TECHNOLOGY, CREATIVITY, IMPLEMENTATION

HUMAN FACTORS: THE PROBLEM OF MAN-MACHINE INTERACTION UNDER THE DIGITALIZATION CONDITIONS

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Summary

The main attribute of a modern labour paradigm is a new type of man-machine interaction – the digital ecosystem. However, despite the improvement of man-machine interaction, the human factor remains the most difficult issue in ensuring the safety of such systems. Moreover, the digitalization process complicated the problem of the human factors because it led to a decline of the human's subjective responsibility for the actions performed because of a significant increase in the share of artificial intelligence in decision-making. As a result, the number of accidents in recent years has decreased but insignificantly. In most cases, the research methods of the human factor are focused on environmental and technical problems of the system functioning, leaving a human unattended. In this regard, the research aims at the peculiarities of human activity in the digital ecosystem. The research was carried out in two directions. The first one is the study of human needs in the digital ecosystem, due to which it was established that a person needs digital safety. This need determined the emergence of a new phenomenon – the safety culture in the digital space. The second direction is the study of the person's resources. The study of this issue showed that the "cycle" of resources and, in particular, its balanced affects the manifestation of the "human factors" phenomenon.

Keywords: human factors, digital ecosystem, viability, resources, hardiness, eco-ergonomics, safety.

DOI: https://doi.org/10.23856/4825

1. Introduction

One of the main problems in man-machine interaction is the human factors *(Petrillo et al., 2018)*. The human factor is a multicomponent phenomenon that is difficult to investigate. At the same time, the problem of the human factor becomes more complicated due to digitalization conditions. The complication lies in the emergence of a new type of man-machine system – a digital ecosystem, which necessitates a rethinking of the decision-making function. At the

stage before digitalization, the man-machine system functioning depended mainly on human decisions. The digitalization conditions led to the necessity of separation of decision-making between person and machine, significantly increasing the share of artificial intelligence. As a result, on the one hand, the man-machine system functioning became safer, on the other hand, a new model of the relationship between person and technology emerged. As a consequence, it led to the emergence of new types of dangers. For now, approaches to solving the problem of human factors include two groups (Fig. 1).

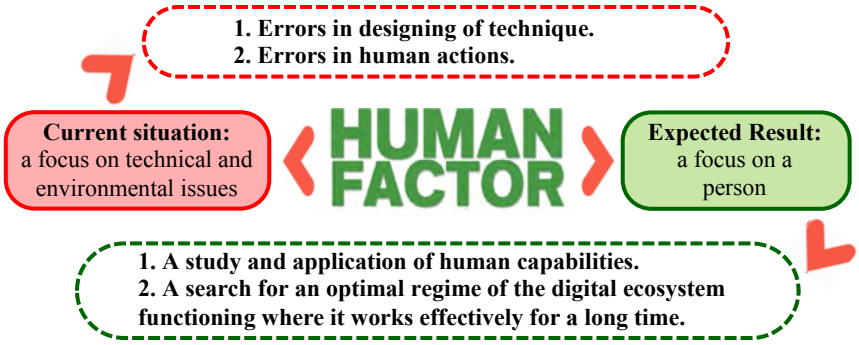

Fig. 1. Approaches to solving the problem of the human factors in the digitalization conditions

In the digitalization conditions in the study of the human factor, a focus of research on the person and his capabilities is prospective *(Teperi et al., 2018)* because an increase in the share of artificial intelligence in decision-making creates only the illusion of raising in the man-machine system safety. Focusing on a person (anthropocentrism) means:

1. Researching human needs and capabilities in the digital ecosystem.
2. Studying the transformation of safety culture in the digitalization conditions.
3. Investigation of the impact of the digital ecosystem environment on the person.
4. Studying the human factor in the digitalization conditions.

The presented research directions are interrelated and together determine the safety of the digital ecosystem (Fig. 2).

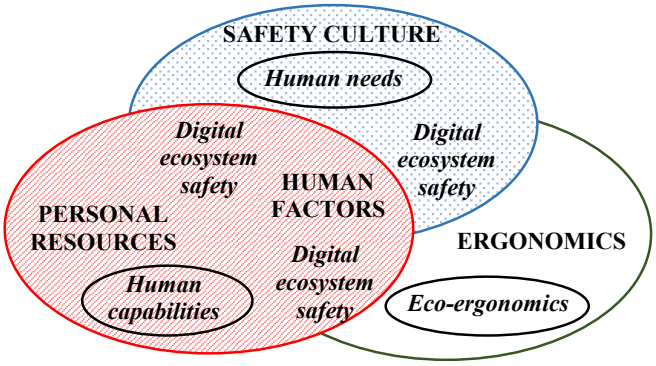

Fig. 2. An anthropocentric approach to the problem of human factors

2. Transformations of human needs and safety culture

Human needs in the digitalization conditions. The starting point of research is the study of the person needs since they determine most of his decisions. The increasing role of digital technologies leads to a gradual change in a person socio-economic, psychological and cultural needs. As a consequence, it affects a person perception of the concept of "safety". Thus, it is not enough for a person just the working conditions corresponding to the current standards. The person has a new need – digital security. Researchers in various scientific fields emphasize the necessity to study this need *(Johnsen et al, 2018; Minchev, 2017; Raziq et al, 2015)*. For example, in research *(Minchev, 2017)*, the author investigated the issue of the person needs and their influence on his life. Among the needs, social ones are presented separately. They reflect the needs of a person for spatial comfort and safety of the working environment. The author showed the influence of the satisfaction degree of these needs on human health. Also, the researcher expressed the opinion about the need for safety culture formation in digital ecosystems.

At the same time, researchers in the field of ergonomics/human factors point to changes in the employees' requests. It manifests in the employees' desire to understand whether the confidentiality of their data while working in the organization is preserved, which way usage of digital technology at a workplace affects mental health, etc.

It should be noted, today a change in the needs of society itself is happening, which is associated with the need to ensure its sustainable development. The key to the successful development of modern society is a capability to ensure the highest level of human needs realization for safety, including in the digital environment.

Safety culture in the digitalization conditions. Requests and needs influence the formation of a safety culture in society. At the same time, the trend for increasing safety culture has different manifestations. For example, in West European countries, the USA, Canada, this process is conducting faster than in the countries of the post-Soviet area. Such a situation is connected with the insufficient level of public awareness of safety issues. This problem is a consequence of a lack of access to relevant information, state and social projects designed to attract attention to safety issues, etc. In recent years, the rise in safety culture in the countries of the post-Soviet area is happening. However, it goes slowly and covers only a part of the population, who mainly lives in large cities, where there is access to information and the possibility of its

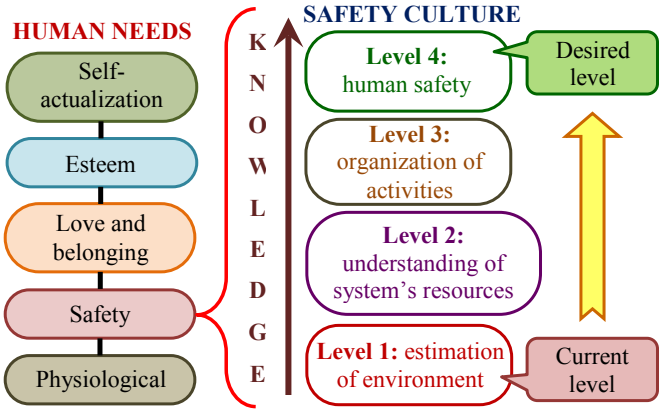

Fig. 3. Human needs and safety culture

propagation. It is also necessary to name another factor that hinders the growth of a safety culture in society – it is the people's psychological unpreparedness. The main reason for this is the quality of education. Culture is an acquired person's characteristic, not innate, and it is formed throughout life. The same concerns the safety culture, which should be formed by teaching the relevant disciplines in educational institutions. In this case, society can reach a level where safety culture is an integral part of life (Fig. 3).

It should be noted that safety culture is an integral part of the human factor because the development level of safety culture is an indicator of a person's understanding of the importance of ensuring safety during interacting with technical devices. Consequently, the effectiveness of human factor management depends on the level of safety culture.

3. A resource-based approach to the research of the digital ecosystem

The problem of the human factor in digital ecosystems is determined by many phenomena and processes *(De Vasconcelos et al.,2018; Dempsey et al., 2006; Hancock et al. 2011; Myhal et al., 2020)*. They can be divided into two groups: internal (associated with physiological, psychological, spiritual, intellectual, social and cultural aspects of human life) and external (environmental factors). Internal factors are the most difficult to study because of the complexity of their identification and assessment. Since each person is an individual and his behaviour in different circumstances is difficult to predict. However, if we analyse the problem by applying a resource-based approach, we can identify ways to solve the human factor problem in the digital ecosystem *(Bodrov, 2006; Vodopyanova, 2009; Holmgreen et al., 2017; Hobfoll et al., 1993; Hobfoll et al., 2011; Hobfoll et al., 2015; Protasenko et al., 2020)*.

Today, there are different views on the problem of resources. However, the most widespread approach is Hobfall's conservation of resources theory. Its basic principle is obtainment and investing a person's resources to maintain a subjective sense of safety and well-being *(Holmgreen et al., 2017; Hobfoll et al., 1993; Hobfoll et al., 2011; Hobfoll et al., 2015)*. In other words, human safety depends on the efficiency of the "cycle" of resources, i.e. the person's ability to receive and spend resources constantly. In most cases, a person receives and invests the resources guided on intuitive feeling, rather than practical knowledge. It can lead to positive results (multiplication of existing and obtainment of new resources) and negative ones (loss of resources without the possibility of rapid recovery). Low efficiency of the "cycle" of resources is often the cause of erroneous human actions. As a consequence, dangerous situations happen. To avoid such situations, a person needs to train in resource

Fig. 4. Resource management skill and digital ecosystem safety

management. The goal of resource management is the most effective usage of human capabilities during activities. Human activity in the digital ecosystem causes a significant transformation of the requirements for himself. It leads to an increase in the likelihood of dangerous situations emergence. Therefore, training a person in resource management skills is a prerequisite for ensuring digital ecosystem safety (Fig. 4).

To choose the optimal system of a person's learning in resource management skill, first of all, it needs to explore the features of man-machine interaction in the digital ecosystem.

3.1. Features of man-machine interaction in the digital ecosystem

To study the features of man-machine systems functioning it is used ergonomics. It has a significant number of methods for this purpose. However, the functioning of the digital ecosystem is studied insufficiently. Currently, ergonomics has no methods for studying and estimating such systems. Also, it found out that the impact of the human factor on a person's safety in the digital ecosystem does not decrease. Moreover, the human factor acquires a new meaning in the digitalization conditions *(Protasenko et al, 2018; Myhal et al., 2019; Myhal et al., 2021)*. This fact conditions the necessity of methods for the research and estimation of the digital ecosystems functioning.

The digital ecosystem is an adaptive, open socio-technical system with the properties of self-organization, scalability and resilience, which is like natural ecosystems. Among the properties of the digital ecosystem, our attention attracted viability. Assessing the viability of a self-organizing system allows us:

1. To analyse the interaction of the system with the external environment.
2. To investigate the internal structure of the system and the hidden connections that affect the reliability of the digital ecosystem operation;
3. To estimate the system properties such as efficiency, usefulness, self-organization, controllability, reliability, etc.

In addition, viability can explain the existence of the "human factor" and the appearance of failures in digital ecosystems *(Johnson, 2006; Kalantari, 2020; Protasenko et al., 2021)*.

The functioning and properties of various system components determine the "viability" of a self-organizing system. Therefore, viability is an emergent property. Accordingly, the issue raises about methods for researching, analysing and estimating the viability. Literary research on this issue showed that in the study of the viability of the self-organizing system, the emphasis is on determining the person's viability *(Mahnach, 2017; Laktionova, 2017)*. However, this is only one element, not the system as a whole. And here, it is necessary to mention the emergent principle, which is a determine special properties (in this case, viability) of the study object, learning their sources (external and internal), understanding their genesis *(Korosov, 2012)*. Thus, it is important to find such properties of each component of the system that affect its viability formation.

A person is a component of a self-organizing system. He has many properties and characteristics that affect the formation of system viability. However, hardiness deserves special attention because it is an integral characteristic of a person, which allows him to resist situations, overcome life difficulties, transforming them into situations of development *(Protasenko et al., 2020; Maddi et al., 1994; Nayyeria et al., 2011)*. Viability is a crucial personality trait that mediates the influence of stressors, allows coping with distress effectively and is always in the direction of personal growth. It follows that human viability depends on resources and the capability to manage them.

The role of a machine in the self-organizing system functioning is to raise the efficiency of a person's activity; therefore, it should be comfortable and safe to operate, which is realized in its ergonomic characteristics. There are a lot of studies investigating the impact of machine ergonomic characteristics on the man-machine system functioning. The research aims to figure out machine characteristics that need to be changed to reduce the possible negative consequences of their impact on the system functioning. According to the available research results *(Raziq et al., 2015; Garbie, 2014)*, we marked out the following pattern: the raise in the self-organizing system viability occurs when the machine ergonomic properties correspond to the person's innate physiological and psychological characteristics.

The working environment is one more component of a self-organizing system. Usually, it is investigated according to the established list of indicators: air temperature, relative humidity, illumination of the work surface, noise and vibration levels, etc. However, in recent years, the issue of greening the working environment has become widespread. As a result, new indicators for estimating the safety of the working environment have arisen, which determine the ecological impact of the working conditions on the employee *(Protasenko et al., 2018; Protasenko, 2018)*. For now, the eco-friendliness of the working environment is an integral characteristic of the working environment because for completeness of information it must estimate both traditional characteristics (temperature, humidity, etc.) and new ones (eco-friendliness of the working environment). Thus, we can talk about the eco-friendliness of the working environment as a characteristic that affects the formation of viability of self-organizing system *(Protasenko et al., 2020)*.

In addition to these points, research of digital ecosystems has to consider the impact of Industry 4.0. In this case, it is not just man-machine interaction, but, as mentioned above, it is a man-machine union. At the same time, in digitalization conditions, a person no longer has a priority role in decision-making. Hence, the problem of a person's perception of controlling decisions from the side of artificial intelligence arise. According to forecasts, in a few years, it can lead to problems in the interaction of a person with the machine because of the too-close intertwining of human and machine, blurred boundaries between human and machine decisions, which will complicate understanding: where human error, and where organizational or technical miscalculation.

Summing up, viability is an emergent property of the digital ecosystem that is determined by hardiness, the working environment ergonomics and eco-friendliness and the degree of manifestation of the human factors (Fig. 5).

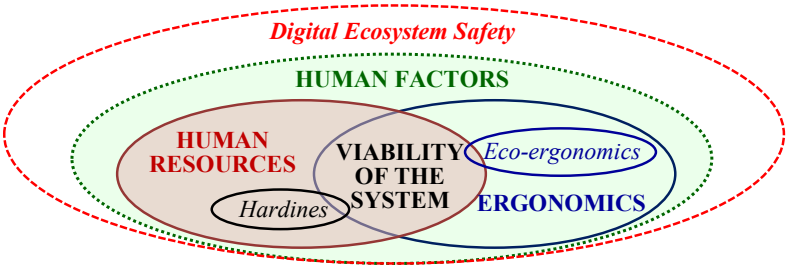

Fig. 5. The digital ecosystem viability as a tool to ensure its safety

Thus, the digital ecosystem is a special type of man-machine interaction, in which the system viability ensures its safety.

PERSONAL RESOURCES			
New knowledge, skills, capabilities		Application of knowledge, skills, abilities in practical activity	
Health, well-being		Achieving certain goals	
Lifestyle (sports, habits, etc.)		Health, well-being	
High level of working capacity		Achieving certain goals	
Self-motivation		Application of knowledge, skills, abilities in practical activity	
Understanding life meaning		Achieving important goals	
Hardiness		Development of skills to control the current situation	
Sum:		**Sum:**	

SOCIAL RESOURCES			
Financial income		Creating a "financial cushion"	
Social support at work		Forming a sense of confidence in the future	
Social guarantees (medical care, paid leave, etc.)		Health, well-being	
Social status		Obtaining new knowledge, skills, abilities	
Sum:		**Sum:**	

OBJECTS RESOURCES			
The psychological climate at home		Health, well-being	
Residence place		Stability of the current situation	
Availability of necessary household items		Stability of the current situation	
Rational and complete nutrition		Health, well-being	
Rest (enough sleep, regular weekends)		Health, well-being	
Savings		Safety, health, well-being	
The level of social safety		Health, well-being	
Sum:		**Sum:**	

Fig. 6. A resource map

ENERGY RESOURCES			
Time		Personal development, health, well-being	
Money		Personal development	
Current opportunities (self-education, social elevator, etc.)		Professional development	
External circumstances (change of residence, etc.)		Hardiness	
Sum:		**Sum:**	

Fig. 6. A resource map (continuance)

3.2. Hardiness is a component of the digital ecosystem safety

According to S. Muddy, hardiness is a person's integral characteristic, which allows him to cope with situations, overcome difficulties transforming them into opportunities for development. In other words, hardiness provides a person with reliable and safe functioning in different conditions. And, as mentioned above, the digital ecosystem viability is related to hardiness, so it is necessary to pay attention to its study.

Attempts to estimate the hardiness using classical methods (Muddy's survey and its adapted versions) do not allow obtaining an adequate result. This fact takes place because the statements in the hardiness surveys do not consider a person's emotional state (emotional uplift or depression), which may influence accurate results. Therefore, it is necessary to find alternative methods of hardiness studying. As an option, in this case, we use the study of the forming process of a person's management resources skill. This is conditioned by two facts:

1. Resource management is the optimal distribution and usage of individual capabilities and opportunities in different conditions of activity to ensure hardiness.

2. Tracking and control of the resource management process make it possible to obtain the dynamics of changes in the hardiness level because, unlike other psychological characteristics, hardiness is not an innate but an acquired characteristic, i.e. can change significantly over a lifetime.

Researching the process of forming resource management skill is a difficult task. In this case, visualizing information about resources and their investment make the process easier. For this purpose, we created a "Resource Map" (Fig. 6).

According to Hobfall's conservation of resources theory, the resource map contains four blocks of resources – personal, social, objects and energy. Statements in the blocks have two parts. The first part is a resource that a person obtains. The second one is a resource that a person invests. The person under the test needs to read each statement, estimate the availability of resource and the possibility of its investment. According to the obtained value, the person determines the balance or imbalance of resources at the moment. In addition, the survey helps to determine which resources are "problematic", i.e. what resources a person actively invest but does not restore them or, conversely, which resources he receives but does not use. Such a procedure a person can perform independently every 2-3 months. The analysis of this information allows a person to choose corrective actions concerning the achievement of resources balance and raise a hardiness level.

The verification of the proposed "Resource Map" was carried out while performing the project on the implementation of the occupational health and safety management system at

the enterprise on the provision of energy source to the population *(Protasenko et al., 2021)*. The object of the study was the heads of the enterprise departments.

A preliminary study of the hardiness level of enterprise management (according to the "Resources Map") showed an average level of hardiness. It was proposed to apply the principles of training in resource management skill. For this, we focused on a study of stress resistance. It allowed us to estimate the possibility of reducing the negative effects of stress and find ways to raise the hardiness.

The study included three stages. At the first stage, we preliminary investigated the subject's level of stress and hardiness. For this purpose, methods of psychological testing were used: personality surveys, methods of sociometric research, and assessment of neuropsychological stability. Based on these data, we did a general psychological profile of each subject. In the second stage, we carried out individual work with each probationer. In particular, we informed the probationer about the level of stress, identified and understood its causes. At the third stage, we applied a training course to develop the probationer's skill of resources assessment and management. The purpose was to stimulate and motivate the employee to work by himself in order to maintain and improve hardiness and occupational health.

The results of repeated research showed a significant decrease in probationers' anxiety, tensity and stress, an increase in their functional reserve. Repeated testing probationers on the "Resource Map" showed a rise in their hardiness levels. Thus, the main result of the work was the development of resource management principles, which allowed forming in probationers a safe model of behaviour. Such a type of behaviour is a basis for improving safety culture and, consequently, reducing the risk of danger emergence.

The study of the process of forming resource management skill makes it possible to estimate the hardiness level, which is a component of human factor management. Thus, hardness is a tool for ensuring digital ecosystem safety (Fig. 7).

Fig. 7. Hardiness as a tool for ensuring digital ecosystem safety

3.3. Eco-ergonomic study of the digital ecosystem

The working environment is a complex system, where different physical, chemical, biological and psychophysiological factors constantly influence humans. It often has negative consequences for human health. As a result, it stimulates the rapid development of an eco-approach to the working environment study. For now, the working environment parameters of the digital ecosystem significantly affect humans and society. It determines the relevance of a person's eco-thinking formation and rising of his eco-culture level.

The eco-ergonomic method of studying the digital ecosystem allows us to find the optimal combination of working conditions and technical support at the workplace, which meets modern psychophysiological, social, engineering and environmental requirements. Moreover, the application of principles of eco-ergonomic method in the digital ecosystem research makes it possible to implement the triune necessary for the maintenance and preservation of human health – eco-friendliness, comfort and safety.

It should be noted that until recently, the issue of safe work was the application of technical, sanitary and social measures at the workplace. Today, workplace safety is a set of economic, social, technical and environmental solutions aimed at preserving human health, the environment and the progress of the sustainable development concept *(Raziq et al., 2015; Protasenko et al., 2020)*. It conditioned the study, analysis and estimation of the digital ecosystem safety through the prism of environmental safety (Fig. 8).

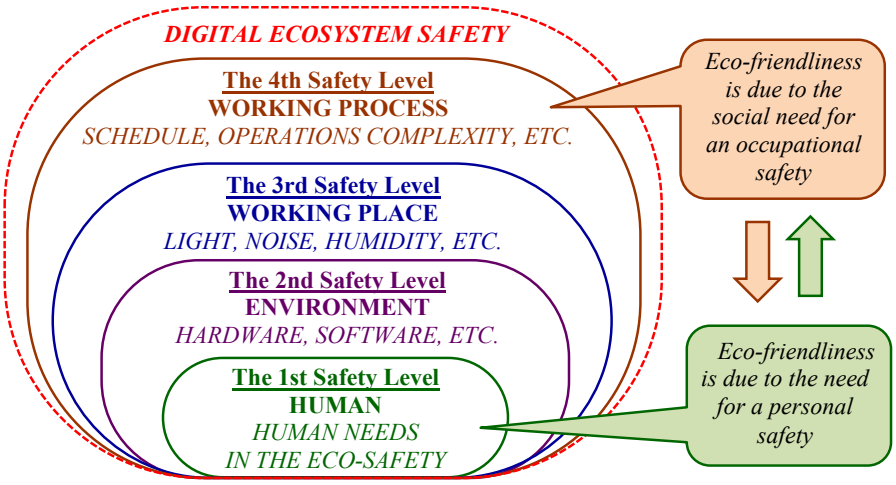

Fig. 8. Eco-safety of the digital ecosystem

Thus, eco-friendliness in the digital ecosystem is realized, on the one hand, through a person's awareness of the need for his eco-safety that is a necessary condition for human safety. On the other hand, at the society level, eco-friendliness is implemented through the eco-quality control of equipment, materials and other elements of the working process. Therefore, we can conclude that with such a two-way approach to the issue of eco-friendliness, it is possible to raise the human safety level in the digital environment. In addition, a high level of eco-friendliness contributes to raise the safety culture of society.

The eco-ergonomic method was tested at several companies. The following jobs were studied: printing designer, programmer, web designer and system administrator. These jobs were chosen because they are examples of digital ecosystems. Research showed the following results:

1. The eco-ergonomics indicators of workplaces were an optimal or acceptable level, which indicated the awareness of workers on safety and a conscious approach to ecological and occupational safety at the workplace.

2. According to the results of assessing the degree of implementation of eco-ergonomic needs of employees in the workplace, 98% of probationers determined that they have comfortable working conditions.

3. The probationers identified that periodic eco-ergonomic estimation of the workplace is a necessary element to ensure an adequate level of safety.

The study confirmed the importance of carrying out an eco-ergonomic study of the working environment of the digital ecosystem to improve its safety.

4. Conclusions

One of the issues in man-machine interaction is the methods of researching the human factor. In most cases, researchers consider technical and environmental problems of the system's functioning. Within the framework of this research, attention is on the factors of human activity in the digital ecosystem. The research had two directions.

The first is the study of human needs in the digital ecosystem. We figured out that the change in the activity conditions led to the formation new request – the person's need for digital safety, which determined the emergence of a new phenomenon – the safety culture in the digital environment. The article substantiates that safety culture is a component of the human factor, therefore, the level of its development affects the effectiveness of human factor management.

The second direction was the study of a person's resources. We figured out that an important point is a person's resources and the possibility of their usage and recovery. The factor of ensuring the man-machine system safety is the "cycle" of resources. The human factor depends on the person's resources balance. It was shown that it is possible to use the study of the process of hardiness formation for resource estimates. Hardiness is not innate, but an acquired person's characteristic, which is formed under the influence of external factors and with the usage of a person's resources. To estimate the process of hardiness formation a "Resource Map" is proposed.

One of the factors affecting the efficiency of man-machine interaction is the working environment. We proposed to use an eco-ergonomic method to study the working environment. The method essence is to study the parameters of the working environment and search for the optimal combination of working conditions and technical procuring, which correspond to modern psychophysiological, social, engineering and environmental requirements. Practical testing of the proposed methods for hardiness estimating and eco-ergonomics of the working environment confirmed the reliability of the obtained results.

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