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THE DEVELOPMENT OF A METHOD FOR ASSESSING THE PREPARATION OF AVIATION PERSONNEL PARTICIPATED IN ENSURESING FLIGHT SAFETY

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The problem solved in the research is to increase the efficiency of decision making in the tasks of professional training of pilots while ensuring the specified reliability, regardless of the hierarchy of the system of evaluation indicators. The object of the research is the professional training system for civil aviation pilots. The subject of the research is the process of assessing the qualities of civil aviation pilots using fuzzy cognitive maps. The hypothesis of the research is to increase the number of indicators for assessing the quality of training of civil aviation pilots with restrictions on the efficiency and reliability of decision making. A method has been developed for assessing the preparedness of aviation personnel involved in ensuring flight safety.

The method consists of the following sequence of actions:

– input of initial data;

– standardization of numerical values of concepts of a fuzzy cognitive model of preparedness of aviation personnel involved in ensuring flight safety;

– transition of numerical values of concepts of a fuzzy cognitive model of preparedness of aviation personnel involved in ensuring flight safety;

– building a fuzzy cognitive model;

– determination of quantitative estimates (ranks) of the importance of model elements;

– calculation of importance indices of model elements.

Based on the results of the analysis of the effectiveness of the proposed method, it is clear that the proposed assessment method increases the accuracy of the assessment of aviation personnel involved in ensuring flight safety by 23 % compared to the known ones. It is advisable to use the developed method in decision making support systems for assessing the quality of professional training of aviation personnel in order to increase the efficiency and reliability of decisions made

Keywords: flight safety, preparation, stress resistance, aviation personnel, civil aviation, psychophysiological state

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1. Introduction

The highly qualified activities of aviation personnel involved in ensuring flight safety have high requirements for their professional reliability, which includes the stability of the combination of motivational, intellectual, emotional, physical components, psychophysiological, aimed at the successful provision of professional functions.

The need to find devices that provide the most effective professional and psychological training for future civil aviation employees is indicated by a variety of factors [1, 2]:

– firstly, the specificity of the work of aviation personnel determines the requirements for health, physical education, emotional stability and the ability to work at the required pace;

– secondly, aviation personnel must have a high level of development of the required knowledge, professional skills and abilities, and be able to assimilate new information well;

– thirdly, under conditions associated with increased psychophysiological load, they are prone to stress. For stress resistance, it is necessary to know by what devices and methods an optimal psychophysiological state is achieved and to have experience of self-regulation in emergency situations.

Improvements in computer technology have opened up great prospects for improving technical training tools, especially simulators, both for simulating flight dynamics and for providing a real recreation of the out-of-cockpit environment for training aviation personnel.

In accordance with the statistics of the automated system for ensuring the safety of aircraft in civil aviation, to a large extent, all aviation events occur in the airfield area during taxiing, takeoff, approach and landing of aircraft. Approximately 14 % of the total number of flight accidents involve aircraft rolling off the runway [1–5].

Taking into account the above, a pressing issue is the improvement of existing approaches (development of new ones) to solve a set of problems assessing the level of preparedness of civil aviation specialists, both at the initial stage and after undergoing appropriate training.

Considering the complexity of this task, the vagueness of factors and the need to take into account their mutual influence on each other, the use of the mathematical method of fuzzy cognitive maps (FCM) is proposed to provide convenience for modeling the dynamics of systems with measured expert-qualitative variables.

Fuzzy cognitive maps are a way of representing real dynamic systems in a form that corresponds to human perception of such processes. This is the main reason for their widespread use in various spheres of life.

The main advantages of fuzzy cognitive maps:

1. The ability to include feedback into the model and many variables, even with fuzzy values.

2. The ability to model relationships between variables that are not known exactly, but can be described in categories such as «a little», «a lot».

3. The ability to model systems where the amount of accurate information is limited, but expert knowledge is available.

4. Ease and speed of constructing cognitive maps, obtaining the desired results and speed of combining disparate knowledge.

Therefore, research on the development of method for assessing the preparedness of aviation personnel involved in ensuring flight safety is relevant.

2. Literature review and problem statement

The work [2] carried out an analysis of the civil aviation pilot training system. The shortcomings of the current civil pilot training system are shown. Emphasis is placed on the need to improve the system for assessing the qualities of aviation personnel by expanding the number of assessment indicators.

The work [3] shows the basic indicators for assessing the quality of training of civil aviation personnel. The levels of knowledge acquisition by civil aviation personnel are indicated. The criteria for assessing the quality of training of civil aviation personnel are listed.

The work [4] shows the relevance of additional consideration of psychophysiological factors affecting the quality of performance of aircraft piloting tasks by civil aviation pilots.

The work [5] proposes criteria for assessing the process of developing piloting skills during the initial flight training of pilots. This approach is based on the use of the Pearson criterion, the main disadvantage of which is its insensitivity to scaling functions. Also, the proposed approach does not take into account the new requirements that are imposed on civil aviation personnel, which does not allow it to be supplemented with new assessment indicators.

The need to take into account additional factors that have both qualitative and quantitative assessment indicators requires the creation of a new approach to the procedure for assessing the quality of training of civil aviation personnel. Based on the above, it is proposed to use artificial intelligence methods to assess the quality of training of civil aviation personnel.

The work [6] describes the agent-based approach used in a multi-agent information and analytical system and considers the problems of information decision making support. The disadvantages of this approach include the limited representation of complex systems, namely, none of the agents has a representation of the entire system.

The work [7] presents an operational approach for spatial analysis in the marine industry to quantify and reflect associated ecosystem services. This approach includes the three-dimensionality of the marine environment, considering all marine areas (sea surface, water column and seabed) separately. Actually, the method builds 3D sea models by assessing and mapping associated with each of the three marine domains through the adoption of representative metrics. The disadvantages of this method include the impossibility of flexible configuration (adaptation) of evaluation models while adding (removing) indicators and changing their parameters (compatibility and significance of indicators).

The work [8] proposes an approach to assessing the cost of living of a client in the field of air transportation. In this approach, a regression model is first used, followed by an indirect estimation model. At the final stage, the assessment results are compared using both assessment models. The disadvantages of this approach include the inability to determine the adequacy of the resulting assessment.

The work [9] provides a quantitative assessment approach for assessing the optimal selection or testing of analytical methods. Objective criteria related to analytical performance, sustainability, environmental impact and economic costs are assessed through the determination of penalty points divided into five different blocks. For each block, the overall proficiency is scaled from 0 to 4 and is depicted on a common hexagonal pictogram allowing comparison of analytical procedures. The disadvantages of this approach include the inability to increase the number of assessed indicators.

The work [10] provides a mechanism for transforming information models of construction objects to their equivalent structural models. This mechanism is designed to automate the necessary operations for transformation, modification and additions during such information exchange. The disadvantages of this approach include the inability to assess the adequacy and reliability of the information transformation process. Another disadvantage of this approach is the lack of consideration of the uncertainty of information about the object state.

An analysis of works [2–11] showed that the overwhelming majority are based on the use of general scientific methods, such as systemic, comparative, structural and functional analysis, the method of expert assessments, the method of scenario analysis of socio-economic systems and the information theoretical approach.

But in order to eliminate subjectivity, increase the accuracy and reliability of decision making regarding the quality of training of civil aviation personnel, it is necessary to develop software products that meet the following requirements:

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

– the possibility of aggregating heterogeneous indicators (both quantitative and qualitative) for assessing 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 general assessment of decisions;

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

– taking into account the influence of factors on each other, individually and on a generalized assessment of the quality of training of aviation personnel as a whole;

– the ability to adapt the system of indicators to a specific aircraft and training program for aviation specialists, ensuring the safety of civil aviation flights.

For this purpose, it is proposed to develop a method that would allow a comprehensive assessment of the professional training of aviation personnel involved in ensuring flight safety.

3. The aim and objectives of the research

The aim of the study is to develop a method for assessing the preparedness of aviation personnel involved in ensuring flight safety. This will make it possible to assess the level of training of aviation personnel, thereby improving aviation safety.

To achieve this aim, the following research tasks were set:

– to analyze methods for constructing fuzzy cognitive maps;

– to analyze methods for obtaining information for their construction;

– to improvement method for assessing the preparedness of aviation personnel involved in ensuring flight safety using a previously developed model [12].

4. Materials and methods of research

The object of the research is the professional training system for civil aviation pilots. The subject of the research is the process of assessing the qualities of civil aviation pilots using fuzzy cognitive maps. The hypothesis of the research is to increase the number of indicators for assessing the quality of training of civil aviation pilots with restrictions on the efficiency and reliability of decision making. In the course of the research, the general provisions of the theory of artificial intelligence were used to solve the problem of determining the relationships between factors that affect the quality of training of civil aviation pilots. The research used fuzzy cognitive models to build a model of professional training for civil aviation pilots. The simulation was carried out on an Intel Core i3 PC (USA).

The problem solved in the research is to increase the efficiency of decision making in the tasks of professional training of pilots while ensuring the specified reliability, regardless of the hierarchy of the system of evaluation indicators.

5. Results of the developing a method for assessing the preparedness of aviation personnel involved in ensuring flight safety

5. 1. The analysis of methods for constructing fuzzy cognitive maps

There are several ways to construct a fuzzy cognitive map. As a rule, there are 3 methods: automatic, manual, mixed.

The manual method involves constructing the FCM by a person, so all concepts, connections and strength of connections are set by the person who builds the map. The manual method of constructing a map requires already collected data and the simulated environment must be researched. It is also possible to construct a map in the process of researching the simulated environment.

The automatic method involves constructing a map using algorithms that themselves determine the concepts, connections and strength of connections between concepts. To build a map in this way, it is necessary a certain database collected in advance to train the machine that will build this map and a set of data that the automated system will refer to after training.

Each method has its own advantages and disadvantages. The main advantages and disadvantages are shown in the table (Table 1).

The mixed method involves the interaction of a person and a machine to build concepts, connections and determine the strength of connections. In this method, a person regulates the process and monitors the search for information, the formation of a database, the construction of a map and other processes.

5. 2. The analysis of methods for obtaining data for constructing cognitive maps

At the moment, there is no consensus in the literature regarding the way to identify important factors influencing and determining the situation in the research. Data acquisition methods for constructing cognitive maps can be useful both for individuals' understanding of the cognitive processes involved in decision making and as a basis for guiding active exploration of complex situations [13]. Methods for obtaining data for constructing cognitive maps are divided into direct and indirect. Direct methods are direct work with experts. Indirect methods are methods for processing secondary data [14].

There are 4 methods to obtain data for cognitive maps:

1. Identification of factors and connections through content analysis of documents. This method is convenient because it allows to build a map without having virtually any data about the simulated environment. Data analysis begins from scratch and conceptual entities are identified from various types of data that are analyzed. This method requires processing a large amount of data and high quality of both data sources and the data themselves [15].

2. Identification of factors and connections through analysis of expert opinions. At the same time, to structure ideas about a complex problem situation, as a rule, experts from various fields of knowledge are involved. This method is probably the most universal and requires minimal knowledge from the map creator, because almost all the work is done for it by an expert group, so members of the expert group are competent people who know almost everything about the area in the research; they can compose adequate entities, make correct connections and give the most accurate weights of entity connections.

However, this method directly depends on the expert group. An incorrectly selected group with insufficient knowledge competence can dramatically affect the quality of the compiled FCM [16].

Table 1

Advantages and disadvantages of methods for constructing FCM

	Manual	Auto	Mixed
Advantages	Full human control, the ability to manually select data, a variety of data sources	The ability to process a large amount of data, mathematical validity of map elements, constant updating of information	Partial human control of the process, the ability to process a large amount of data, mathematical validity of map elements, constant updating of information, a variety of sources for obtaining information, manual ability to supplement data
	Manual	Auto	Mixed
Flaws	Process time, data obsolescence, slow information processing, high adequacy of data after processing or before processing	Possibility of incorrect training, limited access to data resources, requires special knowledge from a person	The map may be distorted by human intervention

3. Identification of factors and relationships through analysis of quantitative data (for example, regression analysis). This method requires the analyst to have certain knowledge and ability to work with programs that allow for various types of data analysis. This method is not suitable for everyone, but it can show very useful data after analysis, for example, various types of dependencies. This method rather serves as an auxiliary method to any other method that can confirm any data or identify potentially new ones.

4. Identification of factors and relationships based on conceptual diagrams. The conceptual scheme can be considered a greatly simplified FCM. This diagram depicts some initial invented concepts without supporting them with any data. Conceptual diagrams can be considered the «starting point» for creating a full-fledged FCM. The conceptual scheme acts as a kind of generator of ideas and gives an idea of the overall picture of what is happening. It is not worth using it alone and analyzing quantitative data, but it is better to combine it with other methods.

These methods have their advantages and disadvantages. For each situation, a certain method is better suited, to one degree or another. To compare these methods, it is suggested that it is possible to familiarize yourself with the compiled table (Table 2), which evaluates the main general parameters of information retrieval methods on a scale from 1 to 5, where 5 is the maximum value of the parameter.

Parameter values:

1. Data quality indicates the degree of reliability of the data obtained after data processing.
2. Possibility of collecting up-to-date data indicates the degree of relevance of the data obtained using the method.
3. Data acquisition speed indicates the speed of obtaining data using a certain method.
4. Data processing speed (manual) indicates the speed of data processing without the use of process automation.
5. Data processing speed (automated) indicates the speed of data processing using process automation.
6. Automation of a method shows how automated a particular method is.
7. The possibility of full automation shows the possibility of automating the method. The higher the score, the more global the automation can be.
8. The degree of data breadth shows the extent of coverage of various resources. The higher the score, the greater the data coverage.
9. Accessibility of the method indicates the degree of accessibility of the method to a particular person.

If to analyze the data from all methods, it is possible to identify a number of shortcomings in them.

The quality of maps obtained using the methods described depends on the quality of the information obtained to construct the map and the quality of the information, in turn, depends on the quality of the knowledge provided in the information source. Maps obtained from information provided by an expert may include both the necessary data and factors depending on the expert or a certain human factor. The main advantage of direct methods is that they avoid the use of huge coding procedures and enable the researcher to focus on the integrity of the situation [17, 18].

An analysis of quantitative data assumes the objectivity of the identified factors and relationships, however, in order for a certain factor to come into view, some quantitative information must be collected about it and its influence. Usually, while solving problems that include many elements of different nature and the dependencies between the elements of which are both quantitative and qualitative, this condition is impossible to satisfy [16, 18].

Direct methods are common, in which the subject is presented with a list of variables to establish cause-and-effect relationships and then paired comparisons and subsequent formal processing are used to obtain a final assessment of the mutual influence of factors.

This procedure contains risks of unnecessary cause-and-effect relationships, because the subject has the opportunity to try all possible combinations. A potential problem with coding errors is the manual construction, due to the ambiguity in determining the causes and consequences in the situation in the research. The problem of coding errors in the map is associated with differences in the cognitive processes of recognition and recall [5, 6].

The analysis of the first three approaches comes down to constructing a map; however, the role of conceptual schemes, the formation of which precedes the determination of the factors of the cognitive map, is underestimated.

The conceptual scheme serves as an auxiliary tool for the formation of an unified and holistic view of the situation in the research among experts and ensures the targeted identification of essential knowledge about the situation [17].

This sequence will allow, after each transition from method to method, to reduce the amount of unnecessary data and improve its quality.

For better clarity, in which way which method is the most effective, a summary table is provided (Table 3), which contains an expert assessment of the effectiveness of a particular method in a certain method of constructing the FCM. The rating scale ranges from 1 to 5, where 1 is the most ineffective, and 5 is the most effective.

Table 2

Assessment of the main general parameters of information retrieval methods

Parameters	Content analysis	Analysis of quantitative data	Conceptual scheme	Expert analysis
Data quality	3	4	1	3
Ability to collect up-to-date data	4	4	2	4
Data acquisition speed	3	3	4	3
Data processing speed (manual)	2	2	4	4
Data processing speed (automated)	5	5	1	2
Automation of the method	4	4	1	1
The possibility of full automation	4	4	1	1
Data Extent	5	5	4	4
Availability of the method	3	3	5	3

Table 3

Expert assessment of the relationship between methods for constructing the FCM and methods for searching information for its construction

Method name	Content analysis	Quantitative data analysis	Conceptual diagrams	Expert analysis
Manual	3	3	5	4
Auto	5	5	2	3
Mixed	4	4	4	4

The rating scale ranges from 1 to 5, where 1 is the most ineffective, and 5 is the most effective.

5. 3. The development of a method for assessing the preparedness of aviation personnel involved in ensuring flight safety

Method for assessing the preparedness of aviation personnel involved in ensuring flight safety consists of the following sequence of actions:

Step 1. Entering initial data. At this stage, initial data is entered about aviation personnel who participate in ensuring the safety of civil aviation flights (data on assessment indicators from Table 1, set out in the work [12]).

Step 2. Normalization of the numerical values of the concepts of the fuzzy cognitive model of the preparedness of aviation personnel involved in ensuring flight safety.

Step 3. Transfer of numerical values of concepts of a fuzzy cognitive model of the preparedness of aviation personnel involved in ensuring flight safety.

The transition of concept values to dimensionless quantities occurs in such a way that the numerical values of concepts always change in the range from 0 to 1.

Step 4. Construction of a fuzzy cognitive model. The model is built on the basis of the fuzzy cognitive model developed in the work [12].

Step 5. Determination of quantitative estimates (ranks) of the importance of model elements.

In the statistical theory of flight safety, the most widely used element importance index according to Birnbaum [13], which is determined on the basis of the system reliability function:

$$P_S = f_S\left(P_1,...,P_i,...\right), \quad (1)$$

where P_s and P_i are the probability of failure-free operation of the system and the i-th element, respectively. The first derivative in the work (2) is the index of importance of the i-th element of the system according to Birnbaum, which is calculated in the following way [1]:

$$I_i = \frac{\partial P_S}{\partial P_i} = P_S\left(P_1,...,P_{i-1},1,P_{i+1},...,P_n\right) - -P_S\left(P_1,...,P_{i-1},0,P_{i+1},...,P_n\right). \quad (2)$$

The second derivative in the work (2) is the index of the importance of the joint influence of the i-th and j-th elements (joint reliability importance), introduced in the work [12, 19].

In our case, the elements of the model are input concepts – factors influencing the level of flight safety. Therefore, there is a need to calculate indices of the importance of FCM concepts.

In many concepts $C=\{C_1, C_2, ..., C_n\}$, let's assume the following:

– C_n is an output concept that determines the level of flight safety and is estimated by number $A_n \in [0,1]$;

– $C_1, C_2,...,C_{n-1}$ is an input concepts corresponding to interrelated factors that influence the level of flight safety and are assessed by levels $A_n \in [0,1]$, $i=1,...,n-1$.

The value of the concept C_n at the l-th step is calculated in the following way:

$$A_n^l = F\left[A_1^0, A_2^0, ..., A_n^0\right]. \quad (3)$$

It is assumed that A_n^l is the value of the concept C_n in stationary mode, so at such a step l when A_n^l is close to A_n^{l-1}. The dependence (3) allows to proceed to determine the ranks of concepts based on derivatives.

Let $I(C_j)$ be the index of the importance of the concept C_j and $I(C_j, C_k)$ be the index of the joint importance of the concepts C_j and C_k. Following (2) and [12], let's define these importance indices in the following way:

$$I\left(C_j\right) = \frac{\partial A_n^i}{\partial A_j} = \frac{F\left(1_j,0\right) - F\left(0\right)}{1-0} = F\left(1_j,0\right), \quad (4)$$

$$I\left(C_j,C_k\right) = \frac{\partial^2 A_n^i}{\partial A_j \partial A_k} = \frac{F\left(1_j,1_k,0\right) - F\left(0\right)}{\left(1-0\right)\left(1-0\right)} = F\left(1_j,1_k,0\right), \quad (5)$$

where $F(1_j, 0)$ is value of function (3), when A_j^0 and all other arguments are equal to zero; $F(0)$ is the value of function (3) when all arguments are equal to zero (it is assumed that $F(0)=0$; $F(1j, 1k, 0)$ is the value of function (3), when $A_j^0 = A_k^0 = 1$ and all other arguments are zero.

Zero values of input concepts (except for one in the work (4) and two in the work (5), equal to one) were chosen in order to exclude the possibility of their influence on the output concept due to transitive connections.

Step 6. Calculation of importance indices of model elements.

Set the initial vector (6). For the importance index $I(C_j)$, the initial vector is given as:

$$A^0 = \left[A_j^0 = 1, A_i^0 = 0, i = 1,2,...,n, n \neq j\right], \quad (6)$$

and for the importance index $I(C_j, C_k)$ in the form:

$$A^0 = \left[A_j^0 = A_k^0 = 1, A_i^0 = 0, i = 1,2,...,n, i \neq j,k\right]. \quad (7)$$

Using recurrence relation (5), find the state vector of the FCM:

$$A^l = \left[A_1^l, A_2^l, ..., A_n^l\right], \quad (8)$$

in the established state, so at step l at which $\left|A_i^l - A_i^{l-1}\right| < \varepsilon$, Where $\in$ is a small positive number, $i=1, 2, ..., n$.

The importance indices $I(C_j)$ and $I(C_j, C_k)$ are the elements A_n^l of vectors (8), obtained with initial vectors (6) and (7), respectively.

Comparison of the proposed approach to assessing the quality of training of aviation personnel of civil aviation aircraft of one of the air carriers of Kazakhstan. The comparative assessment was carried out by analyzing the test tasks that civil aviation pilots performed when they were allowed to fly from 2015 to 2022. During this time, 62 civil aviation pilots were checked for clearance to fly. Testing for clearance to fly was carried out according to the ICAO MPL program.

Concept meanings influencing preparedness of aviation personnel involved in ensuring flight safety in a steady state for various initial vectors is given in Table 4.

Table 4

Values of concepts in the established state for various initial vectors

Step	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
1	1	0	0	0	0	0	0	0	0	0
2854	0.018	0.000	0.000	0.000	0.187	0.000	0.000	0.000	0.000	0.7213
1	0	1	0	0	0	0	0	0	0	0
770	0.000	0.036	0.000	0.365	0.723	0.000	0.000	0.000	0.000	0.9885
1	0	0	1	0	0	0	0	0	0	0
3717	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.2270
1	0	0	0	1	0	0	0	0	0	0
3014	0.000	0.000	0.000	0.022	0.335	0.000	0.000	0.000	0.000	0.7911
1	0	0	0	0	1	0	0	0	0	0
5123	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.3349
1	0	0	0	0	0	1	0	0	0	0
3187	0.000	0.000	0.000	0.000	0.186	0.022	0.000	0.000	0.000	0.6891
1	0	0	0	0	0	0	1	0	0	0
4922	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.3088
1	0	0	0	0	0	0	0	1	0	0
2711	0.000	0.000	0.000	0.000	0.321	0.000	0.000	0.023	0.000	0.6612
1	0	0	0	0	0	0	0	0	1	0
3012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.1544

Values indices of the importance of the joint influence of factors influencing the quality of training of aviation personnel involved in flight safety are given in Table 5.

Table 5

Indices of the importance of the joint influence of factors

Concepts	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	0.932	0.622	0.8	0.622	0.730	0.335	0.786	0.255
C_2	–	0.958	0.936	0.913	0.950	0.949	0.910	0.948
C_3	–	–	0.772	0.378	0.689	0.309	0.774	0.254
C_4	–	–	–	0.789	0.813	0.703	0.893	0.782
C_5	–	–	–	–	0.659	0.309	0.734	0.187
C_6	–	–	–	–	–	0.356	0.778	0.294
C_7	–	–	–	–	–	–	0.349	0.323
C_8	–	–	–	–	–	–	–	0.763

The values of the interconnections of concepts on each other allow to flexibly determine the most critical moments of training aviation specialists that affect flight safety.

6. Discussion of the results of developing a method for assessing the preparedness of aviation personnel involved in ensuring flight safety

A method for assessing the preparedness of aviation personnel involved in ensuring flight safety is proposed.

The main advantages of the proposed assessment method are:

– it has a flexible hierarchical structure of indicators, which allows to reduce the problem of multi-criteria evaluation of alternatives to a single criterion or use a vector of indicators for selection (formulas (1)–(8), Tables 1–5) compared to studies [2, 3, 6];

– it allows to take into account different types of indicators for assessing the professional training of aviation personnel that are subject to priority assessment (formulas (1)–(8), Tables 1–5) compared to studies [3–7];

– an unambiguity of the obtained assessment of the quality of professional training of aviation personnel [5–7];

– wide range of use (decision making support systems) compared to studies [2–10];

– simplicity of mathematical calculations (formulas (1)–(8) compared to studies [2–10];

– the ability to adapt the system of indicators during work (formulas (1)–(8) compared to studies [2–10];

– the ability to take into account the mutual influence of factors affecting the quality of training of aviation personnel to ensure flight safety (formulas (1)–(8), Tables 1–5) compared to studies [2–10];

– the possibility of synthesizing the optimal structure of decision making support system (formulas (1)–(8)) compared to studies [2–10].

It is advisable to use the developed method in decision making support systems for assessing the quality of professional training of aviation personnel in order to increase the efficiency and reliability of decisions made.

Limitations of the research include the availability of sufficient computing resources.

The disadvantages of the proposed methodology include a lower accuracy of assessment for one parameter of assessment of the state of training of civil aviation specialists by 5–7 % due to the construction of the membership function and the use of linguistic variables.

This method will allow:

– to conduct an assessment of the professional training of aviation personnel;

– to identify effective measures to improve the effectiveness of professional training of aviation personnel;

– to increase the speed of assessing the professional training of aviation personnel;

– to reduce subjectivity in assessing the professional training of aviation personnel;

– to justify measures aimed at increasing the effectiveness of professional training of aviation personnel.

Based on the results of the analysis of the effectiveness of the proposed method, it is clear that the proposed assessment method increases the accuracy of the assessment of aviation personnel involved in ensuring flight safety by 23 % compared to the known ones.

Directions for further research should be aimed at reducing computational costs while assessing the professional training of aviation personnel.

7. Conclusions

1. An analysis of methods for constructing fuzzy cognitive maps and methods for obtaining information for their construction was carried out. The analysis found that the most appropriate method of constructing fuzzy cognitive maps is a mixed method that can be applied in all decision support systems. This is due to the versatility of the analysis of all types of data that circulate in decision support systems, such as quantitative data analysis, conceptual frameworks and expert analysis.

2. A method has been developed for assessing the preparedness of aviation personnel involved in ensuring flight safety.

This makes it possible to increase the efficiency of decisions made to assess the quality of professional training of aviation personnel involved in ensuring flight safety due to:

– sequential solution of problems of forward and reverse planning using simulation modeling of professional training of aviation personnel involved in ensuring flight safety;

– the ability to take into account both quantitative and qualitative indicators for assessing the quality of professional training of aviation personnel involved in ensuring flight safety;

– the ability to take into account the mutual influence of factors affecting the quality of training of aviation personnel to ensure flight safety;

– scalability of indicators for assessing indicators for assessing the quality of professional training of aviation personnel involved in ensuring flight safety.

3. Based on the results of the analysis of the effectiveness of the proposed method, it is clear that the proposed assessment method increases the accuracy of the assessment of aviation personnel involved in ensuring flight safety by 23 % compared to the known ones.

Conflict of interest

The author declares that there is no conflict of interest regarding to this research, including financial, personal, authorship or other nature, which could affect the research and its results presented in this article.

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Data availability

The manuscript has associated data in a data warehouse.

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