of Hurwitz criteria. Makarenko M.V, Sapelnykova N.L and Onishchenko V.V. [5] take EVA indicator for the same purpose. Yu, G. F., Fei, W., and Li, D. F. [6] describe an approach to multi-criterial decision-making method, based on criteria weights represented as utility functions. Levykin V, Chala O. [7] build a model of the temporal knowledge base, which allows to define causative relationships between factors, relevant for decision making. Shrestha, Y. R., Ben-Menahem, S. M., & Von Krogh, G. [8] look at the possibility of AI implementation into decision making process and develop a framework for combining human-based and AI-based models of decision making. Shrestha, Y. R., Krishna, V., and von Krogh, G. [9] describe deep learning algorithms for fostering decision making process. Feng, F., Fujita, H., Ali, M. I., Yager, R. R., and Liu, X. [10] describe an algorithm based on intuitionistic fuzzy soft sets for multiattribute decision making. Dankeieva, O., Solomianiuk, N., Strashynska, L., Fiedotova, N., Soloviova, Y., and Koval, V. [11] apply cognitive modeling for improving effectiveness of management decisions. Xu, H., and Deng, Y. [12] improve the traditional method of finding correlation between factors relevant for decision making, which allows the researchers to confirm indirect relationships between two factors through a third factor. Yankovyi, O., Koval, V., Trokhymets, O., Karpenko, M., and Matskevich, Y. [13] describe an approach to determine volumes and payback periods of investment in production with the capital-labor ratio optimum. So, most of recent studies explore the possibility of particular method usage in decision making task.

Aim and tasks. The aim of this paper is to form development principles of integrated methodology of rational production alternative selection based on multiple criteria.

Results. The development and implementation of innovative investment solutions has its own logic, a certain essence of the project management concept as a science and as a philosophy of entrepreneurship. This logic is the same for both decisions in subsystems of project implementation management on the innovative products production, and for decisions made on individual project management processes [1].

The process of making innovation and investment decisions can be represented as a system that interacts with the external environment and with other systems. Today, a systematic approach is used to solve many scientific problems, including decision-making.

From the point of view of a systematic approach, the object of research can be represented as a set of elements connected to each other, which determines its integrity. There can be a fairly wide variety of relationships of elements, cause-and-effect relationships within the system and in interaction with the external environment. In this case, the emergence effect is observed: the properties of the system are not equal to the simple sum of the properties of each of its elements. It is characterized by the appearance of new properties that are not inherent in its elements taken separately. That is, a crucial role in the functioning of the system, apart from constituent elements, belongs to the specifics of existing relationships.

From the point of view of a systematic approach, solving a problem is an integral system that is characterized by a certain type of interaction of its components. Mandatory components of such a system are: the goal that should be achieved as a result of the implementation of the decision; the goals of individual participants in the implementation of the decision; the set of alternatives; the criteria by which alternatives are evaluated.

Using the system approach as a methodology for the decision-making process, we can distinguish the following stages of system analysis of the problem [1; 2; 3; 6]:

a) stating the main goals and objectives;

b) defining the boundaries of the system, separating it from the external environment;

c) creating a list of system elements (subsystems, factors, variables, etc.);

d) identification of the essence of the integrity of the system;

e) analysis of the relationships of system elements;

f) building the system structure;

g) establishing the functions of the system and its subsystems;

h) coordination of the goals of the system and its subsystems;

i) specifying the boundaries of the system and each subsystem;

k) emergence analysis;

l) designing a system model.

The components of the decision-making process are: decision parameters, multiple alternatives, and the final goal.

The parameters of an innovation and investment decision are determined by the characteristics of the situation in which decision-making is carried out. These characteristics are very diverse and can be classified according to various criteria. The most commonly used classification is according to the object of research, under which they are divided into exogenous and endogenous groups. Exogenous parameters include parameters that characterize the external environment of an object, and endogenous parameters characterize its internal state.

It is clear that in order to make an effective innovation and investment decision, it is necessary to correctly define a set of decision-making parameters and indicators that should be used to evaluate these parameters.

In general, the following types of indicators can influence decision-making on the production of innovative products:

- efficiency indicators that characterize the degree of adaptability of innovative products to solution of tasks assigned to them;

- cost-effective, which set the price required to solve problems with a given efficiency;
- temporal, organizational, which characterize the time required for the implementation of certain technical solutions, certain stages of implementation (R & D, adjusting a new technology to the conditions of the enterprise, training employees, etc.);
- which characterize the level of perfection of a particular innovation;
- which characterize the resource and service life of innovative products;
- which characterize the customer's risk in achieving the innovation goals.

Simultaneous consideration of these indicators puts the task of assessing competitiveness and designing rational innovative products alternatives in the category of multiple-criteria assessment of their functional suitability, which significantly complicates the task of performing a comparative analysis of innovation and investment activity.

Multiple alternatives are a prerequisite for the decision-making process. Indeed, if there are no alternative options, the decision-making situation does not occur, and the use of analysis methods and decision-making methods is impractical.

An alternative option is understood as a variant of solving a problem that is quite acceptable from the point of view of decision-making criteria [1]. In addition, those that are worse than others by all indicators selected for comparison should be excluded from the list of alternatives. For this purpose, it is recommended to use the Pareto set. To form a Pareto set, you need to compare all the alternatives with each other in pairs. The Pareto set includes those alternatives that are better than others by at least one criterion.

The early stage of research on alternatives for the production of innovative products introduces two more serious issues in the implementation of this task:

a) a significant number of output alternatives (due to the need for revision of the entire range of innovations);

b) the need for mandatory allowance for the uncertainty of the initial criteria information about alternatives.

The ultimate goal is the goal that must be achieved as a result of implementing the decision made. When making innovation and investment decisions, the final goal is closely related to innovation and investment goals and may have an economic or socio-economic orientation. When making decisions, the final goal is formalized and presented as a set of criteria. The task of making decisions is complicated by the fact that the criteria may contradict each other, as well as the fact that the initial information about the evaluation of criteria for each alternative is usually incomplete, that is, the decision is made under conditions of uncertainty.

The following types of information representation can be selected to describe the initial criteria information:

a) deterministic (to describe fully defined information);

b) probabilistic (when information can be given a probabilistic, random character);

c) interval (when there is no grounds for interpreting information as random, i.e. the nature of its uncertainty is unknown, only its property of being limited is known).

In some cases, rank scores, i.e. scores obtained on an order scale, can be used to measure qualitative criteria (or quantitative criteria, in the case of lack of information). In this case, a notional scale for measuring the criterion is introduced, most often in integer points. However, in general, rank estimates can be reduced to deterministic ones.

Analysis of the main methods for evaluating innovative products has shown that they do not contain a single methodological basis. They use a limited set of quantitative and qualitative indicators of innovative products, and do not fully take into account uncertainties in the initial information.

The quality and efficiency of innovation and investment activity evaluation and selection of rational innovative products alternatives depend on the quality of building the evaluation and decision-making process and the methods used in this process. It is advisable to solve this problem by using the methods of decision making theory.

In the process of solving the problem of innovation and investment activity evaluation and selection of rational innovative products alternatives, the question arises: in what dimension should the space of criteria (indicators) be chosen? The increase in the number of criteria considered, on the one hand, makes it possible to characterize innovative products alternatives multidimensionally, and on the other hand, it makes it difficult to understand the task, especially expert comparative assessments of innovative product alternatives.

To evaluate criterion information, correlation analysis is most often used, which allows the user to identify groups of strongly related criteria with the subsequent exclusion of a number of such criteria from consideration.

One of the most important questions posed by the development of this methodology is the choice of decision-making methods. This choice is influenced by factors such as the acceptability of risk in solving problems, the amount of initial information about criteria and alternatives, the available time to solve the problem, etc.

It can be possible to try to classify decision-making methods, although this classification will be quite notional. For this purpose, we introduce a vector that characterizes a specific decision-making problem, as well as a number of additional conditions for the decision-making process:

$$\vec{V} = \{V_1, V_2, V_3, \ldots, V_7\}, \qquad (1)$$

where V1 is the type of a problem to be solved; V2 —available time to solve the problem; V3 – method of including information about criteria and alternatives; V4 –type of information used; V5 – number of alternatives; V6 – number of performance criteria; V7 – acceptability of the risk level in the task.

In general, the number of vector components is not final and can be increased if the decision-making task needs to be more detailed. For each component of the vector, we can consider the set of permitted values given in Table 1.

Table 1. Description of the criteria space in decision-making

Components	Parameter of a decision making problem	Permitted values of the parameter
V_1	Type of a problem to be solved	1 - linear ranking of alternatives; 2 - group ranking of alternatives; 3 - search for one or more of the best alternatives
V_2	Time available for solution of a problem	1 1 – rather long; 2 2 - limited
V_3	Method of including information about criteria and alternatives	1-explicit; 2-implicit
V_4	Type of information used	1-deterministic; 2-probabilistic; 3-interval
V_5	Number of alternatives	1 1– small ($A \leq 6$); 2– big ($A > 6$)
V_6	Number of performance criteria	2 1– small ($C \leq 6$); 2– big ($C > 6$)
V_7	Acceptability of the risk level in the task	1 1 – risk is acceptable; 2 2 – risk is not acceptable

It is also possible to classify decision-making methods in accordance with the given sets of values of the vector components. With a certain degree of being notional, three groups of decision-making methods can be distinguished to solve our problem.

The first group includes a number of decision-making methods, such as the ideal point method, the best sum of places method, the dominant criteria method, linear and nonlinear convolution of criteria methods, etc. These methods are the most frequently used and fastest-acting, and do not require further expert information. They use deterministic information. They are designed to solve type 1 decision-making problems (i.e., problems of linear ranking of alternatives by preference), and, as a result, can also be used to solve problems of Type 2 and 3. However, these methods require preliminary evaluation of the preferability of criteria by using coefficients of their relative importance. This point is very important, since any change in preferability can significantly alter the final ranking of innovative products alternatives.

Most methods allow for a certain degree of risk when making decisions. However, there are a number of situations where the risk is generally unacceptable or needs to be minimized. In this case, it is advisable to use decision-making methods of the second group: the minimax method, the Hurwitz method, etc. These methods are used when it is necessary to take into account a possible change in external conditions with an unknown possibility of its occurrence and solve the problem one or a small number of times. They mainly use deterministic information, and they also require pre-setting coefficients of relative importance of criteria.

Most often, an expert assessment of the coefficients of criteria relative importance is used. However, it carries a considerable share of unpredictability. In addition, this requires significant experience of the expert, his knowledge of the essence of the studied problem. Moreover, with a large number of criteria, the expert, due to the psychological capabilities of a human, is not able to simultaneously cover all the criteria during comparison, to feel the difference in their impact on the decision as a whole, which leads to insufficient validity of the expert assignment of the importance of criteria.

One of the rational approaches to solving this issue is to use the method of hierarchy analysis, which allows the researcher to measure the impact on the final result by paired expert comparison, which is carried out in terms of the dominance of one element over another. The characteristics of the main representatives of decision-making methods are shown in Table 2.

Table 2. Characteristics and use of decision-making methods

Group number	Decision-making methods	Vector $\vec{V}$ components of decision-making problem description							
		V_1	V_2	V_3	V_4	V_5	V_6	V_7	…
1	Linear convolution of criteria The best sum of places The ideal point Dominant criteria…	1/2/3	1/2	1	1	1/2	1/2	1	…
2	Minimax Hurwitz …	1/2/3 1/2/3	1/2 1/2	1 1	1 1	1/2 1/2	1/2 1/2	2 1/2	…
3	Stochastic dominance method …	1/2/2	1/2	1	2/3	1/2	1/2	1	…

This classification is notional and can be further refined.

Analysis of the existing literature shows that mostly, when developing similar methods, a single (universal) method of decision-making is considered. Such methods require a long preparatory process of work and a significant amount of additional expert information.

Given the complexity of the task of rational innovative production alternative selection, the different degree of uncertainty of the information used in this process, as well as the possibility of fast solution of problems, it is hardly advisable to use any single one, even relatively universal method of decision-making in the methodology.

Such a technique should contain a set of different decision-making methods: from fast, which do not require a large amount of initial information, but are less precise, to more accurate, but also more complex. Their use will also allow us to conduct a study of the stability of the resulting solution for confident and reasonable decision-making on the rational innovative production alternative selection.

The set of decisions implemented should be minimally sufficient to solve the problem in a multiple criteria representation, taking into account different degrees of information uncertainty and the level of risk. The general structure of the proposed complex methodology is shown in Fig. 1.

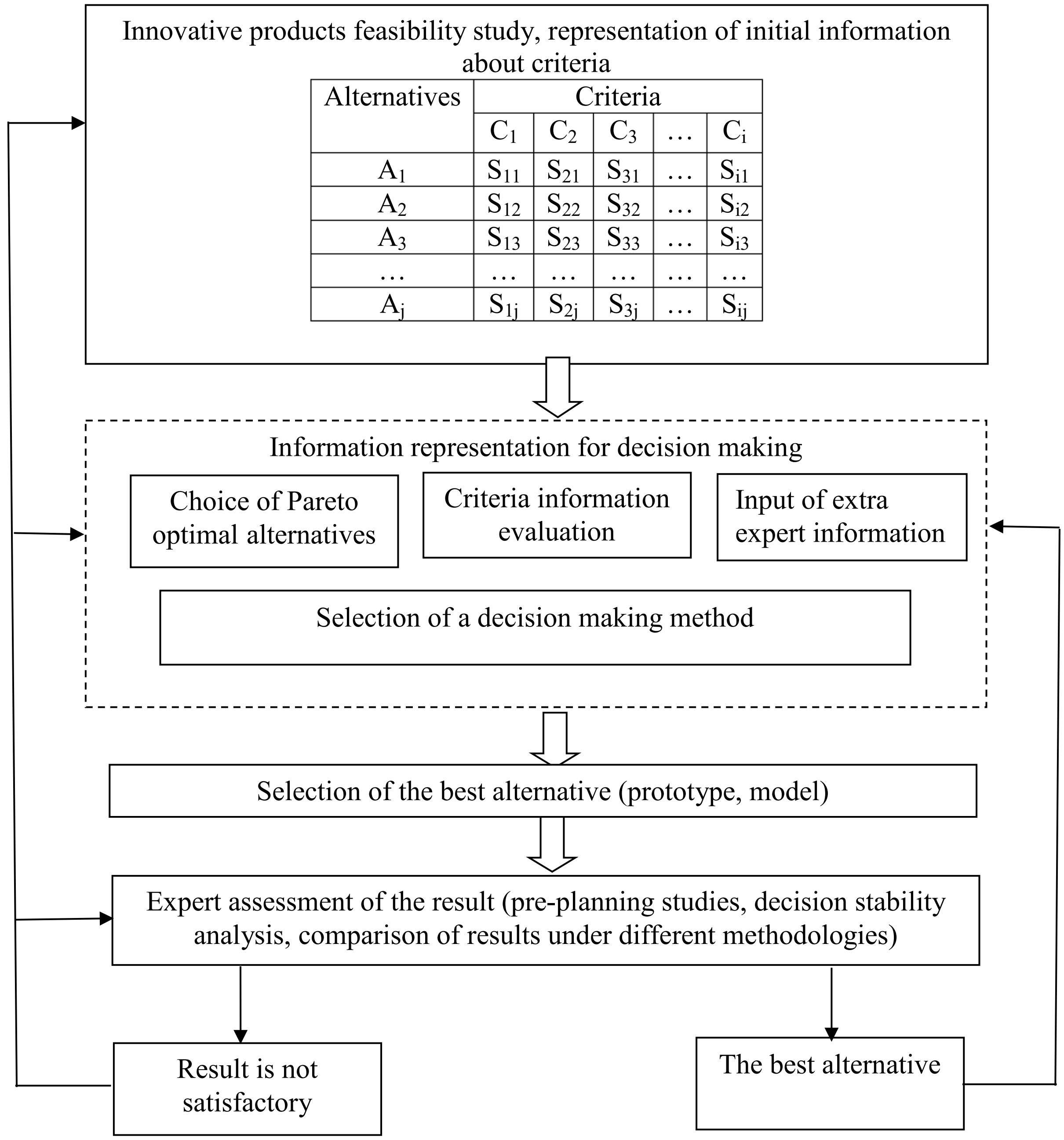

Fig. 1. General structure of rational innovative production alternative selection process.

In order for such a methodology to function, the following must be developed:

- methodology of innovative products feasibility study and formation of initial information on criteria and alternatives;
- methodology of conducting criteria research;
- methodology of reasonable selection of a rational set of decision-making methods.

Conclusions. The problem of the decision effectiveness assessment is complicated by several circumstances. First, as a result of decision-making, as a rule, a set of goals is achieved in different areas of the enterprise's activity, which may have different suitability to formalized assessment and different measurement scales. Secondly, at the time of decision-making, its results are predictive in nature, that is, there is a contradiction between the desired speed and the reliability of decision-making effectiveness assessment. Third, the achievement of results is usually not instantaneous, but occurs over a period of a certain duration, which requires consideration and usage of discounting methods. These listed circumstances do not allow us to use only indicators of economic efficiency for the purpose of evaluating the decision-making process. Such an assessment should use an integrated criterion in which economic efficiency indicators would be of high importance.

Thus, when an integrated methodology of rational innovative production alternative selection should include:

- solution of the decision-making problem in a multiple-criteria interpretation;
- evaluation of a sufficient set of alternatives;
- allowance for the uncertainty of the initial criteria information about alternatives;
- usage of different criteria measurement scales;
- use of alternative information at all stages of the decision-making process.

REFERENCES

1. Klepikova, O. (2017). Information and analytical decision-making systems in enterprise management. *Visnik social'no-ekonomichnih doslidzhen'*, 1(62), 196-204.

2. Hrubyak, S. V. (2017). Modern aspects of development and making managerial decisions. *Ekonomika ta suspil'stvo*, 11, 201-204.

3. Gusarina, N. V. (2017). Featurs of the system of support for adoption of decisions on management of innovative production sphere in the conditions of dynamic change of the external environment. *Hlobalni ta natsionalni problemy ekonomiky*, 20, 1052-1055.

4. Kabachenko, D. V. (2017). Management decision taking under uncertainty and risk. *Ekonomichnij visnik Nacional'nogo girnichogo universitetu,* 2, 107-115.

5. Makarenko, M. V., Sapelnikova N. L. and Onishhenko V. V. (2017). Specifics of justification of a management decision based on the efficiency criterion. *Bulletin of Donetsk State University of Management*, 4, 86-95.

6. Yu, G. F., Fei, W., & Li, D. F. (2018). A compromise-typed variable weight decision method for hybrid multiattribute decision making. *IEEE Transactions on Fuzzy Systems*, 27,(5), 861-872.

7. Levykin, V.M., & Chala O.V. (2018). Support decision-making in information control systems using the temporal knowledge base. *Advanced Information Systems*, 2(4), 101-107.

8. Shrestha, Y. R., Ben-Menahem, S. M., & Von Krogh, G. (2019). Organizational decision-making structures in the age of artificial intelligence. *California Management Review*, 61(4), 66-83.

9. Shrestha, Y. R., Krishna, V., & von Krogh, G. (2021). Augmenting organizational decision-making with deep learning algorithms: Principles, promises, and challenges. *Journal of Business Research*, 123, 588-603.

10. Feng, F., Fujita, H., Ali, M. I., Yager, R. R., & Liu, X. (2018). Another view on generalized intuitionistic fuzzy soft sets and related multiattribute decision making methods. *IEEE Transactions on Fuzzy Systems*, 27(3), 474-488.

11. Dankeieva, O., Solomianiuk, N., Strashynska, L., Fiedotova, N., Soloviova, Y., & Koval, V. (2021). Application of Cognitive Modelling for Operation Improvement of Retail Chain Management System. *TEM Journal*, 10(1), 358-367.

12. Xu, H., & Deng, Y. (2019). Dependent evidence combination based on decision-making trial and evaluation laboratory method. *International Journal of Intelligent Systems*, 34(7), 1555-1571.

13. Yankovyi, O., Koval, V., Trokhymets, O., Karpenko, M., & Matskevich, Y. (2020). Economic assessment of investment on the basis of production functions. *Revista TURISMO: Estudos e Práticas*, 2.