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DEVELOPMENT OF REQUIREMENTS FOR A DECISION SUPPORT SYSTEM FOR A SHIFT SUPERVISOR TO MANAGE PROFESSIONAL STRESS OF AIR TRAFFIC CONTROLLERS

The article is devoted to the current scientific and practical issue of managing air traffic controllers' (ATCO) occupational stress to enhance their professional reliability and flight safety. The main factors of occupational stress in air traffic control and stress management techniques are analyzed. Effective management of ATCO stress is the critical role of the ATC shift supervisors on duty. To solve these problems, they should be provided with decision support tools. It has been determined that there are currently no effective automated tools for real-time monitoring and controlling ATCO occupational stress. The idea of developing a decision support system (DSS) for ATCO shift supervisors, that will provide alerts, information, and recommendations for job-related stress management, is proposed. A functional model of stress management, as a "white box model", provides a comprehensive approach to stress analysis and management at ATCO workplace. The model's data types, constraints, priorities, input and output parameters are defined. The proposed model takes into account feedback loops that allow for the dynamic adaptation of management decisions and individual strategies in accordance with the effectiveness of their application. Global, local and individual priorities in managing ATCO occupational stress are considered. The identified patterns in strategic and tactical management of ATCO occupational stress should contribute to the revision of the enterprise's current stress management methodology, local and individual policies, and priorities. DSS can help ATC shift supervisors make timely and more informed decisions by providing them with data and analysis on different types of stress factors, stress levels, key performance indicators and level of fatigue; producing recommendations and monitoring, organizational, technological and individual coping strategies for managing ATCO stress. This article describes main functional requirements for the DSS, namely, reliability, functionality, adaptability, performance, the user interface and system maintenance requirements.

Key words: *air traffic controller (ATCO), occupational stress, stress management, automated tools, functional model, functional requirements.*

Formulation of the problem. Flight safety is a key objective of civil aviation. Statistical data show that the human factor, in particular the mistakes of aviation professionals, is the cause of the vast majority of aviation accidents and their precursors – serious incidents [1–3]. The contribution of the human factor in aviation accidents don't decrease and amounts to 70 % to 80 % on international air routes, while only 15 % to 20 % are due to design and manufacturing defects of aircraft [4]. The impact of the human factor on the activities of air traffic controllers (ATCO) is especially dangerous.

ATCOs work in a high level of responsibility and complexity of air traffic situations, intensity of mental activity under conditions when the two aspects uncertainty and time pressure come together. The ATCO's stress level is affected by limitations and possible equipment failure, peak load hours, emergency situations and unforeseen circumstances. The decisions of ATCOs are often influenced by the perception of risk to human lives, which creates additional stress for their daily work [5]. In addition, ATCOs must adapt to shift work and constant changes in ATCO shifts throughout the week on weekends and at night, resolve conflict situations in teamwork, and maintain focus in the workplace. The isolated, semi-dark workspace creates more physical and mental strain on ATCO and negatively affects their professional abilities, response time, and attention distribution [6]. Working under such conditions leads to the development of chronic occupational stress. According to some studies, the profession of an ATCO is among the top five most stressful professions [7]. Chronic stress can significantly worsen the psycho-emotional state and cognitive functions of ATCOs. It leads to an increase in the number of errors, a decrease in work efficiency, and an increase in risks to flight safety. The highly stressful nature of work in ATC positions together with high requirements for the level of professional training, directly limits the supply of labor. The aviation industry is already facing a shortage of personnel and airspace

congestion [8, 9]. The potential consequences of occupational stress are disorders in the functioning of the nervous, cardiovascular, and digestive systems, as well as psychoneurotic disorders. All this negatively affects the health, well-being and ATCO performance. Therefore, unregulated intense, long-term, and often repetitive occupational stress can eventually lead to burnout, health deterioration, and shortening of an ATCO career, and reduce their life expectancy.

Despite the urgency of the problem, currently, there are no effective automated tools for monitoring and controlling the occupational stress of ATCO in real-time. Existing methods are mainly based on the subjective assessment of the ATCO state. The lack of objective control over the dynamics of stress in the workplace can lead to errors and aviation incidents. The responsibility for managing the stress of specialists in the ATCO shift should be borne by their managers – supervisors. Thus, Havermans B. et al., based on the results of interviews with employees and supervisors from various industries, identified the need for: 1) communication about occupational stress; 2) paying attention to the determinants of occupational stress (job demands, support from colleagues and supervisors, autonomy/control); 3) providing the favorable circumstances for stress prevention, including a supportive organizational culture; 4) the availability of stress prevention measures in the workplace and so on. Both employees and supervisors believe that the supervisors should communicate about work stress. Employees were reluctant to initiate such communication fearing the consequences, which indicates the importance of creating an atmosphere of psychological safety in the organization [10]. However, currently, supervisors, particularly in the ATC system, do not have special tools of information support for managerial decision-making on this issue. Thus, the development of a decision support system (DSS) for ATCO shifts supervisors, which will provide recommendations for managing stress in the ATCO workplaces, is an important scientific and practical task. Such a system will improve the effectiveness of stress management, psychological stability, and reliability of operators. And this, in turn, will contribute to improving the level of flight safety.

Analysis of recent research and publications. Occupational stress and stressors are the subject of active multidisciplinary research at the intersection of psychology, ergonomics, and management. Researchers use various approaches to conceptualizing and measuring stress, including analyzing physiological indicators, surveying and interviewing staff, observing workplaces and so on. For instance, in their research on gender differences in physiological stress responses to a computer breakdown during a time-limited task, Riedl et al. used skin conductance as a reliable indicator of sympathetic nervous system activity [11]. The Management Standards Indicator Tool (MSIT) questionnaire, considered by researcher Houdmont J. et al., allows for assessing psychosocial risks in workplaces within organizations [12]. A multimodal approach is the most often used to assess stress and workload in pilots. It combines objective measurements (physiological indicators, including cardiac and brain activity, respiration, electrodermal activity, skin temperature, eye movements, muscle strength, voice), subjective methods (questionnaires) and assessment of task performance quality. However, recording certain parameters is problematic in real flight conditions [13].

To prevent ATCO occupational stress, relevant measures should be taken at various levels: socio-economic (improvement of legislation, current regulations and methods of social support); technological and organizational (ensuring an appropriate level of automation in the workplace, improving working conditions and work schedules); ergonomic (optimizing workplace design and work environment according to ergonomic criteria); individual (training in coping strategies, psychological support). According to Giovanni C., important preventive measures include rationalizing ATCO shift schedules based on psychophysiological and social criteria, providing breaks during work and involving ATCO in decision-making processes. Additionally, they need special psychological support in cases of severe emotional stress after aviation incidents to prevent post-traumatic stress disorders. Medical surveillance and screening should be aimed not only at assessment of professional suitability but also at healthcare, early detection and correction of stress-related disorders [14].

The specifics of stress management in the field of ATC are covered in a number of sectoral documents. The International Federation of Air Traffic Controllers' Associations (IFATCA) classifies occupational stressors of ATCO and provides recommendations on policies and procedures for their elimination. Eurocontrol defines three levels of stress management: primary (prevention), secondary (raising staff awareness and preparedness) and tertiary (minimizing consequences and rehabilitation) [15]. In some countries, Critical Incident Stress Management (CISM) programs, based on the Mitchell method, have already been implemented. They

including measures of psychological support and debriefing.

There are a number of studies dedicated to the development of information systems for automated stress monitoring and management. For example, Sazvar Z. et al. presented a comprehensive DSS for assessing stress levels and generating possible solutions to reduce it in project-oriented organizations using expert assessment methods and fuzzy logic [16]. Rodrigues S. et al. proposed monitoring tools for quantitative assessment of occupational health and tracking stress levels in firefighters in real-time. They provide assistance for human resource management and development of anti-stress measures in timely manner [17]. Winslow B. D. demonstrated the feasibility of combining mobile applications for tracking physiological stress, using a commercial wearable device, and cognitive-behavioral therapy to reduce stress in military personnel and other vulnerable populations [18]. The application notifies users about the presence of stress, guides them through stress reduction methods, and transmits information to physicians. This approach leads to increased adherence to therapy and more effective symptom reduction. Masi G et al. note that real-time monitoring of pilots' psychophysiological state is of great importance for improving flight safety, enhancing working conditions, and optimizing pilot interaction with onboard equipment. However, the implementation of new monitoring tools is complicated by strict regulatory standards. Aviation simulators studies provide more opportunities to control experimental conditions and apply various real-time monitoring tools. However, the obtained patterns are not always reproduced in real flights [13].

Task statement. The purpose of article is formulation of requirements for the DSS that supports ATCO shifts supervisor to manage job-related stress among ATCOs.

Outline of the main material of the study. To effectively manage occupational stress among ATCOs, the DSS must be able to perform the following functions:

1. To conduct a comprehensive analysis of the psycho-emotional state of ATCOs using their biometric indicators.

2. To determine the level of ATCO's cognitive workload, taking into account the current airspace congestion, operational constraints, workplace-specific requirements, the effectiveness of team interaction, as well as various events, communicative, psycho-emotional, organizational, and frustration factors.

3. To inform ATCOs and their supervisors about sources of stress and expected dangerous stressors, risks of reaching critical stress thresholds and the predicted overall level of workplace stress by considering individual characteristics of each ATCO.

4. To facilitate the prediction of potential stressful situations, enabling adaptive and proactive intervention to prevent reaching dangerous ATCO stress thresholds. This will be accomplished by providing recommendations to ATCO shift supervisors on the proactive stress management, offering them strategic (long-term organizational actions based on identified trends) and tactical personalized stress management methods for the ATCO workplace. Fig. 1 presents a functional model for the stress management in the ATCO workplace as a "white box model". The model provides a systematic, transparent, and flexible approach to the analysis and management of occupational stress to make informed decisions by the ATCO shift supervisor.

The process of ATCO occupational stress management (S) can be mathematically represented as a set of:

$$S = \langle F, D, P, Y, \alpha, \gamma, \Omega_1, \Omega_2 \rangle \quad (1)$$

where: $F = \langle f_1, f_2, \ldots, f_n \rangle$ – the set of input data;

$D = \langle d_1, d_2, \ldots, d_m \rangle$ – the set of applicable restrictions and regulatory requirements;

$P = \langle p_1, p_2, \ldots, p_s \rangle$ – the set of priorities in stress management;

$Y = \langle y_1, y_2, \ldots, y_k \rangle$ – the set of output data;

α – job-related stress management function;

γ – the feedback function, that updates data on the effectiveness of measures applied to regulate the level of occupational stress;

Ω_1 – the function to adjust the stress management methodology;

Ω_2 – the function of revising local and individual priorities for ATCO' stress.

In this model, the elements of the set "F" are:

f_1 – data on detected stressors;

f_2 – personal data on ATCOs;

f_3 – organizational data on team resource management, structural changes, etc.;

f_4 – data on the effectiveness of ATCOs' occupational stress management strategies.

The set "D" is formed by the following elements:

d_1 – data on best practices and stress management techniques in civil aviation (e.g. CISM) that are being applied;

d_2 – the set of laws, regulations, guidelines and specifications relevant to the setting working hours of the ATCO staff, providing scheduled breaks and rest, airspace sectorization, automation needs;

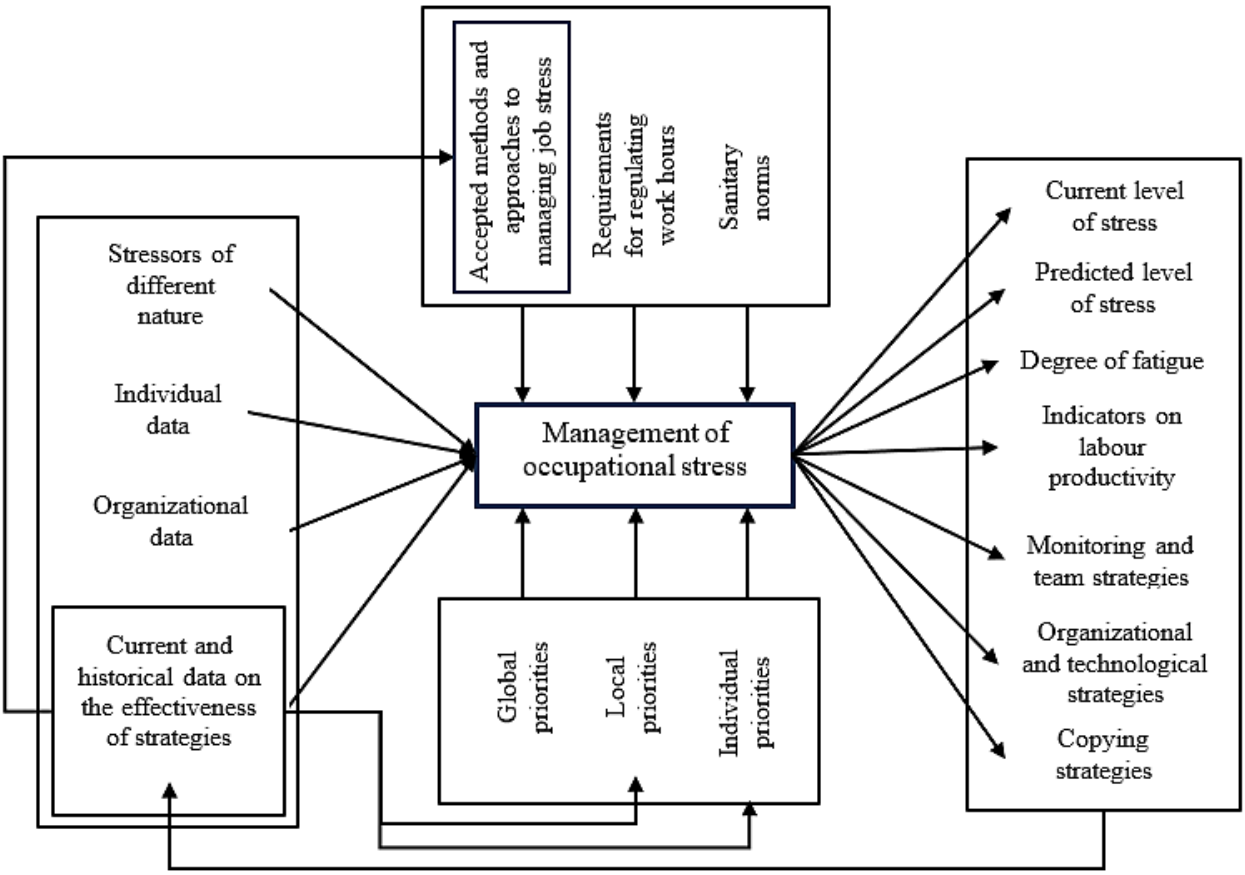

Fig. 1. Functional model of ATCO stress management: the "white box model"

d_3 – sanitary norms on microclimate (illumination, temperature, humidity, noise etc.) at ATCOs' workplaces.

The set "P" consists of the following elements:

p_1 – data on the general (global) priorities for managing ATCOs' stress during work hours;

p_2 – data on local priorities for managing ATCOs' occupational stress;

p_3 – data on individual priorities for managing ATCOs' job-related stress.

The set of output data "Y" includes:

y_1 – the measured level of occupational stress;

y_2 – calculated changes in the level of occupational stress;

y_3 – the degree of fatigue;

y_4 – measured values of labor productivity parameters;

y_5 – stress management strategies of different levels of application.

The feedback loops in the considered model are a key element of effective stress management, as they allow dynamically adapting managerial decisions and individual strategies in accordance with application efficiency. Moreover, the identified trends in the effectiveness of strategic and tactical ATCO stress management should contribute to the revision of the stress management methodology, the global, local and individual priorities in order to create a unique approach, taking into account cultural and local specificities, or prompt a paradigm shift.

The central block "ATCO Stress Management" of the model represents the processes of applying regulatory documents, methods, and recommendations for stress management in ATCO workplaces, empirical knowledge about the phases of potential productivity and functional state of ATCO ("warm-up" or "rising productivity", "stable high productivity", "rising fatigue" and "breakdown"), knowledge about the patterns of influence of the occupational stress levels on the ATCO performance in order to minimize the negative impact of stressors on the functional and emotional state of ATCO, to prevent burnout and ensure conditions for extending their professional life. Stress management of ATCOs must be carried out in accordance with regulatory certification requirements and standards in air traffic management. This includes compliance with working hours and rest norms, ensuring proper working conditions and undergoing regular medical examinations.

Stress factors include various conditions and events that affect the level of ATCO job-related stress, such as workload, "no room for error", fatigue, depression, lack of time for decision-making, conditions at ATCO workplaces, interpersonal relationships within the ATCO shift team, organizational factors, dangerous weather hazards, technical failures of onboard and ground equipment, planned and active restricted airspace, serious incidents etc. **Individual and organizational data** includes: data from surveys and psychological testing of ATCOs; data on recent experience related to serious incidents and accidents; self-assessment data on stress levels and emotional state; data on experience, age, and qualification levels of ATCOs; data on periodic professional (simulator) training; data on long-term work breaks (illness, maternity leave); data on the quantitative and qualitative composition of ATCOs, airspace sectorization, applied ATCO shift schedules and staff distribution; data on the number and duration of breaks within ATCO shifts; information on organizational changes in air traffic service units, changes in ATCO procedures etc. **Subjective data** that may relate to current and historical data on the effectiveness of applying stress management strategies include survey results from ATCOs regarding the perceived effectiveness of stress management strategies (in particular, data on changes in feelings of self-efficacy and job satisfaction before and after implementing the strategies), feedback and suggestions from ATCOs on improving stress management strategies, self-assessment data on stress levels and dynamics of changes resulting from the strategy implementation. **Objective indicators and sources of information include** individual differences in behavioral and psychophysiological indices and individual work performance. The data sets are the basis for applying an adaptive approach to stress management of ATCOs.

The integration and analysis of the above heterogeneous data within a functional stress management model allows for a comprehensive understanding of stress factors, generates organizational, technological and team strategies for ATCO shift supervisor, provides coping strategies tailored to the management of stress and fatigue for ATCOs, evaluates applied techniques. It is important to ensure the reliability, safety and confidentiality of these information flows, as well as to provide mechanisms for filtering and pre-processing data for their effective use in DSS.

In the context of ATCO stress management, **the global priorities** in the model are: 1) ensuring flight safety; 2) maintaining and improving the psychological health of ATCOs; 3) fostering an atmosphere of team support and cooperation; 4) continuously improving approaches and strategies for ATCO stress management; 5) providing ATCOs with opportunities for training and professional development in the context of forming and improving special competence in stress management at the individual and team levels (for example, implementation of a Team Resource Management program). **Local priorities** in ATCO stress management may vary depending on the specifics of a particular structural regional division of enterprise, its service area and other factors. **Individually-oriented priorities** relate to a specific workplace within the particular ATCO units, used to optimizing workload taking into account the individual characteristics, training level, and experience of air traffic ATCOs.

Based on the set of priorities considered, existing stressors, organizational conditions, operational requirements, and applied approaches to ATCO stress management, the optimal set of strategies and techniques for managing ATCO job- related stress is determined. For example, **monitoring and team strategies** may involve the use of additional psychological tests to assess the emotional state, level of anxiety, depression, burnout of ATCOs; conducting surveys on job satisfaction, team support, and other factors affecting stress; using voice analysis methods and behavioral markers to detect signs of stress and emotional exhaustion during communication with pilots and other controllers; conducting debriefings with ATCOs to discuss stress-related issues (serious incidents) and collect their feedback and suggestions etc. **Organizational and technological strategies** may include measures to improve workplace ergonomics and ensure optimal lighting, temperature, and noise levels in the work premises; implementation of convenient and intuitive ATCO interfaces to minimize the ATCO's cognitive load etc. Individual coping strategies include personalized cognitive restructuring strategies, individual emotional regulation strategies, a personal support network from colleagues, personalized professional development programs and relaxation techniques etc.

To develop an automated occupational stress management system in air traffic control, should be taken into account important basic system of requirements are shown in Fig. 2.

Let's take a closer look at these requirements. **Functional requirements** provide the following capabilities: inputting and editing a list of typical stressors with conditions for their identification

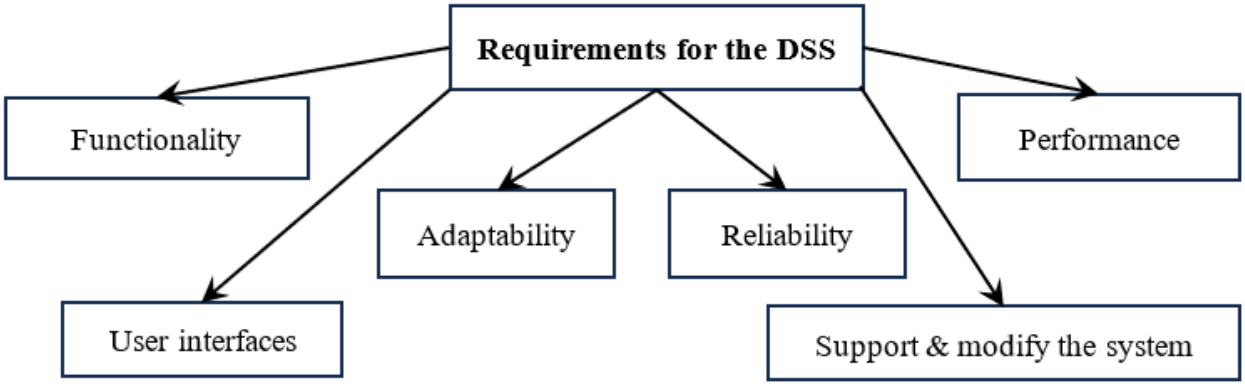

Fig. 2. Basic requirements for stress management in air traffic control

and configuring importance weights; assessing the current level of each stressor on a certain scale (e.g. from 0 to 10); calculating an integral empirical indicator of occupational stress based on the values of stressors and their weights; forming a base of fuzzy inference rules of the "IF-THEN" type to determine the level of stress and displaying the result of stress level assessment in the form of a linguistic variable ("low", "medium", "high", "critical"); selecting the most effective measures taking into account the current constraints (time, financial, organizational etc.); generating notifications and informational messages with explanations regarding the assessment of the current stress level and recommended measures (with the ability to configure the degree of detail of informational and recommendation messages); forming a knowledge base on the effectiveness of various measures applied for managing job-related stress levels.

The requirements for adaptability include: consideration of individual preferences by the system, stress resilience levels of each ATCO, and their psychological profiles to provide recommendations for stress management; detecting trends, predicting stress levels and stress reactions based on historical data for each ATCO; taking into account the time of day, phases of potential productivity and operational environment requirements to form a set of measures to prevent high stress levels in ATC.

User interface requirements provide the following capabilities: flexible configuration of the stressors list, rules, and measures without the need for changes to the program code; use of a convenient and intuitive graphical interface by end users; visualization of results in the form of graphs, diagrams, tables with the ability to print and export; receiving contextual prompts and help information to facilitate user work; differentiation of access rights for different categories of users (administrator, expert, supervisor, ATCO).

Reliability requirements provide the following capabilities: ensuring the integrity and consistency of the knowledge base; checking the correctness of the entered data and protection against user errors; automatic saving of intermediate work results with the possibility of recovery in case of failures; maintaining detailed system logs for tracking and diagnosing potential problems.

Performance requirements provide the following capabilities: obtaining stress level assessment results and recommendations in real-time; optimization of fuzzy logic inference and decision selection algorithms to reduce computation time; working with large data volumes without significant loss of performance.

Maintenance and modification requirements provide the following capabilities: adding, removing, or modifying individual components of the DSS without affecting others due to its modular architecture; maintaining detailed software and user documentation; integration with other enterprise DSS information systems for data import/export; updating the knowledge base based on machine learning or expert assessments.

Conclusions. The application of the considered approach to building a DSS for job-related stress management will increase professional reliability of ATCOs by providing their supervisors with automated tools for supporting operational organizational decision-making in stress management. The proposed functional model will ensure a comprehensive approach to stress management among ATCOs by integrating the collection and analysis of various data, forecasting stress levels, providing timely alerts and recommendations, as well as continuous improvement of the implemented system based on feedback and accumulated experience.

The future directions of research include: 1) identification of different stressors and stress levels among ATCOs, ranking them; 2) investigation

of the relationships between different clusters of stress factors and their synergistic impact on the psychophysiological state of ATCOs; 3) determination and validation of threshold values for the level of occupational stress; 4) mathematical modelling to make predictions the level of job-related stress of ATCOs based on the analysis of the effects of various stress factors; 5) development of personalized methods and strategies for managing the stress of ATCOs, taking into account their individual characteristics and needs; 6) research on the effectiveness of strategic and tactical stress management measures recommended by the DSS, and their impact on the professional reliability of ATCOs; 7) development of interfaces and protocols for interaction of the DSS with available air traffic management and ATC systems in order to obtain data for determining stress factors.

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Пальоний А.С. РОЗРОБКА ВИМОГ ДО СИСТЕМИ ПІДТРИМКИ ПРИЙНЯТТЯ РІШЕНЬ З УПРАВЛІННЯ ПРОФЕСІЙНИМ СТРЕСОМ АВІАДИСПЕТЧЕРІВ ДЛЯ СУПЕРВАЙЗЕРА ДИСПЕТЧЕРСЬКОЇ ЗМІНИ

Стаття присвячена актуальній науково-практичній проблемі управління професійним стресом диспетчерів управління повітряним рухом (УПР) для підвищення їх професійної надійності та безпеки польотів. Проаналізовано основні фактори професійного стресу при УПР і техніки управління стресом. Ефективне управління стресом серед диспетчерів УПР є критично важливою функцією супервайзерів диспетчерських змін. Для успішного вирішення завдань, пов'язаних з цією функцією, вони повинні бути забезпечені засобами підтримки прийняття рішень. Визначено, що наразі відсутні ефективні автоматизовані інструменти для менеджменту професійного стресу диспетчерів УПР в режимі реального часу. В статті запропонована ідея розробки системи підтримки прийняття рішень (СППР) для супервайзерів диспетчерських змін, що надаватиме їм сповіщення, інформацію та рекомендації з управління професійним стресом авіадиспетчерів. Представлено функціональну модель менеджменту професійного стресу авіадиспетчерів у вигляді «моделі білої скриньки», що забезпечує комплексний підхід до аналізу та управління стресом на робочих місцях диспетчерів УПР. Визначені типи даних моделі, обмеження, пріоритети, вхідні та вихідні параметри. Запропонована модель враховує зворотні зв'язки, що забезпечують динамічну адаптацію управлінських рішень та індивідуальних стратегій керування стресом відповідно до ефективності їх застосування. Розглянуто глобальні, локальні та індивідуальні пріоритети в управлінні професійним стресом авіадиспетчерів. Визначені закономірності у стратегічному й тактичному керуванні професійним стресом авіадиспетчерів мають сприяти ревізії діючої на підприємстві методики управління стресом, локальних та індивідуальних політик і пріоритетів. СППР може допомогти супервайзерам диспетчерських змін приймати своєчасні та більш обґрунтовані рішення на підставі результатів оцінки різних видів факторів стресу, рівнів стресу, ключових показників ефективності та рівня втоми; формувати рекомендації та відстежувати організаційні, технологічні та індивідуальні стратегії подолання професійного стресу диспетчерів УПР. У статті розкрито основні функціональні вимоги до СППР, а саме: надійність, функціональність, адаптивність, продуктивність, вимоги до інтерфейсу користувача та супроводу системи.

Ключові слова: *диспетчер управління повітряним рухом (УПР), професійний стрес, управління стресом, автоматизовані інструменти, функціональна модель, функціональні вимоги.*