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PROBLEMS OF THE HUMAN FACTOR IN TRANSPORT SYSTEMS

Summary. *Transport accident statistics and practical safety results indicate that technological solutions cannot ensure the viability (safety, sustainability, reliability and efficiency) of complex systems and structures without addressing human factors. This problem is especially acute for transport systems as highly complex technological and social structures aimed at ensuring the efficiency and safety of an entire sphere of human life. In transportation systems and technologies, the human factor plays a critical role. The successful operation of transport systems requires consideration of the human factor at all levels – starting from the development, design and planning of systems and technologies, training and education to the involvement of society in decision-making processes. Therefore, it is essential to develop the concept of human factor management and analyze the main problems in transport systems associated with the human factor to improve the safety, reliability and efficiency of their functioning.*

The article is devoted to the analysis of the human factor problem in transport systems and the search for solutions to manage it. The purpose of the article is to analyze the main problems in transport systems associated with the human factor and to develop the concept of human factor management for further search for solutions to improve the safety and reliability of transport systems.

A set of instruments was proposed in the study to achieve the goal and solve the set tasks. Problems connected to the human factor in transport systems were analyzed. The main directions for solving problems with the influence of the human factor on the safety of transport systems were systematized. The main principles, models and ways of developing the concept of managing the human factor problem in complex systems, including transport, were outlined. A systematization of the risk management strategy was proposed. A matrix for the relationship between risk management strategies and approaches to managing the safety of complex systems was proposed. A new look at the principle of adaptive ergonomics as an implementation of the tolerance strategy was proposed, and applying the principle of adaptive ergonomics to transport systems was considered.

The main motivation of the work is to attract the attention of the scientific and educational community to the problem of human factor and the need to use the concept of human factor management in the educational process to improve the general safety culture in society.

Key words: *human factor, transport systems, safety, viability, risk management strategy, human factor management concept.*

1. INTRODUCTION

For many years, the axiom in the field of security has been the superiority of technology over human factors. The increase in the number and level of threats has led to new solutions focused on technological tools, but research related to human factors has been limited. For example, organizations most often ignore the human factor in security planning. In recent years, transport accident statistics and practical safety results

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indicate that without addressing human factors, technological solutions are unable to ensure the viability (safety, sustainability, reliability and efficiency) of complex systems and structures. That is, the main problem in the field of security remains the problem of the human factor [1–3].

The catastrophic consequences of the human factor problem were described by psychologist and Nobel laureate Daniel Kahneman in his book “Noise. Flaw in a person's judgment” (2021). There are theories, concepts, approaches and methods for solving security problems that come down to attempts to manage the human factor [1, 2, 4–6]. The practical application of human factors/ergonomics specialists' knowledge is in constant flux. Educational structures are usually more stationary, and the knowledge students receive is basic, but often conservative and outdated. Many say that today's professionals do not have the knowledge and skills necessary to solve problems in the workplace, especially about human-machine systems and human factors problems [7]. The problem is in a clear understanding of the need for human education, which must solve the problem of safety/sustainability/viability of complex systems built on a combination of human-machine interaction, artificial intelligence and robots.

Scientists in the field of human factors-ergonomics-safety are unanimous in the need to create transdisciplinary programs [1, 2, 4, 8–11]. The term “human factor” is polysemantic and multidisciplinary and is often considered as the possibility of a person making erroneous or illogical decisions in specific situations; as the possibility of committing unintentional and even malicious actions. The network of scientific areas for the study of human factors is very multi-vector. These are psychology, neurophysiology, engineering, ergonomics, industrial design, anthropometry, anthropology, safety, et cetera. The intersecting area, on the one hand, is the mental properties of a person, the mechanisms of motivation and decision-making, and patterns of behavior. On the other hand, there are psychophysiological aspects – human capabilities (stress resistance), functional state (stress) and professional selection. In transport systems, the human factor plays a critical role. The successful operation of transport systems requires consideration of the human factor at all levels – from the development, design and planning of systems and technologies, training and education to the involvement of society in decision-making processes.

Therefore, it is essential to develop the concept of human factor management and analyze the main problems in transport systems related to the human factor. It is necessary to find solutions to human factor management mechanisms in transport systems to improve the safety, reliability and efficiency of their operation.

2. PROBLEM STATEMENT

Hybridity of transport systems. Transport systems represent complex technological and social structures aimed at ensuring the efficiency and safety of transport operations and play an essential role in providing social mobility and economic development. In them, the human factor plays a critical role. Vehicles, information systems, safety systems, vehicle maintenance systems, management and logistics systems, infrastructure and its components are complex human-machine systems. They exist thanks to human potential (intelligence, cognitive capabilities, psychophysiological properties), technological potential (transport, infrastructure) and their interaction (management technologies, maintenance, logistics). Developing autonomous vehicles, hybrid technologies, intelligent transport systems, information and communication technologies, security systems and systems for preventing dangerous situations requires special hybrid thinking and hybrid approaches [12].

The problem of human activity in modern transport systems. Efforts to improve the reliability and safety of any system (technical, energy, economic, social) face such complex issues as human error, making deliberately wrong decisions, inconsistency of human physical capabilities, cognitive distortions, inherited properties and formed qualities. That is, the problem with the human factor is an obstacle to creating sustainable and safe systems, especially in the transport sector. Human factor explains 70–80 % of accidents and disasters in aviation and water transport, in motor transport – more than 90 % of cases, and in railway transport – about 50 %. That is, the human factor plays a critical role in the safety and sustainability of transport systems [3, 6, 9].

For many years, ergonomics has noted the growing danger of an increase in the frequency of human errors due to the lag of human capabilities from the level of technical equipment. The increasing complexity of systems leads to an increase in the "price" of human error. Automation and digitalization were supposed to reduce the likelihood of human error but led to its emergence at a new, more complex cognitive level. In autonomous systems, the human factor problem is still relevant. The problem is human trust in technology, ethical and legal aspects of automation, using artificial intelligence, and the growth of cognitive load. The complexity and multi-vector nature of the human factor problem increases with the increase of systems complexity. Ensuring the reliability and efficiency of transport systems requires a specific approach that considers technical innovation and organizational and structural changes through the prism of a person and his mental, physical and social essence. A hybrid approach is needed to solve hybrid problems in complex hybrid systems [12, 13].

The most well-known systematization of the sources of erroneous human actions is the triad: a) errors in perception and information processing; b) errors in decision-making; c) errors in actions. According to transport systems, human factors are essential in the following aspects:

- introduction of innovative management technologies, such as automation and transport management systems, intelligent transport systems, sensors, et cetera, and development of information systems for monitoring and managing traffic flows – to reduce category (a) errors;
- intelligent driver assistance systems, control of his actions, decision support systems, functional state monitoring and fatigue management, driver behavior monitoring and error analysis feedback systems – to reduce category (b) errors;
- ergonomics of vehicles and systems, ergonomics of the cabin and driver's seat, design of control interfaces – reduce category (c) errors.

Therefore, systemic efforts at the levels of education, technology, infrastructure, management and human behavior can significantly improve transport systems. Understanding safety culture, ergonomic design, early detection of ergonomic system deficiencies, ergonomic audits, and human factors principles are all crucial to vehicle safety.

3. AIM AND OBJECTIVES

The purpose of the article is to analyze the main problems in transport systems associated with the human factor and to develop the concept of human factor management for further search for solutions to improve the safety and reliability of transport systems.

The following tasks are solved to achieve this goal:

- analysis of the main provisions of the concept of human factors in transport systems;
- identification of the main problems in transport systems associated with the human factor;
- systematization of the main directions for solving problems of the influence of the human factor on the safety of transport systems.

The motivation is to attract the attention of the scientific and educational community to the problem of human factors and the need to use the concept of human factors in the educational process to improve the overall safety culture in society.

4. ANALYSIS OF LATEST RESEARCH AND PUBLICATIONS

Evolution of interest in the concept of human factors. The first wave of interest in considering the human factor in management science arose in the late 60s and early 70s of the twentieth century relating to research into human-machine systems. A person is considered a subsystem of some complex system in continuous interaction with the technical subsystem and the external environment. At the same time, the human operator was considered a subject and an object of control.

The concept of the "human factor" has a long history of development in various fields that emphasizes the importance of humans' role in the processes of design, operation and interaction with technical systems.

Ideas related to human influence on technical industrial systems began to develop at the beginning of the 20th century. The founders of quality theory and scientific quality management, F. Taylor and E. Deming, emphasized the importance of human resources and the influence of skills and work organization on productivity.

During World War II, aviation incidents and disasters led to awareness of the importance of pilot training, the design of cockpits, aircraft instruments and interfaces, and other aspects related to the human influence on the safety and efficiency of flight.

From the 1950s to the 1980s, research was conducted in the industry to optimize labor and reduce human errors. Ideas of human efficiency and safety influenced the design of workplaces and equipment. The theory and practice of human factors management has evolved to create safer, more efficient, and more user-friendly systems and work environments. In the 90s, there was a leap in understanding the role of the human factor after the Chornobyl disaster, when the lack of a safety culture was named as one of the primary reasons. The consequence was significant changes in approaches to ensuring the safety of critical systems and personnel management and training.

Currently, the concept of human factors is firmly embedded in the design of technical systems. Its role is increasing with the introduction of autonomous technologies, the development of digital interfaces and the widespread use of artificial intelligence.

The evolution of the “human factors” concept emphasizes the constant desire to improve human interaction with technical systems, prevent errors, improve safety and ensure optimal working conditions.

The influence of scientific potential on the concept of “human factor”. Today, the human factor is no longer just a phenomenon, an occurrence, it is a property of a complex human-machine system, which is emergent and arises from human activity, interaction with the environment and technical means.

According to Meister, “The science of human factors is the only science of human behavior oriented in the field of technology, the goal of which is to optimize the system in which a person is included” [14].

Many scientists have contributed to human factors research in various sciences. Frederick Taylor's papers in the field of management and work efficiency have influenced the design of systems and work processes considering human factors. Designer and psychologist Donald Norman, known for his work in human factors and interface design, has extensively researched how people interact with technology. He has also contributed to the development of usability principles. Systems safety and human factors specialist Erik Hollnagel focused on analyzing and preventing human errors in complex technical systems. Nobel laureate and economist Herbert Simon has also worked in the field of human decision-making and artificial intelligence.

Many scientists have contributed to the understanding of the role of human factors in the field of air transport. American physician and aviation safety pioneer Hugh DeHaven analyzed aviation events. Australian psychologist Elwyn Edwards has contributed to understanding the role of human factors in aviation safety, especially the psychology of pilots. John Lauber, Nancy Leveson, David Weinrich, and Edward Hutchins are human factors and safety experts in aviation and other transportation.

Automation and driver technology researcher Ross Harris focuses on driver perception and interaction with technology. Researcher and professor Jeffrey Schnapp studies mobility and the future of transportation, including aspects of design and human interaction.

Scientist Ravi Parasuraman is known for his research in the field of ergonomics and human factors in aviation, transport and other complex systems [5, 6]. He has made significant contributions to the study of the impact of automated systems on the pilots` operation, their perception of information and decision-making, the study of attention and performance in various conditions, the study of human interaction with equipment and machines, including the development and adaptation of interfaces to improve efficiency and safety. Conducted research in the field of control and decision-making systems, including in the context of complex technical systems and vehicles. Parasuraman has contributed of ergonomic aspects of transportation systems, analyzing the impact of vehicle design and infrastructure on drivers and passengers.

In Ukraine, the following institutions were involved in solving ergonomic problems: the Kharkiv State University (KhNU since 1999), the Kharkiv Highway Institute (KhNADU since 2001), the Kyiv Institute of Civil Aviation Engineers (NAU since 2000), Kharkiv Aviation Institute (NAU named after M. E. Zhukovsky since 2000) and others [15]. Ukrainian specialists actively participated in the implementation of many fundamental and targeted comprehensive research programs, such as ergonomic support for the creation and operation of nuclear power plants, development of training equipment for training cosmonauts for landing on the Moon, as well as aircraft simulators and simulators, development of an automated dispatch center for controlling the operation of the railway, ergonomic design of workplaces for drivers of mainline diesel locomotives and drivers of advanced trams, ergonomic research and design development of CNC machines, mini-computers and complex equipment for flexible production systems, development of ergonomic requirements for information systems that were equipped with video terminals, development of the main principles for the creation and operation of an ergonomic data bank, et cetera [15]. The work of these scientists makes a crucial contribution to the modern understanding of human factors, including in the transport sector.

Despite this, the problem of the human factor remains relevant and has several unresolved issues and new challenges. These include:

1. a new look at the psychology of human perception, cognitive problems and distortions and their impact on decision-making and task performance;
2. developing effective methods for reducing human errors;
3. minimizing operator errors by creating intuitive user interfaces;
4. research into the impact of automation and robotization on human activity, including issues of interaction between humans and robots;
5. development of standards and principles for the ethical use of technology that take into account human values, privacy and security.

Overall, developing approaches and tools for identifying, analyzing and managing risks associated with human factors in transport systems remains a challenge and requires further research and development.

5. ANALYSIS OF THE PROBLEM OF HUMAN FACTOR IN TRANSPORT SYSTEMS

5.1. Key aspects of the human factor problem in transport systems

Human factors in transportation systems directly address the influence of human behavior, capabilities, constraints, and decisions on the design and operation of transportation systems and their safety. Understanding human factors is critical to creating efficient, safe and convenient transportation systems.

The main aspects of the human factor problem in transport systems are the person and his interaction with the system itself:

1) person, his behavior and condition:
   - behavior (driver, pedestrian, passenger, et cetera) plays an essential role in ensuring the safety of transport systems. For example, factors such as attentiveness, responsiveness, decision-making and compliance with traffic rules have a direct impact on overall road safety [3];
   - predicting human behavior (for example, pedestrians and cyclists) at intersections and along roads is crucial for designing safe transport infrastructure;
   - functional state of a person in transport systems. Driver fatigue and stress are critical in the transportation system because it significantly increases the risk of an accident. Labor organization, planning, professional selection, stress management, and intelligent systems can mitigate these factors [2, 3, 6];
   - cognitive load: with the introduction of advanced driver assistance systems (ADAS) and autonomous technologies, cognitive load has increased significantly, resulting in distraction and reduced situational awareness;
   - training and education: adequate training and education for drivers, as well as other participants in the transport system; education of designers of transport systems and people who carry out its life activities [3, 8, 10];

   - social, cultural and religious factors influencing transport safety. Understanding them helps create and adapt policies and systems;
2) human-machine interaction:
   - design of interfaces and vehicle controls;
   - implementation of decision support systems such as collision avoidance systems, lane departure warnings and adaptive cruise control;
   - implementation of control systems over human actions in the transport system.

Managing human factors in transportation systems requires an interdisciplinary approach that combines engineering, psychology, education, and policy development to create transportation systems that are both efficient and safe for all users. The successful integration of transportation technologies depends on how well they match human capabilities and expectations.

5.2. Ergonomic problems of automation, digitalization and artificial intelligence in transport systems

Digitalization has led to the growth of cyber threats, the complexity of integrating various transport systems and human factor problems. For example, the collection of personal information raises issues of privacy protection and control of personal data; automation and digitalization are already affecting jobs, creating the need for retraining and updating skills. Today, there are sociocultural and psychological barriers to the perception of new digital technologies in transport. Ethical issues also become acute when digital systems must make decisions that affect the lives and safety of people.

Human factors in autonomous vehicles remain a critical aspect even as we move to the level of autonomy, where vehicles can perform certain functions without active human intervention. Automation, including autonomous systems and artificial intelligence, despite its advantages, can cause several ergonomic problems [16]:

1) the problem of trust in automated systems, especially when they need to intervene or make decisions in critical situations. Moreover, trust may be excessive, unrealistic or absent:
   - unrealistic expectations of automation capabilities and limitations;
   - a feeling of anxiety when a person loses control over a situation;
   - double perception of security – the illusion of security or mistrust;
2) ethical, legal and psychosocial (for example, fear of losing a job) aspects of automation and the use of artificial intelligence;
3) cognitive load and human-machine interface problems:
   - the emergence of complex interfaces and systems that require management and control from employees;
   - poorly designed interfaces can lead to errors and increased cognitive load.

Artificial intelligence affects ergonomics, including interface design, workflow optimization and increasing the efficiency of technical systems. Artificial intelligence has become an essential tool for creating more human-centric and efficient systems, thanks to:

- creating more intuitive and adaptive user interfaces;
- implementation of voice recognition and natural language processing technology;
- freeing a person from routine and monotonous tasks;
- ability to predict behavior based on analysis of previous user behavior;
- the ability to analyze large volumes of data on work processes and working conditions;
- decision support based on data and statistics.

Interestingly, using artificial intelligence makes it possible to transform automated systems into cognitive systems that process information and make decisions. In this case, it is about the interaction of two cognitive systems – living and technical [17].

Research and technological progress in the field of autonomous vehicles continues. It is crucial to pay attention to human factors to ensure safe and effective interaction between humans and technology in the context of autonomous mobility. Solving these problems requires the joint efforts of engineers, legislators, psychologists, the public and other interested parties.

6. HUMAN FACTOR MANAGEMENT IN TRANSPORT SYSTEMS

6.1. The concept of Human Factor Management

Human Factor Management is a field that focuses on designing systems, environments, and tasks to minimize the possibility of human error. Depending on the three categories of dangerous factors (avoidable, normalized, and permanent), the Human Factor Management concept can be generally described in three stages:

– avoidable hazards are eliminated;
– normalized hazardous factors are regulated;
– means of protection are developed against constant (systematic) factors.

In this case, the systematic factors are of interest since they most influence the safety of systems. One of the most important patterns of human factor engineering is the distribution of random (10 %) and systematic (90 %) risk factors. The vast majority of systematic errors are the result of activity. Note that the organizational factor has a decisive influence on the functioning of complex systems in extreme conditions. It is under the influence of stress factors that all the typical problems of the human factor begin to appear, such as random errors of memory or action, errors of ignorance and inability, and consequences of fatigue/stress/illness of a person. And even organizational errors are created by people. Some vicious circle of problems associated with the phenomenon of the human factor is evident. Security formation is based on programming a model of safe human behavior, which can be illustrated by a model based on the Heinrich pyramid (Fig. 1) [18].

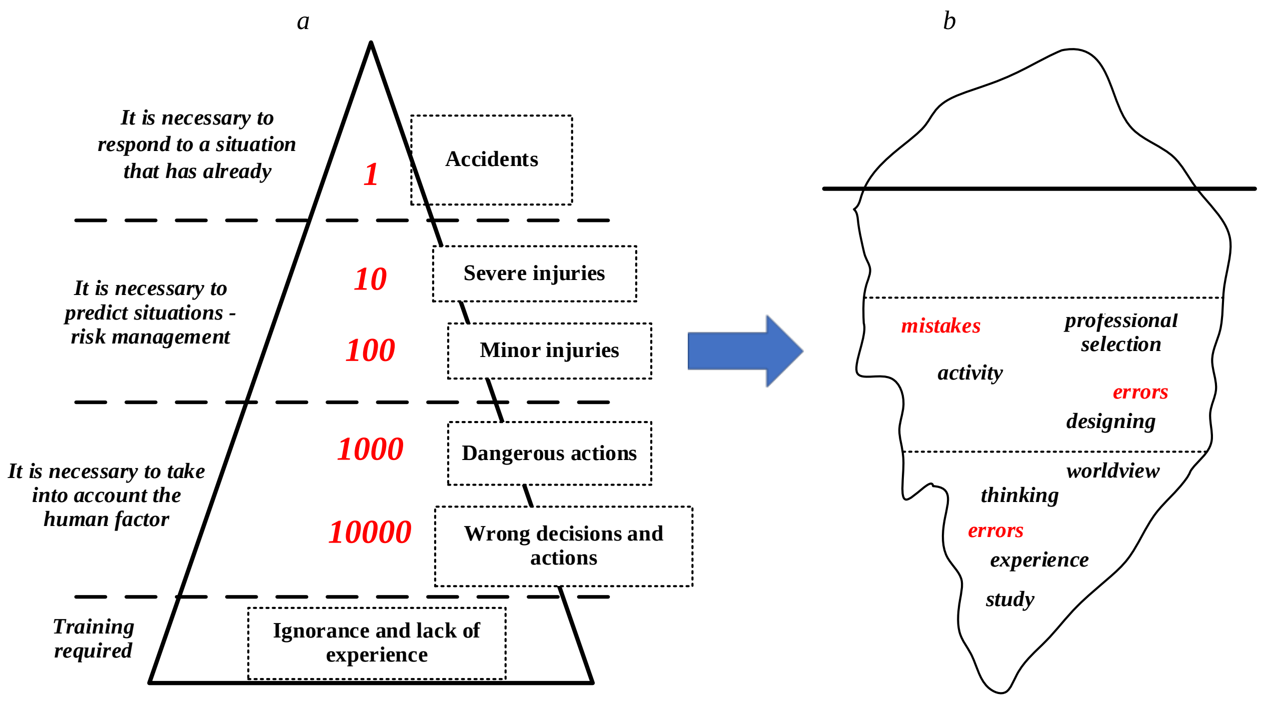

Fig. 1. The modified Heinrich pyramid as a model of the evolution of a problem into a dangerous event (a) and a reflection of the concept of human factor management in the form of an iceberg model (b).

According to the pyramid presented in Fig. 1, the basis for creating safe operating conditions is the mastery by workers of the concept of the “human factor” and its importance for ensuring safety.

Therefore, the analysis of the theoretical provisions existing today and the practical results of research into the problem of the human factor in complex systems made it possible to formulate the provisions of the concept of Human Factor Management in complex systems, which include transport factors:

a. human errors are inevitable;

b. professional selection allows reducing/mitigating errors but cannot avoid them;
c. a person is only the perpetrator of the error, but not its source or cause. A person has the right to make mistakes, but the system must be designed so as not to allow him to use this right;
d. there are no wrong people, but there are wrong systems. However, the question remains: by whom were they designed? Today, it is impossible to manage complex systems by ignoring basic human knowledge during design;
e. a properly designed system allows for the possibility of human error and has everything necessary to ensure that human errors and their consequences are not critical. Namely, a properly designed system is flexible, adaptive, sustainable and resilient.

Therefore, the concept of control through the iceberg model receives a new interpretation (see Fig. 1b). We don't see thousands of decisions and actions leading to a critical error or accident. However, we must ensure that thousands of decisions and actions are carried out so that this risk (error, accident) is not catastrophic for the system and this system remains viable ("afloat"). It can be achieved by using the Shewhart-Deming quality cycle, which is an algorithm of actions for managing a process/system and achieving its goals:

1) *plan:* organizational culture and safety culture; designing systems taking into account the physiological and psychological characteristics of a person; effective professional selection; optimization of the workplace, operating mode, load, et cetera;
2) *do:* implementing technologies such as monitoring and warning systems that can help prevent human errors and improve safety in work environments;
3) *check:* conducting an ergonomic audit of the system to identify risks that provoke the manifestation of the human factor; analysis of risks associated with human factors and development of strategies to manage them.
4) *adjust:* personnel training and development programs aimed at increasing skills and competence; developing strategies for managing fatigue and stress, such as regulating working hours, providing breaks, training to increase stress resistance, et cetera; managing corporative culture, including communication within the organization, training, coaching and leadership.

For example, new ergonomic problems related to human factors arose with the advent of automated systems. It is important to consider human factors and ergonomic principles when designing and implementing automated transportation systems (ATS) to mitigate these ergonomic issues:

1) Transfer of control:
   - the driver must be ready to take control of the vehicle, and the process of transferring control between technology and man must be intuitive and safe;
   - systems should provide clear signals and alerts so the driver can take control.
2) Trust in technology: standardization, training and active interaction with society. Building this trust requires clear and understandable communication from the technology, predictability of its behavior, and demonstration of reliability in different situations.
3) It is essential to learn how to work with ATS and know their capabilities and limitations.
4) Ethical issues related to decision-making in difficult situations, as well as issues of liability in the event of accidents, require the development and establishment of clear rules and regulations.
5) Managing psychological aspects: with partial autonomy, it is crucial to consider the possibility of distraction for the driver, who, knowing that the technology is in control, may lose attention to the road. Understanding the emotional and psychological aspects of ATS use, such as stress, anxiety, or feelings of safety, is also essential for successful technology adoption.

6.2. Security strategies in complex technical systems

The human factor affects the success and failure of measures to ensure the security and sustainability of systems and technologies, enterprises and services, and information systems. The proven possibility of the unpredictability of human actions can destroy even the smartest system. The system becomes vulnerable if its security is overlooked by the developer during the design stage. Not taking into account the laws of interaction between the components of a complex system is a direct path to creating conditions that provoke human error and then an accident. Security strategies in complex technical systems are developed to prevent, identify and manage risks associated with their operation and performance.

The generalized system strategy is based on timely identification of the causes of emergencies; promptly preventing the transition of regular situations into non-routine, emergency or emergencies; identification of risk factors; forecasting the main indicators of the survivability of an object; eliminating the causes of a possible transition to a disabled state [19, 20].

Risk management strategies can be systematized as follows:

1) response strategy – responding to existing problems and risks;
2) error mitigation strategy – applied directly by reducing or eliminating factors contributing to the occurrence of error: active observation and feedback; notifications and alarms; training and simulations; error management training; checks; engineering controls such as automatic trips;
3) error prevention strategy – regulation and standardization, human factor in design and development, ensuring competence, training and coaching, procedural control, activities to identify and assess risks;
4) interception strategy – assumes that an error can be made, so its goal is to “intercept” the error before consequences arise;
5) tolerance strategy – assumes that a mistake will be made; therefore, the system is fully prepared for it, but the consequences will not be destructive, and the system remains stable.

Fig. 2 shows a matrix of relationships between risk management strategies and approaches to managing the security of complex systems.

Security Management Approaches	***Risk Management Strategies***				
	response	mitigation	prevention	interception	tolerance
retrospective	elimination of consequences				
retroactive		standardization and regulation			
proactive			eliminating risks during production		
predictive				eliminating design risks	
strategic					willingness to take risks

Fig. 2. Matrix of relationship between risk management strategies and approaches to managing the security of complex systems (the color corresponds to the degree of risk – from unacceptable (red) to acceptable (green))

For example, the implementation of a tolerance strategy in the form of Smart concepts of “Smart road”, “Smart car”, and “Smart transport”. Smart transport is energy efficiency, environmental friendliness, ergonomics, comfort and efficiency, and modern systems based on IT technologies. Road infrastructure that forgives human errors and takes into account human fragility. Infrastructure compensates for human imperfections through design solutions and technological innovation (Smart Roads concept). This concept uses speed sensors, acoustic sensors, IP CCTV cameras, Smart traffic lights, condition or weather monitoring systems and digital signage. The ideology of a safe “Smart” car is based on the need to compensate for human imperfections at the expense of new technologies. In addition, for example, the Vision Zero concept is implementing a strategic approach and thinking for achieving zero deaths on the road.

6.3. The principle of adaptive ergonomics as the implementation of a tolerance strategy

Adaptive ergonomics is a modern design concept rooted in bionics and is closely related to hybrid thinking [12, 13, 17, 21]. The main idea is to make technologies and systems adaptive to a person's individuality (the main focus is on cognitive and psycho-emotional qualities). It means creating hybrid systems characterized by flexible functioning under constant exposure to stressors. That is, the creation of flexible systems and technologies that can compensate for human imperfections and in which human error is not a critical factor affecting safety and sustainability.

For example, adaptive ergonomics can be implemented by the following activities:

1) When designing the system itself:
   – by ensuring modularity and customizability: creating systems in which components or elements can be easily replaced or customized according to user needs;
   – by ensuring technological flexibility: using technologies that make it easy to integrate new functions, update software or adapt devices to changing needs;
   – by creating an adaptive interface and control: development of user interfaces and control systems that can be adapted to users` preferences and skill levels.
2) When designing a human operator’s workplace:
   – creating an adaptive workplace: using furniture, equipment, interfaces, et cetera, which can be easily adjusted according to ergonomic parameters to ensure maximum interaction;
   – custom design: designing products and systems to suit the individual operator, considering different physical, mental and cognitive abilities.

Implementation of the principle of adaptive ergonomics in the field of transport systems. Adaptability in the context of transport systems means the ability of a system to adapt and function effectively in the face of changing demands, technological innovations, changes in road infrastructure and other factors. Adaptability of transport systems is crucial to ensure more efficient, safe and sustainable movement of people and goods. Here are some aspects of the adaptability of transport systems.

1) Adaptability to a person’s individuality:
   – mobile applications and services that provide real-time traffic information, allow optimizing routes and using different modes of transport;
   – ensuring inclusivity, that is, considering the needs of people with disabilities and creating adaptive transport solutions to ensure accessibility for everyone.
2) Adaptability to the environment:
   – adaptive road infrastructure: designing road infrastructure to be flexible and rapidly upgradable to accommodate changing traffic flows, resilience and safety;
   – autonomous vehicles: using autonomous vehicles which can adapt to dynamic traffic conditions and provide safer and more efficient traffic.
3) Adaptability to new needs and technologies:
   – Intelligent transport systems: the introduction of Artificial Intelligence technologies, data analytics, the Internet and automation to create Intelligent transport systems that can adapt to current needs;
   – flexibility and modularity of vehicles: designing vehicles that can be easily modified and upgraded to adapt to new technologies, environmental standards and passenger needs.
4) Electromobility and green transport infrastructure: developing green energy and stimulating electromobility to create sustainable and adaptive transport systems with low environmental impact.
5) Optimization of complex transport systems:
   – intermodality, that is, the development of systems that combine different modes of transport (cars, trains, aviation, et cetera) to create convenient and efficient routes;
   – flexible tariff systems: development of tariff systems that can be adapted to different groups of passengers, time of day and other factors.

Adaptability of transport systems plays a crucial role in improving efficiency, sustainability and the ability to cope with the challenges of the modern transport environment.

6.4. Safety culture

To summarize, we come to the concept of safety culture as a set of norms, beliefs, values, attitudes and assumptions in the field of safety that are inherent in the daily activities of an organization and reflected in the actions and behavior of all departments and personnel of the organization. The main idea of this concept is that safety should be everyone's responsibility; it is a core value, not an obligation or a burdensome cost. The central concept is the attitude to safety as a priority and the public awareness of the responsibility of each member of the organization to ensure safety in the work environment. Structurally, safety culture has two interdependent components: 1) the planning of the conditions, goals and policies of the organization related to the responsibility of management and 2) the understanding and awareness of personnel at all levels of their safety responsibilities. Identifying the causes and developing measures to prevent emergencies caused by the human factor are among the most important research tasks in occupational psychology, engineering psychology and ergonomics.

The existence of this connection can only be ensured by the transdisciplinary knowledge of specialists at all levels – the combination of engineering sciences, information technology, psychology, bioengineering, neuro- and cognitive sciences, which makes it possible to create conditions for ensuring the safety, reliability and sustainability of complex human-machine systems designed and operated [1, 8, 9, 10, 17, 22–24]. Particular attention should be paid to the development of ergonomic thinking for everyone whose activities concern the life cycle of a complex system – developers, operators, technicians, and managers. Ergonomic thinking is a whole system of views on the development of complex human-machine systems and the role of humans in them. It is an understanding of the complex processes of human-machine interaction, the ability to predict risks in these systems and plan the development of systems with preliminary consideration of these risks. Ergonomic thinking for a specialist of the present, and even more so of the future, along with ecological and critical thinking, is a sign of education and is the foundation of a highly qualified specialist [23, 25].

7. CONCLUSIONS

The problem of increasing safety, reliability and efficiency in transport systems remains unresolved, as evidenced by the sad safety statistics. It is essential to develop the concept of Human Factor Management and analyze the main problems associated with the human operator to find solutions to improve safety in transport systems.

The following steps were made in the study to achieve the goal and solve the set tasks:

– the main problems in transport systems associated with the human factor were analyzed;
– the main directions for solving problems with the influence of the human factor on the safety of transport systems were systematized;
– the main principles, model and ways of developing the concept of managing the human factor problem in complex systems, including transport, were outlined;
– a systematization of the risk management strategy was proposed;
– a matrix for the relationship between risk management strategies and approaches to managing the safety of complex systems was proposed;
– a new look at the principle of adaptive ergonomics as an implementation of the tolerance strategy was proposed, and applying the principle of adaptive ergonomics to transport systems was considered.

We emphasize that identifying the causes and developing measures to prevent emergencies caused by the human factor are among the most crucial research tasks of labor psychology, engineering psychology and ergonomics, which do not lose relevance even with the widespread use of Artificial Intelligence, the introduction of automation and digitalization.

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ПРОБЛЕМИ ЛЮДСЬКОГО ЧИННИКА В ТРАНСПОРТНИХ СИСТЕМАХ

Анотація. *Статистика аварій у сфері транспорту та практичні результати у сфері безпеки вказують на те, що без вирішення проблематики людського чинника технологічні рішення не здатні забезпечити життєздатність (безпеку, стійкість, надійність та ефективність) складних систем та структур. Особливо гостра ця проблема для транспортних систем як надзвичайно складних технологічно-соціальних структур, що орієнтовані на забезпечення ефективності та безпеки цілої сфери життя людства. У транспортних системах та технологіях людський чинник відіграє критичну роль. Успішне функціонування транспортних систем потребує врахування людського чинника на всіх рівнях – від розроблення, проєктування та планування систем і технологій, від навчання та освіти до залучення суспільства до процесів прийняття рішень.*

Тому актуальними є розвиток концепції управління людським чинником та аналіз основних проблем у транспортних системах, що пов'язані з людським чинником, з метою підвищення безпеки, надійності та ефективності їх функціонування.

У статті проаналізовано проблеми людського чинника в транспортних системах та пошуку рішень щодо управління ним. Метою статті є аналіз основних проблем у транспортних системах, що пов'язані з людським чинником, та розвиток концепції управління людським чинником для подальшого пошуку рішень щодо підвищення безпеки і надійності транспортних систем. Для досягнення мети та вирішення поставлених завдань у дослідженні запропоновано набір інструментів. Проаналізовано основні проблеми транспортних систем, що пов'язані із людським чинником. Систематизовано основні напрями вирішення проблем впливу людського чинника на безпеку транспортних систем. Викладено головні засади, модель та шляхи розвитку концепції управління проблемою людського чинника в складних системах, до яких належать транспортні. Запропоновано систематизацію стратегії управління ризиками, матрицю взаємозв'язку стратегій управління ризиками та підходами до управління безпекою складних систем. Запропоновано новий погляд на принцип адаптивної ергономічності як реалізацію стратегії толерантності та розглянуто застосування принципу адаптивної ергономічності до транспортних систем.

Головною метою роботи є привернення уваги наукової та освітньої спільноти до проблеми людського чинника та необхідності використання концепції управління людським чинником у навчальному процесі для підвищення загальної культури безпеки в суспільстві.

Ключові слова: *людський чинник; транспортні системи; безпека; життєздатність; стратегії управління ризиками; концепція управління людським чинником.*