The object of the study is decision support systems. A methodology for evaluating information and analytical support in decision support systems was developed. The method consists of the main stages: assessment of the type of uncertainty about the state of the analysis object, calculation of criteria and determination of development options, determination of system reaction time, formation of the initial scenario. The next steps are establishing the target state of the object, analyzing options for influencing the analysis object, obtaining intermediate target states of the analysis object, and determining options for the development of the analysis object.

The method was developed because of the need to process more information and has a moderate computational complexity.

It was found that the proposed method has a computational complexity of 10–15 % lower compared to the methods for evaluating the effectiveness of management decisions. This method will allow assessing the state of information and analytical support and determining effective measures to increase efficiency. The method will allow analyzing possible options for the development of the assessment object in each development phase and the moments in time when it is necessary to carry out structural changes that ensure the transition to the next phase. In this case, subjective factors of choice are taken into account while searching for solutions, which are formalized in the form of weights for the components of the integral efficiency criterion. The maximization of the criteria, calculated taking into account the preferences, makes it possible to determine the best option for the development of the assessment object. The method allows increasing the speed of assessment of the state of information and analytical support, reducing the use of computing resources of decision support systems, developing measures aimed at increasing the efficiency of information and analytical support

Keywords: information and analytical support, fuzzy cognitive models, computational complexity, system of indicators, fuzzy models

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DEVELOPMENT OF A COMPREHENSIVE METHODOLOGY FOR ASSESSING INFORMATION AND ANALYTICAL SUPPORT IN DECISION SUPPORT SYSTEMS

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1. Introduction

The basis of any management is the decision of the manager (head), which represents a certain order and methods of performing tasks. Preparing and making decisions is one of the most important functions of the manager (head) in object management [1]. Therefore, the reasonableness and timeliness of the manager's decision are the most important task of the relevant officials and analytical units in management.

The efficiency of performing this complex task by officials is greatly affected by decision-making methods, the improvement of which is carried out on the basis of complex automation and informatization [1].

Thus, the creation and implementation of new highly effective automated systems and information technologies for decision support into the practice of modern managers are one of the most important directions for improving strategic management.

Software support systems are being actively developed, which will increase the efficiency of information and analytical support for the activities of officials.

The factors that stimulate the development of this class of software systems are their use for solving poorly structured and difficult to formalize problems in conditions of uncertainty and inaccuracy.

In recent decades, the trend of using artificial intelligence methods has been increasing. However, their application in existing management systems is mainly limited to an expert approach in the interests of automation and informatization of individual stages of information preparation in strategic decision-making.

The works [2–6] present studies on the development of methods (approaches) for multi-criteria evaluation of complex objects. As a mathematical apparatus, these works use fuzzy set theory, analytic hierarchy process and expert evaluation methods.

These approaches have the following disadvantages:

– provide only a general assessment and distract from the vision of specific connections between objects;

– complexity of processing heterogeneous data of a quantitative and qualitative nature;

– limited dimensions of models used;

– the difficulty of decision-making under uncertainty.

In such conditions, the development of methods for multi-criteria evaluation of complex objects and alternatives becomes important.

Considering the above, the use of artificial neural network theory and fuzzy cognitive maps for decision support systems is a relevant direction for further scientific research. This will allow decision-makers to make adequate and prompt decisions.

2. Literature review and problem statement

The work [8] describes an agent-based approach used in a multi-agent information and analytical system and considers the problems of information support for decision-making. The disadvantages of the approach include the limited representation of complex systems, namely, none of the agents has an idea of the entire system.

The work [9] provides an operational approach for spatial analysis in the marine industry for the quantitative assessment and display of related ecosystem services. This approach covers the three-dimensionality of the marine environment considering all marine regions (sea surface, water column and seabed) separately. In fact, the method builds 3-dimensional models of the sea by estimating and mapping those associated with each of the three marine domains through the adoption of representative indicators. The disadvantages of this method include the impossibility of flexible setting (adaptation) of evaluation models while adding (removing) indicators and changing their parameters (compatibility and significance of indicators).

The work [10] presents a machine learning model for automatic identification of requests and provision of information support services exchanged among members of the Internet community. This model is designed to process a large number of messages from users of social networks. The disadvantages of the model are the lack of mechanisms for assessing the adequacy of decisions made and high computational complexity.

The work [11] presents a method of analyzing large data sets. The method is focused on finding hidden information in large data sets. The method includes the operations of generating analytical baselines, reducing variables, detecting sparse features, and specifying rules. The disadvantages of the method include the impossibility to take into account different decision evaluation strategies.

The work [12] proposes an approach for estimating the cost of client's living in the field of air transportation. In this approach, a regression model is first used, and then an indirect estimation model is applied. At the final stage, the evaluation results are compared using both evaluation models. The disadvantages of the approach include the impossibility of determining the adequacy of the obtained estimate.

The work [13] presents an approach to quantitative assessment for evaluating optimal selection and/or testing of analytical methods. Objective criteria related to analytical performance, sustainability, environmental impact and economic costs are assessed by defining penalty points divided into five different blocks. For each block, the overall qualification is scaled from 0 to 4 and is represented by a regular hexagonal icon, allowing a comparison of analytical procedures. The disadvantages of this approach include the impossibility to increase the number of evaluated indicators.

The work [14] presents the mechanism of transformation of information models of construction objects to their equivalent structural models. This mechanism is designed to automate the necessary conversion, modification, and addition operations during such information exchange. The shortcomings of the mentioned approach include the impossibility to assess the adequacy and reliability of the information transformation process. Also, the disadvantage of the approach is the lack of consideration of uncertainty of information on the object state.

The work [15] developed an analytical web platform to study the geographical and temporal distribution of incidents. The web platform contains several information panels with statistically significant results by territory. The web platform includes certain external sources of data on social and economic issues that allow studying the relationship between these factors and the distribution of incidents at different geographic levels. The disadvantages of the analytical platform include the impossibility to assess the adequacy and reliability of the information transformation process and high computational complexity.

The work [16] developed a method of fuzzy hierarchical assessment of library service quality. The method allows evaluating the quality of libraries based on a set of input parameters. The disadvantages of the method include the impossibility to assess the adequacy and reliability of the assessment.

The work [17] carried out a comparison of the effectiveness of two analytical hierarchy assessment methods and the fuzzy analytical hierarchy method. The advantages and disadvantages of these methods are given. The shortcomings of the methods include the lack of consideration of the compatibility of unevenly significant indicators and the impossibility to assess the adequacy of decisions made.

The work [18] carried out an analysis of 30 algorithms for processing large data sets. Their advantages and disadvantages are shown. It was found that the analysis of large data sets should be carried out layer by layer, in real time and have the opportunity for self-learning. The shortcomings of these methods include high computational complexity and the impossibility to check the adequacy of the obtained estimates.

The work [19] presents an approach to evaluating input data for decision support systems. The essence of the proposed approach consists in the clustering of the basic set of input data, their analysis, after which the system is trained based on the analysis. The disadvantage of this approach is the gradual accumulation of assessment and training errors due to the lack of an opportunity to assess the adequacy of decisions made.

The work [20] presents an approach to processing data from various sources of information. The disadvantages of this approach include the low accuracy of the obtained estimate and the impossibility to verify the reliability of the obtained estimate.

The work [21] carried out a comparative analysis of existing decision support technologies, namely: analytic hierarchy process, neural networks, fuzzy set theory, genetic algorithms and neuro-fuzzy modeling. The advantages and disadvantages of these approaches are indicated. The scope of their application is defined. It is shown that the analytic hierarchy process works well with complete initial information, but due to the need for experts to compare alternatives and choose evaluation criteria, it has a high share of subjectivity. For forecasting problems under risk and uncertainty, the use of fuzzy set theory and neural networks is justified.

The work [22] considered problematic aspects of information and analytical support of strategic decision-making in modern management. The role and place of the process of developing and making management decisions in strategic planning are specified. The existing approaches to accounting for the patterns of progress and result of strategic processes are analyzed. In the course of the analysis, it was found that approaches and methods of modern model theory in control systems, which allow linguistic approximation of mathematical models of cybernetic systems, are of particular interest. Such an approximation ensures the achievement of the highest level of abstract description of systems, which allows identifying the most general concepts and exploring relationships between them. However, the results do not fully apply to organizational management systems. To solve strategic management problems, it is proposed to use fuzzy set theory and neural networks.

The work [23] describes the tools and methods of analysis and processing of information about the number and quality of personnel of the Ministry of Defense of the Czech Republic. The shortcomings of the approach include high computational complexity, impossibility to assess the adequacy and reliability of decisions made.

The work [24] describes approaches to the processing of constantly updated information circulating in social information communications, namely: the active use of methods of content monitoring and content analysis in this process. The disadvantages of these methods include high computational complexity.

The work [25] provides a system of hierarchical fuzzy assessment of factors affecting the process of rice growing. The shortcomings of this method include the accumulation of evaluation errors due to the impossibility of assessing the adequacy of the obtained estimate.

In [26], a methodology for determining and assessing the strategic economic potential of theoretical and methodological foundations for the formation and assessment of the level of the strategic economic potential of economic systems was developed. The methodology is based on the use of the analytic hierarchy process. The shortcomings of the method include the dependence of the obtained results on experts' competence and high computational complexity.

In [27], an approach to determining the impact of factors affecting the efficiency of economic activity on the economy of integrated structures was developed. The approach is based on the use of the expert evaluation method. The disadvantages of this approach include the dependence of the obtained results on experts' competence and high computational complexity.

In [28], a systems approach for evaluating the effectiveness of strategic plan implementation was developed. The systems approach is based on the use of the expert evaluation method. The disadvantages of the systems approach include the dependence of the obtained results on experts' competence and high computational complexity.

The analysis of [1–28] showed that the vast majority are based on the use of general scientific methods, such as systematic, comparative, structural and functional analysis, expert evaluation method, the methodology of scenario analysis of socio-economic systems and the theoretical and informational approach.

Common limitations of existing methods of multi-criteria evaluation of alternatives are:

– the complexity of forming a multi-level evaluation structure;

– the lack of consideration of the compatibility of unevenly significant indicators;

– the lack of taking into account the uncertainty about the state of the evaluation object;

– the lack of possibility of joint performance of direct and reverse evaluation tasks with the support of the selection of the best solutions.

To create decision support software, it is necessary to create evaluation methods that must meet the following set of requirements:

– the possibility of forming a generalized evaluation indicator and choosing solutions based on sets of partial indicators that change taking into account a complex multi-level evaluation structure;

– the possibility of aggregating heterogeneous evaluation indicators (both quantitative and qualitative) and selecting solutions that differ in measurement scales and ranges of values;

– taking into account the compatibility and different significance of partial indicators in the generalized assessment of decisions;

– consideration of various decision evaluation strategies;

– flexible setting (adaptation) of evaluation models while adding (removing) indicators and changing their parameters (compatibility and significance of indicators);

– ensuring the possibility of implementation of the direct task of evaluating the generalized indicator based on partial indicators, inverse evaluation problem and joint performance of direct and inverse evaluation problems within the framework of a single model.

For this purpose, it is proposed to develop a methodology that would allow evaluating complex information and analytical support in decision support systems, have a flexible configuration, and implement direct and reverse evaluation within a single model.

3. The aim and objectives of the study

The aim of the study is to develop a comprehensive method for evaluating information and analytical support in decision support systems using fuzzy logic. This will make it possible to take into account a larger number of factors affecting the efficiency of information and analytical support, and also have different units of measurement and nature.

To achieve the aim, the following objectives were set:

– to develop an algorithm for the evaluation methodology of information and analytical support in decision support systems;

– to give an example of the application of the proposed methodology in the analysis of the enterprise state.

4. Materials and methods

In the study, to solve the problem of analyzing the state of objects in intelligent decision support systems, the general provisions of artificial intelligence theory were used. Thus, artificial intelligence theory is the basis of the study. The study used fuzzy cognitive models and evolving artificial neural networks. The simulation was carried out using MathCad 2014 software (USA) and an Intel Core i3 PC (USA).

5. Development of a methodology for evaluating information and analytical support in decision support systems

5. 1. Development of an algorithm for evaluating information and analytical support in decision support systems

The method of comprehensive evaluation of information and analytical support in decision support systems consists of the following sequence of actions (Fig. 1):

1. Input of initial data. At this stage, the initial data about the state of the object are entered. The number of sources of information, the type and amount of initial data are determined.

2. Determination of the degree of uncertainty of the initial data. At this stage, the degree of uncertainty of the initial data is determined based on the authors' previous research. The degree of uncertainty of the initial data is as follows: complete uncertainty, partial uncertainty and full awareness [29, 30].

3. Calculation of criteria and definition of development options.

The developed method is designed to solve the problems of both direct and reverse planning of the development of the research object.

The values of the input parameters $\{X_i\}$ and the structure of the system-dynamic model determine the dynamics of the A_i value over time (i is the number of the computational experiment).

4. Determination of system reaction time.

For the further calculation of the criteria, it is necessary to take into account the initial rate of development of the event – A_0, the maximum achievable rate of development of the event $A_{\max}$ and the time of reaching $A_{\max}$ equal to $t_{\max}$. During the simulation modeling, development options in which the value of the development rate of the event falls below the value of $A_0/2$ are not considered, since this trend reflects negative processes.

To take into account the end of the development phase, a time characteristic t_{stop} is considered, which contains information about the stop time of the computational experiment. Its value can be determined by calculating $A_{stop}=kA_{\max}$, where k is given by the parameter, and $0<k<1$. Since there are usually two values at which $A=A_{stop}$, the time characteristic at which $t_{stop}>t_{\max}$ is considered.

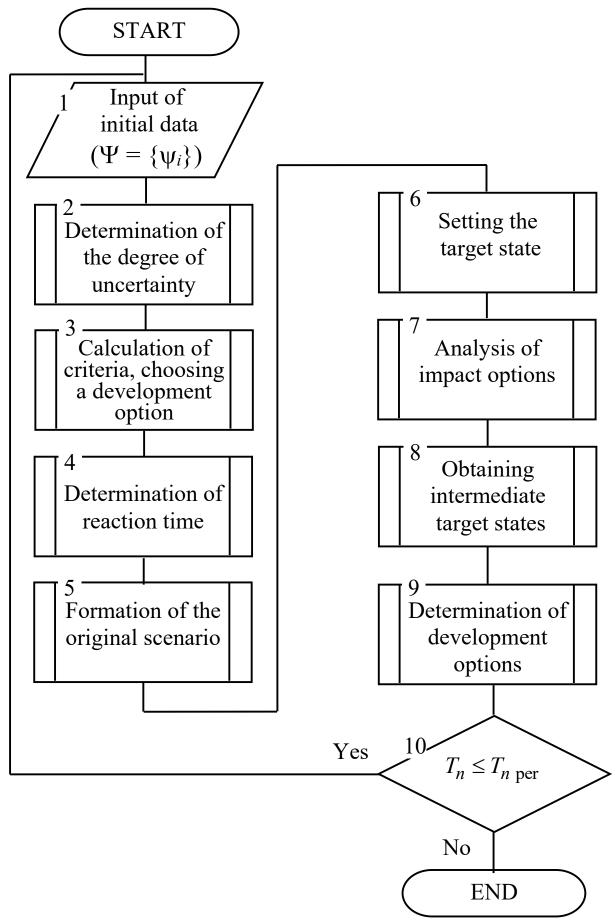

Fig. 1. Algorithm for the implementation of a complex method for evaluating information and analytical support

5. Formation of the original scenario.

As a result of a series of N computational experiments, related sets of input and output data are formed: $\overline{X}_i \to \overline{Y}_i, i=\overline{1,N}$.

For each data set of the $\overline{Y}_i$ vector, the values of the elements $A_{\max}$, $t_{\max}$, S_p are normalized:

$$A_{\max_i}^{norm} = A_{\max_i} \Big/ \max\left(A_{\max_i}\right)\Big|_{i=1,\dots N},$$
$$S_{p_i}^{norm} = S_{p_i} \Big/ \max\left(S_{p_i}\right)\Big|_{i=1,\dots N}, \quad (1)$$
$$t_{\max_i}^{norm} = t_{\max_i} \Big/ \max\left(t_{\max_i}\right)\Big|_{i=1,\dots N},$$

where $N=|\{x_1\}^*\{x_2\}^*\{x_3\}|$ is the number of options of computational experiments.

6. Setting the target state of the object.

Using the obtained values of the required parameters, the K_{ri} criteria are calculated for each scenario, taking into account the weights of the indicators ($0<wes_*<1$) set on the basis of user preferences, which characterize the effective management of the development of the analysis object:

$$K_{r_i} = wes_1 \cdot Sp_i^{norm} + wes_2 \cdot A_{\max_i}^{norm} - wes_3 \cdot t_{\max_i}^{norm},\ i=\overline{1,N}. \qquad (2)$$

7. Analysis of options of impact on the analysis object.

The parameters and results $\overline{X}_{req}=\overline{X}_j;\overline{Y}_{req}=\overline{Y}_j$ are sought for the j-th computational experiment, for which the obtained value of the criterion is the maximum: $K_{r_j}=K_{r_{\max}}=\max(K_{r_i})\big|_{i=1,\dots,N}$.

8. Obtaining intermediate target states of the analysis object.

The search of the point t_{req} of effective transition to the next phase of the development of the analysis object on the time axis is carried out by conducting another series of simulations taking into account the change at each point $[t^-, t^+]$, determined with some step Δt. As a result of the calculation of the criteria for the newly obtained options, the desired t_{req} point is determined.

If necessary, a new set of values $\overline{X}'$ can be specified at the t_{req} point. The point of transition to the next phase t_{req} is determined by the same scheme, but with a change in the structure and possibly the parameters of the model at the t_{req} point.

Then a set of values $\left(X_{req}, X'_{req}, X''_{req}, t_{req}, t'_{req}, A''_{stop}\right)$ is formed, including:

– X_{req}, X'_{req}, X''_{req} – the sets of parameters characterizing the analysis object at the beginning of each of the analyzed development phases;

– t_{req}, t'_{req} – the points corresponding to the time of implementation of structural changes, which translate each of the development phases, respectively;

– A''_{stop} – the value of the development rate at the end of the forecasting time interval.

This set determines the best option for the development of the analysis object given the initial conditions X_{req}.

9. Determination of development options of the analysis object.

The system of states for determining development options of the analysis object is a final weighted directed graph *Gr*. The vertices of the graph mutually uniquely correspond to the states of the system, characterized by the current rate of the event (A_b), the arcs are the control determined by a set of parameters ($\overline{X_b}$), the weights of the arcs w_b are the costs of the corresponding transitions calculated by the following formula:

$$w_b = \sum A_b - fond_b,\ \ fond_b \geq 0,\ \ b=\overline{1,l}, \qquad (3)$$

where $\sum A_b$ is the total value of the cost of the analysis object in the b-th simulation experiment; $fond_b$ is the corresponding additions embedded in the analysis object, l is the number of scenarios leading to the specified states.

To determine the required development trajectory of the analysis object, which ensures the achievement of the target state, the best path is calculated on the formed graph *Gr* by the dynamic programming method in accordance with the Bellman optimality principle.

Based on the theory of the dynamic programming method [17], the *Sys* system is considered, which is translated from the initial state Sys_0 to the final state Sys_{end} as a result of some *Manag* management, divided into a finite number of *Step* steps. It is taken into account that decision-making is carried out consistently at each step. The control that switches the system *Sys* under consideration from the initial state Sys_0 to the final state Sys_{end} will be a set of step-by-step controls *Step*, each of which is characterized by the corresponding value of the function *W*(*Manag*).

The solution to the dynamic programming problem consists in finding from all possible controls *Manag* such $Manag^*$ in which the function *W*(*Manag*) will acquire the maximum (minimum) value of $W(Manag^*)$.

It is assumed that the state of the S_{ys} system under consideration at each z-th step is determined by a numerical set $XS^{(z)}=\left(xs_1^{(z)}, xs_2^{(z)}, \dots, xs_n^{(z)}\right)$. This sequence is formed by implementing $Manag_z$ control influences, which ensure the transition of the system from the previous state $XS^{(z-1)}$ to the next one – $XS^{(z)}$. Moreover, the $XS^{(z)}$ state depends only on the $XS^{(z-1)}$ state and the selected $Manag_z$ control, but not on the method of transition to a new state.

If the implementation of the z-th step leads to a certain income $W_z(XS^{(z-1)}, manag_z)$, which also depends on $XS^{(z-1)}$, then the entire income while passing all steps will be:

$$Gain = \sum_{z=1}^{Step} W_z\left(X^{(z-1)}, Manag_z\right). \qquad (4)$$

Solving the dynamic programming problem involves finding such a set of controls $Manag^* = \left(manag_1^*, manag_2^*, \dots, manag_{step}^*\right)$, the application of which brings the system from the initial state to the final state, and the total income (4) acquires the greatest value.

10. Checking the efficiency of decisions made.

At this stage, the permissible decision-making time in the task of evaluating and forecasting the state of the analysis object is determined. The criterion for the efficiency of decisions made is T_n.

The optimal strategy can be found by sequentially determining the optimal control strategies at the last step, then the last two steps are considered, then three, and so on, until we reach the initial state of the system. At the same time, it is necessary to take into account conditionally optimal management of all possible results of the previous step.

When the initial state is reached, similar operations are carried out, but in the reverse direction – from the initial state to the final state.

To evaluate the effectiveness of the developed methodology for evaluating information and analytical support in decision support systems, it was compared with the most popular software products for enterprise management:

– ARIS Business Performance Edition (IDS Scheer AG, Germany);

– IBM WebSphere Business Modeler (IBM, USA);

– System21 Aurora (Campbell Lee Computer Services Limited, Great Britain);

– SAP Strategic Enterprise Management (SAP, Germany);

– Hyperion Performance Scorecard (Oracle, USA),

– CA ERWin Process Modeler (CA, USA).

5. 2. An example of the application of the proposed method in the analysis of the enterprise state

For a comparative assessment, the real state of the company was evaluated. «Everest Limited» LLC (Kyiv, Ukraine) was used as the research object.

The results of assessing the real state of the company are shown in Table 1, which presents the standardized assessment results.

Table 1

Comparison of the computational complexity of the software and the developed methodology for assessing the real state of the company

No.	Software	Number of calculations	Developed method (by the number of calculations)
1	ARIS Business Performance Edition (IDS Scheer AG)	67,000	57,260
2	IBM WebSphere Business Modeler (IBM)	64,500	52,330
3	System21 Aurora (Campbell Lee Computer Services Limited)	57,000	46,540
4	SAP Strategic Enterprise Management (SAP)	39,830	33,000
5	Hyperion Performance Scorecard (Oracle)	46,200	40,194
6	CA ERWin Process Modeler (CA)	43,050	37,023

6. Discussion of the results of the development of a method for evaluating information and analytical support in decision support systems

A method for evaluating information and analytical support in decision support systems is proposed. Simulation of the proposed method was carried out in the MathCad 14 software.

In the course of the research, an algorithm was developed for evaluating the information and analytical support of strategic management using fuzzy logic, the graphic representation of which is shown in Fig. 1.

As can be seen from Table 1, the advantage of the method over the known ones is the reduction of computational complexity, which in turn increases the efficiency of decision-making relative to the object of management.

The main advantages of the proposed evaluation method are:

– a flexible hierarchical structure of indicators, which allows reducing the task of multi-criteria evaluation of alternatives to one criterion or using a vector of indicators for selection;

– the unambiguity of the obtained estimate of the state of information and analytical support;

– wide scope of use (decision support systems);

– simplicity of mathematical calculations;

– no accumulation of errors during training;

– consideration of the type of uncertainty about the state of the evaluation object;

– the possibility of adapting the system of indicators during operation;

– the possibility of synthesizing the optimal structure of the decision support system.

The disadvantages of the proposed method include:

– lower accuracy of assessment by a single parameter of assessment of the state of information and analytical support;

– the need for a decision-maker to indicate the type of uncertainty;

– lower assessment accuracy compared to other assessment methods.

This method makes it possible:

– to assess the state of information and analytical support;

– to identify effective measures to increase the effectiveness of information and analytical support;

– to analyze possible options for the development of the assessment object in each phase of development and the moments in time when it is necessary to carry out structural changes that ensure the transition to the next phase. In this case, subjective factors of choice (decision-maker preferences) are taken into account while searching for solutions, which are formalized in the form of weights for the components of the integral efficiency criterion. The maximization of the criteria, calculated taking into account the preferences, makes it possible to determine the best option for the development of the evaluation object.

– to increase the speed of assessment of the state of information and analytical support;

– to reduce the use of computing resources of decision support systems;

– to develop measures aimed at increasing the efficiency of information and analytical support.

According to the results of the analysis of the efficiency of the proposed method, it can be seen that its computational complexity is 10–15 % lower compared to the methods for evaluating the efficiency of decisions made presented in Table 1.

This study is a further development of research carried out by the authors aimed at developing methodological principles for improving the efficiency of information and analytical support [28, 31–38].

Areas of further research should be aimed at reducing computing costs while processing various types of data in special-purpose systems.

7. Conclusions

1. In the study, an algorithm for evaluating information and analytical support in decision support systems was developed. This makes it possible to increase the effectiveness of decisions due to:

– the consistent solution of forward and reverse planning problems using simulation modeling of the dynamics of the analysis object;

– providing a set of development trajectories of the analysis object at each phase;

– analysis of possible options for the development of the assessment object in each development phase and moments in time when it is necessary to carry out structural changes that ensure the transition to the next phase. In this case, subjective factors of choice (decision maker preferences) are taken into account while searching for solutions, which are formalized in the form of weights for the components of the integral efficiency criterion. The maximization of the criteria, calculated taking into account the preferences, makes it possible to determine the best option for the development of the evaluation object;

– taking into account the uncertainty about the state of the analysis object.

2. An example of the application of the proposed method in the analysis of the enterprise state is presented. According to the results of the analysis of the effectiveness of the proposed method, it is clear that its computational complexity is 10–15 % lower compared to the methods for evaluating the effectiveness of decisions made.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

References

1. Rodionov, M. A. (2010). Informatsionno-analiticheskoe obespechenie upravlencheskikh resheniy. Moscow: MIGSU, 400.
2. Roy, B. (1996). Multicriteria methodology for decision aiding. Springer, 293. doi: https://doi.org/10.1007/978-1-4757-2500-1
3. Saaty, T. L. (1980). The Analytic Hierarchy Process, Planning, Priority Setting, Resource Allocation. McGraw-Hill, 287.
4. Bellman, R. E., Zadeh, L. A. (1970). Decision-Making in a Fuzzy Environment. Management Science, 17 (4), 141. doi: https://doi.org/10.1287/mnsc.17.4.b141
5. Mamdani, E. H., Assilian, S. (1975). An experiment in linguistic synthesis with a fuzzy logic controller. International Journal of Man-Machine Studies, 7 (1), 1–13. doi: https://doi.org/10.1016/s0020-7373(75)80002-2
6. Sugeno, M. (1985). Industrial applications of fuzzy control. Elsevier Science Pub. Co., 269.
7. Fuller, R. (1995). Neural Fuzzy Systems. Abo Akademi University, 348. Available at: https://uni-obuda.hu/users/fuller.robert/ln1.pdf
8. Onykiy, B., Artamonov, A., Ananieva, A., Tretyakov, E., Pronicheva, L., Ionkina, K., Suslina, A. (2016). Agent Technologies for Polythematic Organizations Information-Analytical Support. Procedia Computer Science, 88, 336–340. doi: https://doi.org/10.1016/j.procs.2016.07.445
9. Manea, E., Di Carlo, D., Depellegrin, D., Agardy, T., Gissi, E. (2019). Multidimensional assessment of supporting ecosystem services for marine spatial planning of the Adriatic Sea. Ecological Indicators, 101, 821–837. doi: https://doi.org/10.1016/j.ecolind.2018.12.017
10. Xing, W., Goggins, S., Introne, J. (2018). Quantifying the Effect of Informational Support on Membership Retention in Online Communities through Large-Scale Data Analytics. Computers in Human Behavior, 86, 227–234. doi: https://doi.org/10.1016/j.chb.2018.04.042
11. Ko, Y.-C., Fujita, H. (2019). An evidential analytics for buried information in big data samples: Case study of semiconductor manufacturing. Information Sciences, 486, 190–203. doi: https://doi.org/10.1016/j.ins.2019.01.079
12. Çavdar, A. B., Ferhatosmanoğlu, N. (2018). Airline customer lifetime value estimation using data analytics supported by social network information. Journal of Air Transport Management, 67, 19–33. doi: https://doi.org/10.1016/j.jairtraman.2017.10.007
13. Ballester-Caudet, A., Campíns-Falcó, P., Pérez, B., Sancho, R., Lorente, M., Sastre, G., González, C. (2019). A new tool for evaluating and/or selecting analytical methods: Summarizing the information in a hexagon. TrAC Trends in Analytical Chemistry, 118, 538–547. doi: https://doi.org/10.1016/j.trac.2019.06.015
14. Ramaji, I. J., Memari, A. M. (2018). Interpretation of structural analytical models from the coordination view in building information models. Automation in Construction, 90, 117–133. doi: https://doi.org/10.1016/j.autcon.2018.02.025
15. Pérez-González, C. J., Colebrook, M., Roda-García, J. L., Rosa-Remedios, C. B. (2019). Developing a data analytics platform to support decision making in emergency and security management. Expert Systems with Applications, 120, 167–184. doi: https://doi.org/10.1016/j.eswa.2018.11.023
16. Chen, H. (2018). Evaluation of Personalized Service Level for Library Information Management Based on Fuzzy Analytic Hierarchy Process. Procedia Computer Science, 131, 952–958. doi: https://doi.org/10.1016/j.procs.2018.04.233
17. Chan, H. K., Sun, X., Chung, S.-H. (2019). When should fuzzy analytic hierarchy process be used instead of analytic hierarchy process? Decision Support Systems, 125, 113114. doi: https://doi.org/10.1016/j.dss.2019.113114
18. Osman, A. M. S. (2019). A novel big data analytics framework for smart cities. Future Generation Computer Systems, 91, 620–633. doi: https://doi.org/10.1016/j.future.2018.06.046
19. Gödri, I., Kardos, C., Pfeiffer, A., Váncza, J. (2019). Data analytics-based decision support workflow for high-mix low-volume production systems. CIRP Annals, 68 (1), 471–474. doi: https://doi.org/10.1016/j.cirp.2019.04.001
20. Harding, J. L. (2013). Data quality in the integration and analysis of data from multiple sources: some research challenges. ISPRS – International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XL-2/W1, 59–63. doi: https://doi.org/10.5194/isprsarchives-xl-2-w1-59-2013
21. Rybak, V. A., Ahmad, S. (2016). Analysis and comparison of existing decision support technology. Sistemniy analiz i prikladnaya informatika, 3, 12–18.
22. Rodionov, M. A. (2014). Problems of information and analytical support of contemporary strategic management. Nauchniy vestnik Moskovskogo gosudarstvennogo tehnicheskogo universiteta grazhdanskoy aviatsii, 202, 65–69.
23. Bednář, Z. (2018). Information Support of Human Resources Management in Sector of Defense. Vojenské rozhledy, 27 (1), 45–68.

24. Palchuk, V. (2017). Suchasni osoblyvosti rozvytku metodiv kontent-monitorynhu i kontent-analizu informatsiynykh potokiv. Naukovi pratsi Natsionalnoi biblioteky Ukrainy imeni V. I. Vernadskoho, 48, 506–526.
25. Mir, S. A., Padma, T. (2016). Evaluation and prioritization of rice production practices and constraints under temperate climatic conditions using Fuzzy Analytical Hierarchy Process (FAHP). Spanish Journal of Agricultural Research, 14 (4), e0909. doi: https://doi.org/10.5424/sjar/2016144-8699
26. Kljushin, V. V. (2014). Theoretical and methodological basis for the formation and evaluation of the level of the economic system's strategic economic potential. Modern Management Technology, 12 (48). Available at: https://sovman.ru/article/4805/
27. Bogomolova, I. P., Omel'chenko, O. M. (2014). Analysis of influence factors of economic efficiency on the economy of the integrated structures. Vestnik Voronezhskogo gosudarstvennogo universiteta inzhenernyh tehnologiy, 3, 157–162.
28. Sherafat, A., Yavari, K., Davoodi, S. M. R. (2014). Evaluation of the Strategy Management Implementation in Project-Oriented Service Organizations. Acta Universitatis Danubius, 10 (1), 16–25.
29. Dudnyk, V., Sinenko, Y., Matsyk, M., Demchenko, Y., Zhyvotovskyi, R., Repilo, I. et. al. (2020). Development of a method for training artificial neural networks for intelligent decision support systems. Eastern-European Journal of Enterprise Technologies, 3 (2 (105)), 37–47. doi: https://doi.org/10.15587/1729-4061.2020.203301
30. Sova, O., Shyshatskyi, A., Salnikova, O., Zhuk, O., Trotsko, O., Hrokholskyi, Y. (2021). Development of a method for assessment and forecasting of the radio electronic environment. EUREKA: Physics and Engineering, 4, 30–40. doi: https://doi.org/10.21303/2461-4262.2021.001940
31. Alieinykov, I. V. (2018). Analiz faktoriv, shcho vplyvaiut na operatyvnist protsesu zboru, obrobky i peredachi informatsiyi pro protyvnyka pid chas pidhotovky ta vedennia oboronnoi operatsiyi operatyvnoho uhrupuvannia viysk. XVIII naukovo-tekhnichnoi konferentsiyi «Stvorennia ta modernizatsiya ozbroiennia i viyskovoi tekhniky v suchasnykh umovakh». Chernihiv, 38.
32. Alieinykov, I. V., Zhyvotovskyi, R. M. (2018). Udoskonalennia informatsiyno-analitychnoho zabezpechennia za rakhunok formuvannia intehrovanoi informatsiynoi systemy upravlinnia viyskamy. Zbirnyk materialiv VI mizhnarodnoi naukovo-praktychnoi konferentsiyi «Problemy koordynatsiyi voienno-tekhnichnoi ta oboronno-promyslovoi polityky v Ukraini. Perspektyvy rozvytku ozbroiennia ta viiskovoi tekhniky». Kyiv, 165–166.
33. Kalantaievska, S., Pievtsov, H., Kuvshynov, O., Shyshatskyi, A., Yarosh, S., Gatsenko, S. et. al. (2018). Method of integral estimation of channel state in the multiantenna radio communication systems. Eastern-European Journal of Enterprise Technologies, 5 (9 (95)), 60–76. doi: https://doi.org/10.15587/1729-4061.2018.144085
34. Pievtsov, H., Turinskyi, O., Zhyvotovskyi, R., Sova, O., Zvieriev, O., Lanetskii, B., Shyshatskyi, A. (2020). Development of an advanced method of finding solutions for neuro-fuzzy expert systems of analysis of the radioelectronic situation. EUREKA: Physics and Engineering, 4, 78–89. doi: https://doi.org/10.21303/2461-4262.2020.001353
35. Zuiev, P., Zhyvotovskyi, R., Zvieriev, O., Hatsenko, S., Kuprii, V., Nakonechnyi, O. et. al. (2020). Development of complex methodology of processing heterogeneous data in intelligent decision support systems. Eastern-European Journal of Enterprise Technologies, 4 (9 (106)), 14–23. doi: https://doi.org/10.15587/1729-4061.2020.208554
36. Shyshatskyi, A., Zvieriev, O., Salnikova, O., Demchenko, Y., Trotsko, O., Neroznak, Ye. (2020). Complex Methods of Processing Different Data in Intellectual Systems for Decision Support System. International Journal of Advanced Trends in Computer Science and Engineering, 9 (4), 5583–5590. doi: https://doi.org/10.30534/ijatcse/2020/206942020
37. Koshlan, A., Salnikova, O., Chekhovska, M., Zhyvotovskyi, R., Prokopenko, Y., Hurskyi, T. et. al. (2019). Development of an algorithm for complex processing of geospatial data in the special-purpose geoinformation system in conditions of diversity and uncertainty of data. Eastern-European Journal of Enterprise Technologies, 5 (9 (101)), 35–45. doi: https://doi.org/10.15587/1729-4061.2019.180197
38. Mahdi, Q. A., Shyshatskyi, A., Prokopenko, Y., Ivakhnenko, T., Kupriyenko, D., Golian, V. et. al. (2021). Development of estimation and forecasting method in intelligent decision support systems. Eastern-European Journal of Enterprise Technologies, 3 (9 (111)), 51–62. doi: https://doi.org/10.15587/1729-4061.2021.232718