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PRELIMINARY RESEARCH OF INFORMATION TECHNOLOGY FOR ASSESSING THE LEVEL OF FATIGUE OF AIR TRAFFIC CONTROLLERS

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Abstract. The work carried out a preliminary study of the development of the information technology concept for assessing the level of fatigue of air traffic controllers using special technical means, software, and expert opinion. For this purpose, it is proposed to construct an information technology that can consist of three consecutive stages: assessment of air traffic controllers' fatigue, based on the use of special technical means and software; expert evaluation of the level of fatigue of air traffic controllers; information technology that combines data from special technical means and experts' conclusions to derive a complex linguistic level of fatigue of air traffic controllers. Each stage has its permissible levels. Non-compliance with any of them leads to automatic notification of the decision maker (DM). The value of information technology is that it will consider data from special technical means and software on the one hand and, and the other hand, consider the opinions and experiences of experts on the fatigue of air traffic controllers. The technology works dynamically and involves experts only in case of need. For information technology, it is proposed to model uncertainties for technical and expert evaluation and use logical derivation to formalize knowledge. At the output, the comprehensive level of fatigue of the air traffic controller is obtained, in the opposite case, DM is signaled to immediately take measures to remove from official duties and replace the air traffic controller. The knowledge obtained about air traffic controllers' fatigue levels is important for ensuring flight safety. Proper management of fatigue can help reduce the risk of human error and improve working conditions for staff.

Keywords: air traffic controllers, level of fatigue, flight safety, information technology, intellectual analysis of knowledge, expert assessments.

1. INTRODUCTION

To prevent incidents at airports, an important component is the effectiveness of the air traffic control team [1]. Fatigue-induced loss of concentration, even for a very short period, during air traffic control duties can have serious consequences. Fatigue can affect air traffic controllers' ability to make adequate decisions and effectively manage air traffic. It can lead to errors in navigation, incorrect instructions to pilots, punctuality of flights, speed of response to unforeseen situations, the effectiveness of air traffic controllers in general, and threats to flight safety.

Implementing strategies and policies to prevent and manage air traffic controller fatigue is an important task that can significantly improve flight safety and personnel well-being. Optimization of work schedules may belong to such strategies. Developing flexible work schedules that allow air traffic controllers to get enough rest and recovery between shifts. Today, a lot of attention is paid to training and education, namely: stress management, relaxation techniques, and emotion management. The next task is the ergonomic design of the working environment [2]. Creation of a comfortable and ergonomic working environment that contributes to energy conservation and reduction of physical and psychological stress. Such strategies also include monitoring and tracking fatigue. The use of systems

for monitoring physiological and psychological indicators, allows monitoring the level of fatigue of air traffic controllers and responding in time to possible risks.

The preliminary research is focused on the development of information technology for fatigue monitoring, tracking, and signaling. In the study, the fatigue of air traffic controllers is considered unconscious, and therefore there is a need for both technical tools and software to detect such fatigue for management decision-making. In the case of signaling the air traffic controllers fatigue, it becomes necessary to make some management decisions, for example, about temporary rest or replacement. Such a management decision is made by a person (expert) based on his experience and knowledge. Therefore, there is a need to combine technical means of data collection and processing with expert opinions, which will enable a comprehensive and well-founded analysis of data and knowledge, which leads to better management decisions. Such a combination is embodied in information technology, which we will call hybrid. Technical means enable the collection and processing of large volumes of data, while expert judgments enable the interpretation of this data and understanding of its meaning in the context of a specific situation. Expert opinions allow you to quickly adapt the analytical process to new conditions or unforeseen situations, which can be important in a dynamic air traffic environment. Hybrid technology makes it possible to reduce decision-making time, as experts can quickly interpret data and provide recommendations. It allows for a more comprehensive assessment of risks and the determination of their management strategies.

To date, there is no comprehensive study of the assessment of the level of fatigue of air traffic controllers based on the principles of a hybrid approach and using the modern theory of intellectual analysis of knowledge [3]. As for risk assessment of the efficiency of operators of critical infrastructure facilities, it is possible to single out works [4-5]. In [4], a model of the risk management system for dangerous actions of dispatchers is considered through the study of controllers, to create a recommendation for reducing the level of risk of dangerous actions. To reduce the number of dangerous events caused by air traffic control, scientists in works [6-7] studied the factors affecting controller fatigue. Based on this, management models were built based on risk factors that affect the dangerous actions of controllers [8].

It is noted that in 2016, the Civil Air Navigation Services Organization (CANSO), the International Civil Aviation Organization (ICAO), and the International Federation of Air Traffic Controllers Associations (IFATCA) issued a fatigue management guide for air traffic service providers [9]. This manual provides guidance for air traffic controllers (ATCs) to address this issue. It is a collaborative effort and can be used as a source of information and guidance for fatigue management. Based on this manual, a study [10] to measure the fatigue levels of air traffic controllers using the Samna-Perelli Fatigue Scale is highlighted and tested in the control tower of an international airport in Taiwan. Instead, no study also considers expert opinions on the fatigue of air traffic controllers.

Next, studies using various physiological measures to detect fatigue in air traffic controllers are reviewed. In work [11], such a problem is solved with the help of voice analysis - Electroencephalography. As a result, it has been proven that voice parameters determine the level of stress and/or energy, based on which fatigue is detected. Other researchers [12] propose to use a deep neural network to recognize the level of mental fatigue of control dispatchers based on various sensors. Research [13] uses biometric indicators of the human operator, namely the pulse, which can serve as input data for the operator's condition monitoring system. In the study, a person's heart rate is measured with a regular fitness bracelet, the data from which is transmitted directly to the system for making management decisions. The authors in work [14] detect unconscious fatigue in a healthy person with blood sugar measurement thanks to implanted glucometers under the skin on the abdomen or the arm. In addition to the methods of detecting unconscious fatigue in healthy people, there is an opportunity to detect and classify such fatigue by specific eye movements [15].

Technologies for assessing the level of fatigue of air traffic controllers use a combination of different methods and tools to assess and monitor the degree of fatigue. Such technologies may include:

- Objective physiological measures are the use of special devices or technologies, such as heart rate, brain activity or movement monitors, to objectively assess physiological indicators of fatigue;

- Psychological assessments are the use of psychological tests or questionnaires to assess the level of stress, concentration of attention, emotional state, and other psychological aspects that may indicate fatigue;
- Analysis of behavioral indicators is the consideration of behavioral aspects such as speed of reaction, accuracy of decision-making, number of errors, etc., which may indicate the level of fatigue;
- Data integration – the collected data can be integrated and processed using computer algorithms to create a comprehensive assessment of the level of fatigue;
- The use of artificial intelligence (AI) is the use of artificial intelligence techniques to analyze and predict the level of fatigue based on a large amount of data;
- Natural experts evaluate the involvement of experienced air traffic controllers to collect information about their feelings and observations regarding the level of fatigue.

Therefore, information technology for assessing the level of fatigue of air traffic controllers can help to detect signs of fatigue in time and take measures to ensure safety in the airspace.

The study aims to carry out preliminary research on the development of the concept of information technology for assessing the level of fatigue of air traffic controllers using special technical means, software, and expert opinion.

2. MATERIALS AND METHODS

Consider air traffic controllers $A = \{a_1; a_2; \dots; a_n\}$, working at some airport. It is necessary to carry out a dynamic assessment of the level of fatigue of air traffic controllers using special technical means, software, and expert opinion in some periods of their work $\mathrm{t}_1, \mathrm{t}_2, \dots, \mathrm{t}_\mathrm{m}$. Air traffic controllers will be evaluated based on the analysis of data obtained from software and special technical means, as well as when signaling the level of fatigue of an additional expert opinion. The input data processing system for the conducted research consists of two types of data, namely: v_a – predicted quantitative assessment of fatigue obtained with the help of technical means and specialized software; e_a – expert assessment of fatigue obtained based on the opinions of experts E. The processed input data will be calculated using a fuzzy model for determining the level of fatigue of an air traffic controller – HM_{atc}.

The concept of information technology for assessing the level of fatigue of air traffic controllers using technical means and specialized software can be formally presented in the form of an operator:

$$\Theta(A, t, E, v_a, e_a, HM_{atc}) \to \delta(\alpha_{ATC}, LF). \quad (1)$$

Where Θ is the operator that, based on the input data A, t, E, v_{ai}, e_{ai} and the fuzzy model HM_{atc} matches the set of initial values δ. As a result, two values are obtained: α_{ATC} – generalized quantitative assessment of air traffic controllers' fatigue; LF is the linguistic complex level of fatigue of air traffic controllers.

The knowledge obtained about air traffic controllers' fatigue levels is of great importance for ensuring flight safety. Proper management of fatigue can help reduce the risk of human error and improve working conditions for staff. This may include implementing regular break strategies, optimizing work schedules, and providing support to maintain psycho-emotional health.

The following management subjects are defined for this study:

- experts are persons who, based on experience, make conclusions about the psycho-emotional state of an air traffic controller while performing official duties;
- a decision maker (DM) is a management entity that uses the acquired knowledge to ensure flight safety;
- a system analyst is a person who configures all processes of hybrid technology assessment.

The structural diagram of the information technology for assessing the level of fatigue of air traffic controllers is presented in the form of Fig. 1.

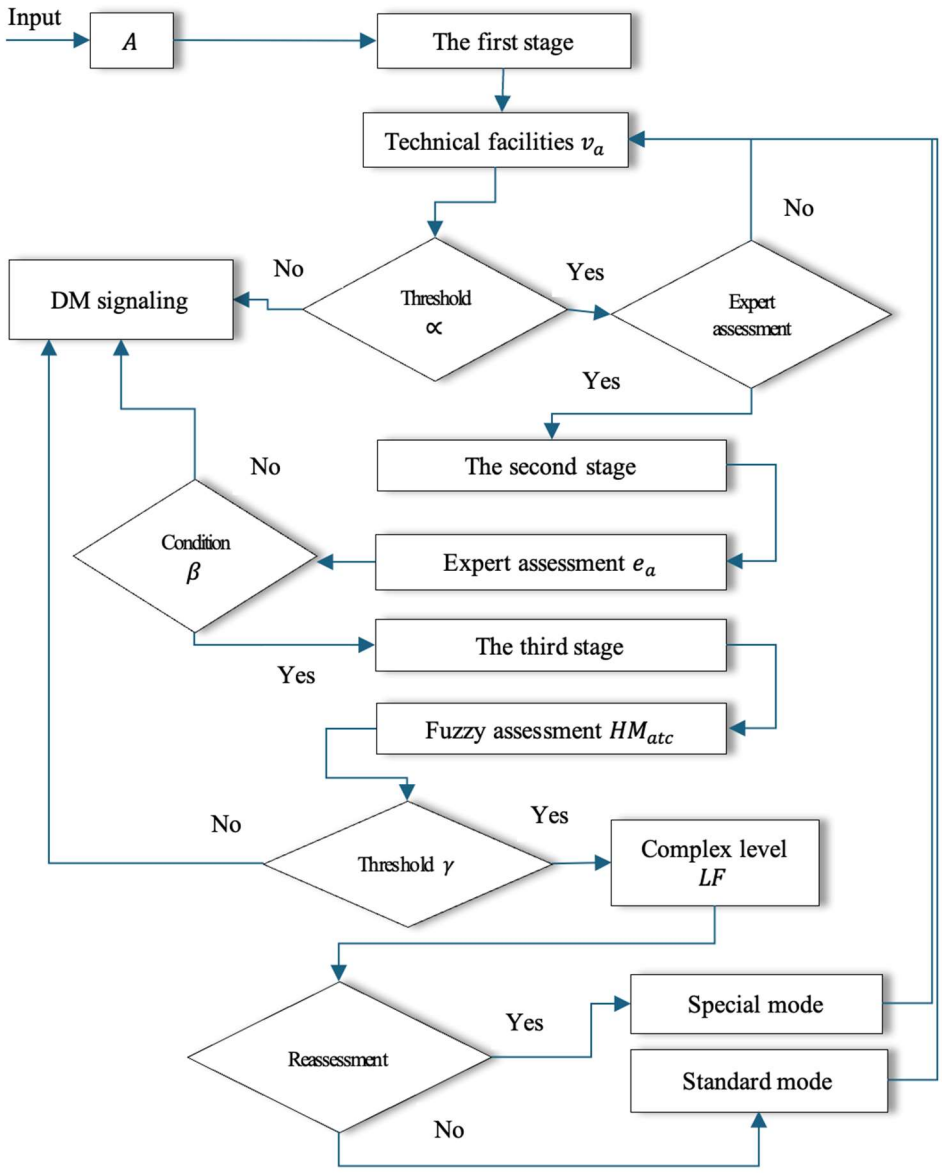

Figure 1. Structural diagram of information technology for assessing the level of fatigue of air traffic controllers

Fig. 1. displays a three-stage information technology for assessing the level of fatigue of air traffic controllers.

The first stage is the assessment of air traffic controllers' fatigue based on special technical means and software.

At the entrance, the air traffic controller (A), is determined, which is dynamically evaluated with the help of special technical means. At the first stage, normalized estimates $v_{a(t_j)}(a_i) \in [0;1]$, ($t_j$ – evaluation time, $i = \overline{1,n}$, $j = \overline{1,m}$), are obtained, representing are predicted quantitative assessments of air traffic controllers' fatigue. Such estimates are obtained with the help of special technical means and processed by software.

Special technical means may include fitness bracelets for heart rate monitoring; implants for measuring sugar level; electroencephalographs; voice analyzers; video surveillance for analyzing the dynamics of the operator's eye movements and others.

The resulting normalized values of v_a will have the following meaning: when v_a goes to 0 it will mean the maximum possible fatigue of a person, and vice versa, when v_a goes to 1, then a person feels energetic, rested, and ready for action.

The second stage is an expert assessment of the level of fatigue of air traffic controllers.
The obtained scores are compared with some numerical threshold $\propto, \propto \in [0; 1]$. VExpert evaluation occurs at the request of the DM and on the condition that the predicted quantitative estimates of air traffic controllers' fatigue are greater than or equal to the threshold $\propto$ ($(v_{a(t_j)} \geq \propto)$. In the opposite case ($v_a < \propto$) the DM is signaled to immediately take measures to remove from official duties and replacement of the rated air traffic controller.

For expert assessment, the expert needs to express his opinion $e_{a(t_j)}(a_i)$ regarding the fatigue of the air traffic controller A in question at some point in time t_j. Such expert opinion should be unified. For this, you can use the theory of fuzzy logic and the term set of linguistic variables, for example, high level or low level of fatigue.

The third stage is information technology for deriving the linguistic level of fatigue of air traffic controllers.

Next, there is a transition to hybrid evaluation, provided that expert linguistic evaluations of air traffic controllers' fatigue satisfy some logical condition β. In the opposite case, DM signaling occurs similarly. As a result of fuzzy estimation, α_{ATC} is obtained - a generalized quantitative assessment of air traffic controllers' fatigue. To obtain this estimate, it is proposed to use logical derivation using an S-shaped membership function. This is because the predicted quantitative assessment of fatigue of air traffic controllers v_a obtained with the help of technical means and specialized software is based on the logic that the larger the value, the better. The e_a expert fatigue score also uses the same logic: the higher the score, the better. As a result, $v_a\ \alpha_{ATC(t_j)}(a_i) \in [0; 1]$ is obtained - a generalized quantitative assessment of the fatigue of air traffic controllers a_i.

After that, the threshold $\gamma,\ \gamma \in [0; 1]$ is entered. Under the condition that $\alpha_{ATC} \geq \gamma$, LF is derived - the linguistic complex level of fatigue of air traffic controllers. In the opposite case ($\alpha_{ATC} < \gamma$), DM signaling occurs.

To derive the linguistic complex level of fatigue of air traffic controllers (LF), it is necessary to compare the obtained estimate $\alpha_{ATC(t_j)}(a_i)$ at some point in time t_j, to one variable term-set LF. For example, such a variable can have the following wording: “low comprehensive level of fatigue of the air traffic controller”.

After obtaining the linguistic level, there is a re-evaluation. Two options are offered here: the standard mode, or special mode. In the case of a special regime, a reduction in the time limits for evaluation may be provided. Also, a special mode should be used when the obtained linguistic assessment of LF will characterize a high comprehensive level of fatigue of the air traffic controller.

It is noted that information technology provides for dynamic evaluation during the air traffic controllers shift, and the period t and the need for expert evaluation are determined by the DM himself.

3. DISCUSSION

The work carried out a preliminary study aimed at determining the level of fatigue of air traffic controllers, followed by signaling and proactive response by the manager, to improve air traffic safety. For this purpose, it is proposed to construct an information technology that can consist of three consecutive stages: assessment of air traffic controllers' fatigue, based on the use of special technical means and software; expert evaluation of the level of fatigue of air traffic controllers; information technology that combines data from special technical means and experts' conclusions to derive a complex linguistic level of fatigue of air traffic controllers. Each stage has its permissible levels. Failure to match any of them will result in an automatic DM notification. The information technology needs to be verified and adjusted on the real data of the work of air traffic controllers.

For this study, it is proposed to use the theory of fuzzy sets, expert evaluation, and intellectual analysis of knowledge. Such a mathematical apparatus can adequately process input and expert data, which will make it possible to improve the quality of determining the level of fatigue of air traffic controllers. This

leads to the value of the obtained results, to stimulate the introduction of information technologies and artificial intelligence to improve air traffic safety.

The value of information technology is that it will consider data from special technical means and software on the one hand and, and the other hand, consider the opinions and experiences of experts on the fatigue of air traffic controllers. The technology works dynamically and involves experts only in case of need.

4. CONCLUSIONS

The main purpose of the conducted research is to carry out preliminary research on the development of the information technology concept for assessing the level of fatigue of air traffic controllers using special technical means, software, and expert opinion. For this purpose, the concept of information technology consisting of three successive stages of dynamic evaluation was developed for the first time. For information technology, it is proposed to model uncertainties for technical and expert evaluation and use logical derivation to formalize knowledge. At the output, the comprehensive level of fatigue of the air traffic controller is obtained, in the opposite case, the DM is signaled to immediately take measures to remove from duty and replace the air traffic controller.

Further research of the problem is planned in the development of the technology itself. Algorithmic support for the three stages of research will be provided here. It is necessary to clearly define special technical means for obtaining input data. After that, design software that outputs predictive quantitative estimates of air traffic controller fatigue. Information technology should be verified and adjusted based on the real data of the work of air traffic controllers, who can be, for example, students of the Faculty of Aeronautics at the Technical University in Košice.

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