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HUMAN RESOURCES ARE A FACTOR IN APPLYING OF MAN-MACHINE SYSTEMS SAFETY

Human resources are the important issue in the applying of man-machine systems safety. It is shown that the quality and quantity of human resources depend on how effective "resources cycle" occurs. It led to the development of three types of human resources inflow-outflow models, which can determine the effectiveness of "resources cycle". It is established that the formation at the employee three types of skills (the resources estimation skill, the resources balance determination skill, the resources management skill) allows increasing efficiency of "resources cycle". The primary measure to provide the formation of these skills is training. It was proposed "Resource Balance Card" to help the employee to determine the resources inflow-outflow balance independently.

Keywords: *safety, reliability, human factor, human resources.*

Introduction

The statistics of accidents and catastrophes of complex man-machine systems testifies to the ineffectiveness of existing methods for ensuring reliable human activity. The problems add up to two issues: providing the corresponding of the human functional state to specific activity conditions and qualified employee training. The problems of the human functional state providing are next:

1. Difficulty in identifying the transient human functional states.

2. Lack of methods and means for estimating the role of individuality in the functional state formation.

3. The complexity of predicting of the worker's functional failures.

4. The complexity of express-identification of human functional states in critical conditions of activity.

The basic approach to solving the problem of providing a reliable activity of human is ergonomic. The task of ergonomic is to study the interaction between human and the elements of a technical system to optimise the worker's activity and the overall system performance. Herewith, traditional ergonomic assessments focus only on the estimating of the final activity results and ignore the contribution of human resources (personal, social, etc.) to the achievement of these results. Besides, approaches and methods are used for the functional state diagnosing and providing worker's reliable performance at the workplace, make the process of estimating the human functional capabilities laborious and hardly applicable to the real activity conditions.

The problems of skilled employee training are next:

1. An extended period from the moment of new knowledge emergence to their widespread implementation in the practical worker activity.

2. Lack of a sufficient number of training centres for the continuous professional development of specialists.

3. The narrow focus of the work of training centres, i.e. they focus only on a specific type of knowledge (for example, new programming languages for IT professionals, innovations in OSH legislation for OSH professionals, etc.).

The Problem Formulation

Summarizing the above, it can be concluded that the main problem of ensuring the reliability of man-machine systems functioning is associated with a human, or more exactly with a human factor. However, the recognition of the problem has not led to the appearance of effective solving ways yet. There are several reasons that define the complexity of the problem. Firstly, there is no clear definition of this concept, which creates ambiguity in its perception. As a result, events that occur during the working process experts evaluate differently: sometimes their importance is underestimated, and sometimes – vice versa. Secondly, there is no established checklist of the primary factors that affect decision-making and specific actions by the employee. For instance, this checklist can include such factors as experience, skills, the employee personal qualities, effects of the environment, etc. **According to this, it can be formulated a scientific problem including two parts:**

1. The detection of the basic factors that most influence the decisions and actions of an employee that, in turn, can lead to the emergence of the human factor.

2. Reducing the effect of the human factor on the reliability of human-machine systems through the application of new approaches to employee training.

Literature Review

A lot of phenomena and processes determine the problem of the human factor [1–4]. However, they can be divided into two groups: **internal** (related to physiological, psychological, spiritual, intellectual and social aspects of human life) and **external** (factors of the environment). Among these groups, the highest complexity is internal factors, because of the difficulty of their detection and estimation, as each human is an individuality whose manifestations in different circumstances are complicated to predict. However, if we look at this problem from the standpoint of combining and generalizing some aspects of the human personality into a single conglomerate, in that case, it will be possible to identify new ways to overcome the human factor problem. The application of the concept of "the human's resources" can facilitate the creation of such conglomerate [5–12].

There are different views on this concept definition. From the standpoint of the psychological approach, resources are the physical and spiritual capabilities of a person, the mobilization of which provide the implementation of programs and behavioural strategies to prevent or alleviate stress [5]. According to this, resources can be two types: personal resources, which include human psychological, physical and professional abilities, qualities and skills, and environmental ones, which include the ability to receive support from the social environment and social security. This approach provides integrity in the estimating of human resources. However, it has a significant disadvantage, which is inattention to how human receives and spends resources. This fact is important because human is a complex system whose life depends on a constant inflow and outflow of information and energy. It is necessary a certain ratio between the resources obtaining and expense to the preservation and maintaining human safety of the vital activity. In other words, it is essential the maintaining of the energy and information balance. The lack of such a balance can lead to a decrease in the employee's results quality of the activity. For instance, an employee received professionally needed information (passed refresher training) that he can use during the working process. There is the situation of resources inflow because he has new knowledge. However, the employee does not use information in his working activity. There is the situation of a lack of necessary the resources outflow because knowledge is not applied. As a result, a decline in employee performance results happens.

In addition, there is another widely used definition of resources concept within the psychological approach. According to it, resources are internal and external variables that contribute to psychological resilience in stressful situations; these are emotional, motivational-volitional, cognitive and behavioural constructs that human actualises to adapt to the stressful work and life situations [6]. In this case, a stressful situation means any events that cause a tense human state. This definition emphasises the human psychological qualities and properties, ignoring the physical and psychophysiological components. Besides, the definition does not consider the information-energy balance of human resources inflow-outflow.

From labour safety standpoint, employee resources (or potential) are the degree of development professionally essential qualities and traits personality, which provides the successful performance of work tasks by the employee and the practical solution of production problems. This definition is narrowly focused and takes into account only the professional side of the employee's development. Meanwhile, personal characteristics stay without consideration. It is a minus of such approach because personal characteristics can significantly affect not only the effectiveness of employee's activities but also the level of safety at the workplace in a whole. The rationale for this fact is that often-dangerous situations at the workplace arise not because of the employee insufficient skills and experience, but due to his problems (for example, family problems, health problems, professional burnout, etc.). Therefore, we also cannot use the above definition as a base one. In Hobfall's conservation of resources theory, resources are everything that is important to a person and helps him to adapt to difficult life situations [7–10]. This definition is somewhat vague, but has a significant advantage over the previous ones – it covers various aspects of human life, which determines the possibility of obtaining different types of resources and their use. To explain this statement, consider the classification of human resources in the framework of this theory (fig. 1).

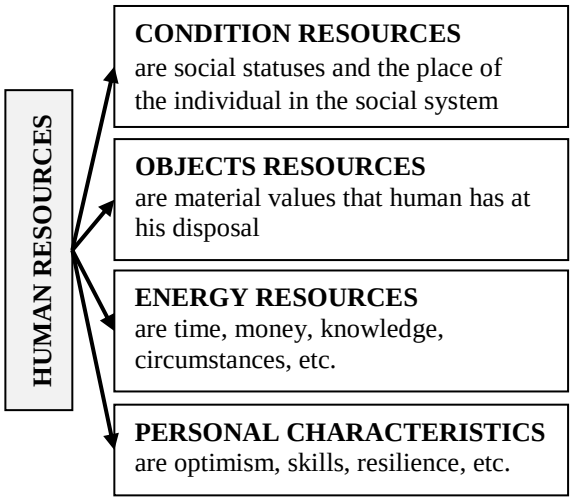

Fig. 1. Human resources classification according to Hobfall's conservation of resources theory

According to Hobfall's point of view, resources mean any information (or energy) that human can receive in the life process, and in some way dispose of them; thus, there is the resources inflow and outflow. However, this theory has a drawback – it focuses on the receipt and subsequent conservation of resources because for human, according to Hobfall, more stressful is the threat of resource loss than the loss itself. However, we emanate that human is an information-energy system that needs a balance for safe and efficient operation. In that case, we should pay attention to the development of skills to manage his resources. Understanding by the human of what resources he has, how he can use them in a particular situation, how he can invest them wisely to gain benefits in the future, etc., will make the human activity safer and more efficient.

The purpose and objectives of the article

Thus, the work aims to study the problem of human resources and methods of managing them to provide the reliability of human activity, reduce the likelihood of the human factors and, consequently, increase the safety of man-machine systems.

Discussion of Results

One of the main principles of Hobfall's theory is the human's need to invest his resources to maintain a subjective sense of safety and well-being. Besides, investing creates conditions for the inflow of new resources [7–10]. Thus, there is a so-called "resources cycle". The "resources cycle" efficiency defines the human safety level. However, in most cases, human invests his resources based on intuitive feelings, rather than practical knowledge. It can lead to both positive results (the multiplication of existing resources and obtain the new ones) and negative (loss of resources without the possibility of their rapid recovery). The negative consequences of investing resources cause complex human stressful states which lead to his erroneous actions and, as a result, to the emergence of dangerous situations. The analysis showed that the negative consequences of investing resources occur in three cases:

1. Ignorance (or misunderstanding) of own resources. In this case, there is an erroneous estimate of resources, which is often a prerequisite for irrational resources investment.

2. Narrowly focused investment. Human invests his forces in the development of only one or several types of resources. In this situation, there is a resource imbalance, which creates dangerous conditions for human, because the requirement for maintenance of safety life is the development of all four types of resources.

3. An incorrect estimate of expected investments and future results. In this case, there are two variants: human invests more resources than receives, or human invests little and gets a lot. In both cases, there is the resource imbalance, which creates the conditions for arising of dangerous situations.

According to this, in our opinion, the most fundamental and essential thing is to teach worker to three skills:

1. The resources estimation skill. Human understands which resources from each of the four groups mentioned above he has.

2. The resources balance determination skill. Human identifies which resources need outflow and which – inflow.

3. The resources management skill. Human makes a perspective planning of the "resource cycle" that takes into account the inflow and outflow of all four groups of resources.

The formation of these skills will increase the level of human's safety both in everyday life and at work. Let's consider how each of the skills can be formed.

The resources estimation skill. A human can develop this skill through the advanced professional training courses, which will involve specialists in practical, personal and organisational psychology, sociology, economics and planning, ergonomics, etc. It is a complex task undoubtedly, and it requires two conditions for implementation:

1. Involve a significant number of specialists, as each resource type is a specific area of knowledge.

2. The staged realisation of training because it takes a lot of time to workers can master a significant set of diverse knowledge.

However, this will allow human to avoid the emergence of a subjective imbalance between who he is real and who he imagines himself; as a result, it permits to increase personal security. It should be noted that the imbalance of the concepts "I am imaginary – I am real" is one of the most spread causes of dangerous situations arising. In this case, human overestimates (or underestimates) own capabilities; consequently, it can lead to making and implementing wrong decisions (or inaction).

The next step in the issue of rational resource management is the formation of the resources balance determination skill. For this, first of all, it is necessary to determine how the process of resources inflow and outflow happens. In our opinion, this process can realise by one of the three models of "resource cycle" (fig. 2).

According to **model 1**, resources recover entirely, but the human implements them partly. It is the case when narrowly focused requirements for the profession stipulate the use of only specific resources types; as a result, other resources remain without developing. In this case, human activity is monotonous, which can potentially cause professional burnout [8]. Besides, worker awareness of the fact of specific resources possession and his inability to implement them can cause intrapersonal conflict. As a result, it can lead to the devel-

opment of long-term latent human stress state. The final result of such a model is the resources imbalance and the decline of the "resource cycle" efficiency. It reduces the level of human safety in a whole.

Model 2 of the resources inflow-outflow causes a usage by the human of all resources types, but their recovery is partial. In this case, there is a dangerous situation of psychophysiological exhaustion, which ultimately leads to erroneous worker actions and, further, to accidents and catastrophes. In addition, the implementation of this type of model can cause the development of long-term latent human stress state. Human awareness of the fact the resources investment far exceeds the expected results can create a feeling of internal dissatisfaction. The final result of such a model is the same as in the case of model 1. It is the resources imbalance and the decline of the "resource cycle" efficiency. It reduces the level of human safety in a whole.

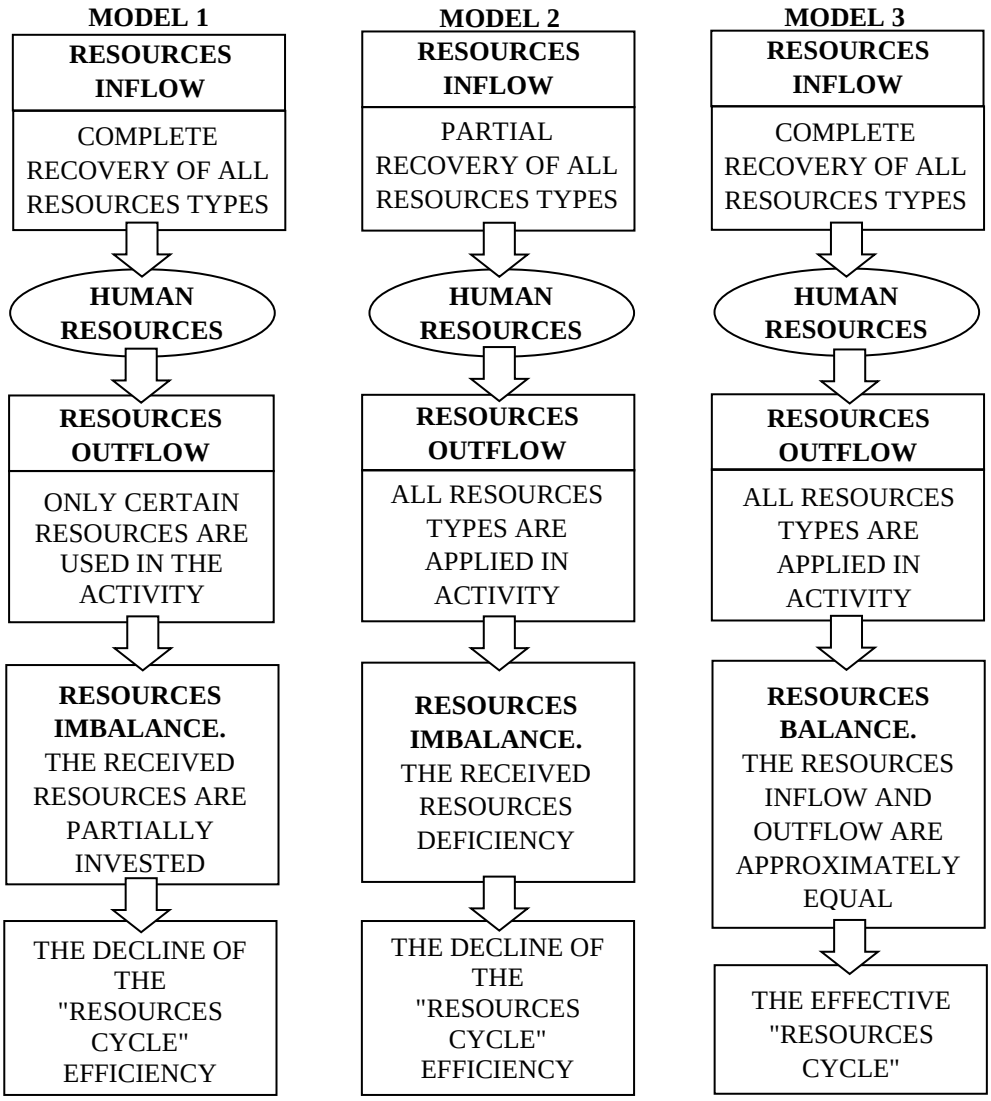

Fig. 2. The human resources inflow-outflow models

The most rational variant for the resources inflow-outflow is **model 3**, according to which the resources inflow-outflow are approximately equal. In this case, we have an effective "resource cycle", which is a prerequisite for safe human activity.

Determining the type of resource inflow-outflow model allows us to understand in which direction it is necessary to apply corrective actions to improve human safety.

The third skill is resources management skill. The main task of resource management is the most effective usage of the worker individual abilities and capabilities following the goals of the enterprise upon the condition of conservation of each human health. It should be noted that currently in enterprise management, the staff requirements transformation occurs; as a result, an increase of dangerous situations likelihood happens. This creates conditions under which the usual personnel management models and methods are unable, and it requires organisations to change the structure to provide the necessary safety level. Therefore, the formation of

resources management skill is an essential condition for creating new approaches to give enterprise safety.

Besides, this skill is a logical continuation of the previous one, as it allows taking the next step in defining the of the resources inflow-outflow model - to determine which resources need to be restored, which to be invested, and which require both processes simultaneously. Indeed, this is a difficult task, but visualizing information about available resources can significantly facilitate this process and help to understand the problem resources and develop practical models for their investment. To visualize the information on available resources, the worker can use the "Resource Balance Card" (table 1).

Table 1.

Resource Balance Card (simplified version)

PERSONAL CHARACTERISTICS				**CONDITION RESOURCES**			
Inflow		**Outflow**		**Inflow**		**Outflow**	
	soft skills		soft skills		social status		social status
	hard skills		hard skills		social support		social support
	optimism		optimism		wages level		wages level
	hardiness		hardiness		social guarantees		social guarantees
Overall inflow:		**Overall outflow:**		**Overall inflow:**		**Overall outflow:**	
ENERGY RESOURCES				**OBJECT RESOURCES**			
Inflow		**Outflow**		**Inflow**		**Outflow**	
	time		time		residence		residence
	money		money		own transport		own transport
	circumstances		circumstances		money savings		money savings
	knowledge		knowledge		safety means		safety means
Overall inflow:		**Overall outflow:**		**Overall inflow:**		**Overall outflow:**	

Note: on the left side in the columns "inflow" and "outflow" you should put any sign if this resource you receive or spend.

After filling of the card, it is necessary to calculate the inflow and outflow resources for each block. It allows determining:

1. The resources inflow-outflow model. It allows understanding which resources are in balance or imbalance state.

2. Types of "problematic" resources. Which resources are intensively spent but not recovered and, conversely, which ones are received but not used.

The analysis of this information will allow choosing the correct actions to establish the human resources balance under the resources inflow-outflow model.

It should be noted that the employee by himself can implement this approach. The worker can do this procedure once every 2–3 months to monitor resources constantly. If it is necessary, the worker can take the corrective action using the skill to assess resources, as mentioned above.

The researching next stage is the verification of the approach to determining the balance between the human resources inflow and outflow and methods of managing them. According to this purpose, we carried out a comprehensive study of the impact of employee training in skills to identify, estimate and manage own resources on his activity results [13–15].

The research is the part of the project on the implementation of the occupational health and safety management system at the enterprise of the fuel energy complex. The research object is the department managers of the enterprise.

The study of the enterprise management functional state showed a relatively high level of stress and anxiety. In this regard, it is proposed to apply the principles of training resource management skills (in particular stress resistance) to explore the possibility of reducing stress. Thus, the researching aim is to determine the impact of specially selected training courses on the quality of employee activity.

During the work, we studied the next indicators that characterise the level of human stress at the beginning and after training:

1. According to the Lusher's test, we examine activity and working efficiency factors.

2. According to the Spielberger's questionnaire, we study the level of personal anxiety.

3. According to the stress level, we examine the individual stress level.

4. According to the integrated health indicator, we study the stress index and the functional reserves level.

We can achieve a drop in the stress level in employees through executing an action sequence, namely:

1. The study of the stress level and its accompanying characteristics (the anxiety level, the tension index) with the help of stress tests. At this stage, we use the personality questionnaires, sociometric research, and estimating of neuropsychological stability. According to

these data, we form a general psychological employee profile.

2. Determination of psychophysiological "activity price". We do an objective estimate of the individual psychophysiological ability to perform an activity. For the purpose, we use the rapid assessment and prognostication systems of individual functional state, performance and stress. In particular, we study the psycho-emotional state, health level, psycho-emotional reserves, the cardiovascular system reserves. The integrated indicators are the integrated health indicator, the stress index and the functional reserves level. At this stage, we reveal early signs of the cardiovascular system predisease and the body weakening in response to overexertion, stress or illness.

3. Informing the employee about the stress level. Identifying and understanding the causes of stress which are related to the working activity.

4. Conducting a training course to develop the skills of identifying, estimating and managing resources to reduce stress. The purpose of this stage is to stimulate and motivate the employee to individual work to maintain and improve occupational health.

The employees' functional state re-examination revealed a significant drop in anxiety, tension and stress, increase in functional reserve.

According to the researching results, it is proposed to implement the following innovations at the enterprise:

1. Introduction into the training system of department managers a cycle of classes on psychophysiological staff features and technologies of own resources management of taking into account individuality of the person.

2. Personnel structuring according to the danger categories level at the workplace or in the process of the activity. Besides, it is proposed to include in the enterprise documents list the employee health passport.

3. Implementation of the proposed measures at the enterprise is essential for minimising the accident and catastrophe risks and, accordingly, reducing the cost of maintaining safety, compensation payment, fines payment in the field of labour protection.

Thus, the main result of the work is the development of human resource management principles and methods of the management system implementing of occupational health and safety through including in the staff training the psychophysiological systems management, which increase professional reliability of personnel (fig. 3).

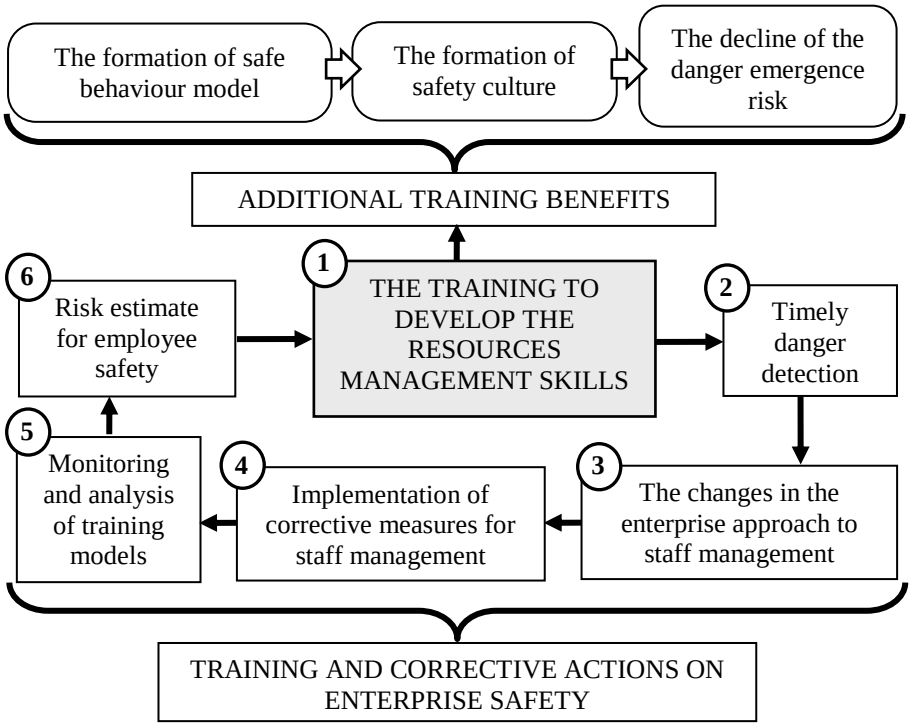

Fig. 3. Algorithm for the development of safety principles at the enterprise

Conclusions

Summarizing the above, we can draw the following conclusions:

1. Despite the constant improvement of production processes and technologies, production automation, etc. the issue of human safety remains relevant; because the central element of the production is still human, therefore, man-machine system safety ultimately depends on human decisions and actions. That is why the human factor is an important issue that needs comprehensive research.

2. Human resources affect significantly on the role of the human factor in the safety issue. Availability of

human resources, their development level and opportunity to carry out inflow-outflow cycle determine the man-machine system safety.

3. The quality and quantity of human resources depend on the effectiveness of "resources cycle". There are three types of human resources inflow-outflow models which determine the effectiveness of "resources cycle".

4. The formation at the employee three types of skills (the resources estimation skill, the resources balance determination skill, the resources management skill) allows increasing efficiency of "resources cycle". The primary measure to provide the formation of these skills is training.

5. A "Resource Balance Card" helps the employee to independently determine the resources inflow-outflow balance.

6. The resources management approach was verified. It was experimentally shown that through including in the procedure of staff training methods of own resources management allows increasing the professional reliability of staff.

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ЛЮДСЬКІ РЕСУРСИ ЯК ЧИННИК У ЗАБЕЗПЕЧЕННІ БЕЗПЕКИ ЛЮДИНО-МАШИННИХ СИСТЕМ

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На сьогодні існує незаперечний факт: не дивлячись на постійне удосконалення виробничих процесів і технологій, автоматизацію виробництва, питання безпеки життєдіяльності людини залишається актуальним. Цей факт обумовлений тим, що центральним елементом виробництва, як і раніше, є людина, а отже від її рішення і дій у кінцевому підсумку залежить безпека. Саме тому людський чинник – важливе питання, яке потребує всебічного дослідження.

Інформаційно-аналітичний пошук показав, що на те, яку роль – позитивну чи негативну – людський чинник зіграє у питаннях безпеки, значною мірою впливають ресурси людини: їхня наявність, розвиненість, можливість забезпечення їхнього припливу та відтоку, уміння раціонально управляти ними тощо. Таким чином, людський чинник безпосередньо пов'язаний з ресурсами людини, що і зробило останні об'єктом дослідження.

Базовою для дослідження й оцінювання людських ресурсів обрано теорію збереження ресурсів Хобфолла. Одним з головних принципів теорії є необхідність інвестування людиною власних ресурсів, оскільки це створює умови для надходження нових ресурсів, що призводить до виникнення так званого "кругообігу" ресурсів, від ефективності перебігу якого залежить рівень безпеки життєдіяльності людини. Проте у більшості випадків людина інвестує свої ресурси, керуючись інтуїтивними відчуттями, а не практичними знаннями, що обумовлює одержання як позитивних результатів, так і негативних. У роботі запропоновано підхід до формування в працівника трьох видів навичок (оцінювати власні ресурси; визначати баланс власних ресурсів; керувати процесом інвестування ресурсів), що дозволяє підвищити ефективність "кругообігу" його ресурсів. Основним заходом із забезпечення формування навичок є навчання.

Новизна виконаної роботи полягає у такому: а) розроблено три типи моделей притоку-відтоку ресурсів людини, за якими можна визначити ефективність їхнього "кругообігу"; б) запропоновано "Карту визначення балансу ресурсів", яка допомагає працівнику самостійно визначити баланс припливу-відтоку ресурсів, тобто встановити, які саме ресурси потребують відновлення, які інвестування, а які реалізації обох процесів одночасно.

Практична значимість роботи полягає у такому: експериментально показано, що шляхом включення до процедури навчання персоналу методики управління власними ресурсами дозволяє підвищити професійну надійність персоналу.

Ключові слова: *безпека, надійність, людський чинник, ресурси людини.*