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IMPROVING THE RELIABILITY OF TRUCKING IN THE CONDITIONS OF A MINING ENTERPRISE

Purpose. Improving the efficiency of trucking (TR) in the conditions of a mining enterprise by means of developing recommendations aimed at enhancing reliability of the transport process.

Methodology. To determine the factors influencing the reliability of TR the “Functional Resonance Analysis Method” (hereinafter – “FRAM”) was used, which is based on the study on the functions of freight automobile transportation process with respect to six different aspects: time, control, output, resource, prerequisites, and entrance.

Findings. The transport process of TR in the conditions of a mining enterprise is represented by five main functions: preparation of TR, supply of the truck for loading, loading of cargo, transportation and unloading of cargo at the destination point. For each function of the transport process TR we determined its variability as based on the accuracy and timeliness of the transport operation; identified factors that affect the reliability of the transport process, namely driver experience, administrative control, time of the transport operation, complexity of the transport operation, workplace ergonomics, workload and stress, the level of management support that may worsen the final result of goods delivery to the point of unloading. It is determined that preparation and transportation of cargo to the destination point is the least reliable function of TR transport process. This is due to the significant changeability and variability, a large number of production tasks and high variable standards of transport work. It is proposed to strengthen the control over the psychophysiological condition of the driver in order to improve the reliability of TR in the conditions of a mining enterprise and to reduce the probability of failures during the performance of transportation work.

Originality. It consists in establishing the relationship between the functions and factors of the transport process of TR in the conditions of a mining enterprise, which allows assessment of the reliability level of the task in a timely manner.

Practical value. It consists in a quantitative assessment of the impact of transportation process factors on the reliability of TR in the conditions of a mining enterprise.

Keywords: *reliability, transportation process, driver, psychophysiological condition, “FRAM” method, safety*

Introduction. The main purpose of road transport at the mining enterprise with a continuous cycle of open pit mining is to transport the extracted raw materials to the receiving point [1]. No less important for the production activity of the technological process of extraction is the delivery of auxiliary materials, equipment, fluids, that is carried out by technological trucks. Unfortunately, for this transport technology, there is almost no information on the development of the logistics chain for the transportation of these materials from the manufacturer to the transport services customer. This, as a rule, leads to worsening of the conditions of the organization process of trucking (TR), which leads to a decrease in the extraction of raw materials and deterioration of productivity of technological vehicles at the mining enterprise. It results in higher prices for the final product. Therefore, one of the main requirements for TR technological transport is to ensure the reliability of transportation [2], which is an objective characteristic and are assessed by the probability of trouble-free operation of trucks (T), that is determined not only by performance indicators of Ts (reliability, durability, maintainability and safety), but also by the functionality of the entire chain of movement of goods in space. That is, reliability, in this context, is seen as an ability to meet commitments over time, which combines a number of risk factors: physical, economic, technological and organizational ones. Issues of reliability assessment in the system “driver-automobile-road-environment” (hereinafter the system “DARE”) have been studied in detail by well-known scientists such as R. V. Rothenberg, W. A. Trikozuk, E. M. Lobanov. Trikozuk, E. M. Lobanov. However, in

their studies there are no random factors that can affect significantly the final outcome of TR. Based on this, there is an urgent problem in finding new methods to assess the TR effectiveness in the mining company, which would provide a rapid response to changes in the external environment, changing behaviour of consumers of transport services, regulatory requirements and demand for transportation.

Literature review. Most research published in recent years on the efficiency and reliability of quarrying, focuses on increasing productivity and reducing the cost of transporting the particular type of cargo, i.e. to economic issues, while the reliability of the TR transport process, is, unfortunately, not considered at the proper level [3]. At the same time, these issues are very carefully worked out for public road transport. Thus, the main reasons for improper implementation of the transport process include the occurrence of road accidents (RA).

According to [4], about 1.3 million people die every year as a result of RA. The damage suffered by most countries as a result of RAs reaches 3 % of their gross domestic product. Another 20 to 50 million people receive non-fatal injuries, which in many cases lead to disability. According to statistics [5] in the European Union in 2020, 18,800 people died in RA. Compared to 2019, there was an unprecedented drop of 17 % in the number of accidents. This means that in 2020, almost 4000 fewer people died on EU roads compared to 2019. The decline in traffic due to the Covid-19 pandemic has had a clear, albeit unbelievable, impact on road deaths. For the conditions of Ukraine, according to [6] in 2020, the total number of accidents was 168,107 in which 3,541 people died and 31,974 were injured. For the period 01.01–31.08.2021, the sad statistics consist of the following data: the total number of RA is 15,613, in which 1,914 people died and 19,309 people were injured.

According to research [7, 8], this situation has developed due to unprofessional selection of drivers; difficult working conditions of the driver when performing TR; unsatisfactory psychophysiological condition and the state of the driver's own health; heavy traffic. At the same time, in the study [9], the destructive factors that significantly impair the reliability of the TR transport process include the state of vehicle fleet, which occupies a leading position in the scheme presented by the authors. In general, the study presents the concept of analysis of the reliability of vehicle fleet under only two conditions: suitable or unsuitable ones, which in some way limits the ability to make management decisions aimed at improving the transport process of TR in a mining company. On the other hand, the study [10] highlights that in order to ensure the reliability of TR, it is important to pay more attention to the collection and timely processing of various data on cargo safety control using GPS navigation (global positioning system). This is a key element for time analysis, planning index, downtime index, and power reserve. However, in order to make managerial decisions aimed at improving the reliability of the TR, it is proposed to use statistical hypotheses of possible scenarios. This requires determining the uncertainty of the measurements to verify the adequacy of the model. At the same time, solutions may be limited in time and require additional input. In another study [11], the following criteria were chosen as the basis for developing a model to assess the reliability of the transport process: travel time and traffic volumes. As a result of the study, the authors obtained a model that can predict the standard deviation of travel time based on the ratio of volume to capacity and travel time. Unfortunately, this does not take into account such important indicators that characterize the impact of available or missing resources and prerequisites. For example, as noted in the analytical review in [12] financial costs and economic benefits being a key in making management decisions in the organization of the transport process are often not included in the analysis of the reliability of TR. In contrast to the above study, in [13] it was proposed to assess the reliability of the transport process analytically, based on the failure tree based on weights depending on its proportion. However, unfortunately the procedure for calculating the weights requires further discussions.

Recently, the "FRAM" method has become very popular in assessing the reliability of complex technical systems. The main advantage of this method over others is the ability to consider various negative impacts on the entire management system of the transport process, taking into account the functional relationship between its individual components [14], which sometimes allow you to get unexpected results. For example, scientists Woltjer and Hollnagel used the "FRAM" method to analyse the causes of the crash of flight 261 of "Alaska Airlines", which allowed them to reflect the dynamic and non-linear nature of the detected system failure. During the re-analysis of the crash of flight "5191 Comair", a number of additional countermeasures were found using the "FRAM" method, which expanded the official report of the National Transportation Safety Board. The "FRAM" method also helps to carry out detailed monitoring of variables that occur in dynamic systems [15]. In addition, the results obtained are always the basis for improving both transport safety and its reliability [16].

Purpose. The purpose of the paper is to increase the efficiency of TR in the conditions of the mining enterprise resulting from the development of recommendations aimed at improving the reliability of the transport process.

Methods. To increase the reliability of TR in the mining company it is important to study in detail the impact of various causal links of the transport process of cargo transportation at each stage. This will identify possible functional resonance effect when the system is unable to operate normally due to changes in its daily productivity described by the several principles:

- *the principle of equivalence of success and failure*: they are similar in nature and caused by similar causes, so it is important not only to pay attention to the causes of failures, inci-

dents or accidents, but also to study carefully the factors that lead to successful daily work [17];

- *the principle of approximate adjustments*: the daily productivity of socio-technical systems must be adapted to current conditions in the workplace, which requires appropriate adjustment of employees' behaviour to the requirements of the system to achieve the desired result;

- *the principle of emergency operations*: it is impossible to explain the features of a complex system simply by describing the performance of its components, because the combination of certain variables always carries some uncertainty of the final result, creating a significant number of variations and thus increasing the undesirable result;

- *the principle of functional resonance*: a new dangerous signal detected is a result of the normal variability of many different signals in a given environment.

The basis of the "FRAM" analysis is to determine the influence of variable functions in complex systems, such as the system "DARE", on the probability of occurrence of certain factors that may reduce the reliability of TR. To identify these factors, six different aspects are introduced (Fig. 1) (time, control, output, resource, prerequisites, and input), which allows calling the systemic interaction of each function aimed at search of potential sources of resonance – danger [17].

Results. To increase the reliability of TR in the conditions of the mining enterprise, it is important to find weak processes (functions) during transportation that can lead to an undesirable result: an incident caused by a change in the psychophysiological state of the driver. To do this, we will study the factors of the TR transport process in the conditions of the mining enterprise with the help of "FRAM" analysis that consists of four main steps.

Step one. We describe the stages of the transport process in accordance with the six aspects of this method. For each component of the TR transport process: supply of the truck for loading; cargo loading; cargo transportation; unloading at the destination we find out what is the input element that starts the function, the prerequisite for its operation and the necessary resources. It is important to understand how to control its implementation at a given time to get the end result i.e. the output function.

The study [18] lists the questions to describe the six aspects of each function used to build the FRAM method model. The answers to the questions are made in the form of a table (Table 1) from the analysis of which we determine the factors that most affect the transportation process.

Step two. Determination of variability of functions. The characteristics of the variability of functions will be determined by their initial results (performance), which can be variable in time and accuracy [19].

The state of productivity of the function can be represented by four categories: the function is performed perfectly and on time; the function is performed satisfactorily and on time; the function is performed satisfactorily, but out of time; and the last one, the function is performed unsatisfactorily and out of time.

E. Hollnagel points out the need to monitor the production process to assess the activities of workers, the uniqueness and nature of production, the presence of hazards. In addition, productivity is affected by the emotional state of employees, their attitudes, knowledge, psychological and physiological state and functionality [17].

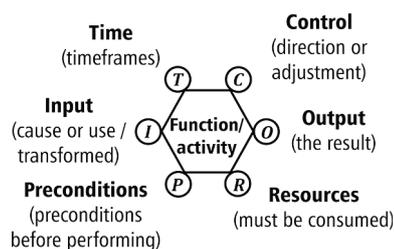


Fig. 1. Functional hexagon of the "FRAM" method [17]

Determining the main functions of the elementary transport process of cargo transportation in the conditions of the mining enterprise

“FRAM” function element	Action contents/Contents of the transport operation
Stage 1. Preparation of trucking	
“I”	<i>What is the function start?</i> Analysis of operational properties of T; analysis of environmental conditions: development of the route of movement; drawing up a traffic schedule; pre-trip technical inspection of T; pre-trip medical examination of the T driver; pre-trip check of transport documentation
“O”	<i>What is the result or results of the function?</i> Readiness of the driver to carry out serviceable vehicle for transportation of the corresponding type of cargo in the corresponding volume in the corresponding climatic conditions of external environment
“C”	<i>What should be monitored for the effective functioning of the function?</i> Control of professional admission of the driver, monitoring the ergonomics of the workplace; monitoring conditions of social satisfaction of professional activity
“P”	<i>What should be present for the normal performance of the function?</i> Efficient T, maintained and repaired, adapted to transport the appropriate type of cargo in the appropriate amount in the appropriate climatic conditions; instructions on the professional admission of the driver to drive T, which carries out the transportation of the relevant type of cargo; job description of the mechanic allowing vehicle fleet on line; job description of the doctor performing the medical pre-trip examination of the driver
“R”	<i>What resources are needed to perform the function?</i> Effective competencies of the manager for the organization of trucking; effective competencies of the mechanic allowing vehicle fleet on line; effective competencies of the doctor performing the medical pre-trip examination of the driver
Stage 2. T delivery for loading/Stage 5. T Unloading	
“I”	<i>What is the function start?</i> Analysis of the location of the loading/unloading point; analysis of the possibility of maneuvering; analysis of the possibility of waiting for the download in the case of queue
“O”	<i>What is the result or results of the function?</i> Timely delivery by driver of T to the loading/unloading point in determined time
“C”	<i>What should be monitored for the effective functioning of the function?</i> Control of the schedule of T delivery for loading/unloading; control of T placement on the loading/unloading platform
“P”	<i>What should be present for the normal performance of the function?</i> The place for loading/unloading the cargo must satisfy the possibility of T maneuvering and the possibility of waiting for loading/unloading in case of queue
“R”	<i>What resources are needed to perform the function?</i> Effective competencies of the T driver; the geometric dimensions of the loading/unloading platform must allow T maneuvering and waiting for loading/unloading in the case of a queue
Stage 3. Loading and fastening of cargo in a T body	
“I”	<i>What is the function start?</i> Analysis of operational properties of the loading and unloading mechanism; analysis of the conditions of placement of cargo in the T body; analysis of the conditions and means of fastening the cargo in the T body; calculation of weight distribution on the corresponding T axes; pre-trip technical inspection of the placement and fastening system for the cargo in the T body
“O”	<i>What is the result or results of the function?</i> Readiness of the driver to carry out the driving of T with the placed and fixed cargo in a body of T, according to requirements of the current legislation of Ukraine regulating requirements to weight and dimensional characteristics of motor vehicles
“C”	<i>What should be monitored for the effective functioning of the function?</i> Control of cargo placement in the T body; control of fastening of cargo in the T body; control of the distribution of weight load on the corresponding T axles
Stage 4. Transportation of cargo in the T body	
“I”	<i>What is the function start?</i> T is in working condition; the cargo is loaded and fastened in the T body; weight norms of load distribution on the corresponding T axles are met; transport supporting documentation is correctly completed and fully available
“O”	<i>What is the result or results of the function?</i> The cargo was delivered on time, due to the T schedule, without damage in full with minimal transport costs, without violating the traffic rules
“C”	<i>What should be monitored for the effective functioning of the function?</i> Control of the psychological and physiological state of the T driver; control of the road situation of T; control of T operational properties; control of cargo placement in the T body; control of adherence to the schedule of T movement
“P”	<i>What should be available for the normal performance of the function?</i> Favourable climatic conditions; efficient transport infrastructure; quality fuel; adherence to the schedule of movement and rest; compliance with traffic regulations
“R”	<i>What resources are needed to perform the function?</i> Professional experience of the driver; stress resistance; good physical and psychophysiological condition of the driver

In most cases, numerical values (points) are used to estimate the variability of functions, taking into account the indices of damping or amplification of the output result (Table 2). The most common is the formula [20]

$$CV_{ij} = V_j^T \cdot V_j^P \cdot a_{ij}^T \cdot a_{ij}^P,$$

where V_j^T is the index that takes into account the variability of the function over time; V_j^P is the index that takes into account

the variability of the function in terms of accuracy; where a_{ij}^T is the damping index of the output by the elements of the function (time, control, prerequisites, resources); a_{ij}^P is the amplification index of output result by elements of the function (time, control, prerequisites, resources).

The initial result of the functions was evaluated according to the established scale on the basis of expert judgment and deep knowledge of the conditions of the TR transportation process in the conditions of the mining enterprise (Table 3).

Table 2

Numerical values of parameters $V_j^T, V_j^P, a_{ij}^T, a_{ij}^P$

Indices V_j^T, V_j^P	Score	Indices of damping or amplification a_{ij}^T, a_{ij}^P	Score
Perfectly and on time	1	Critical	0.4
Satisfactorily and on time	2	Significant	0.3
Satisfactorily and out of time	3	Moderate	0.2
Unsatisfactorily and out of time	4	Insignificant	0.1

The value of the variability of the function can range from 0 to 4, where from 0 to 15 it is characterized as minimal, i.e. the performance of the functions is predictable. The variability index from 1 to 2 characterizes satisfactory performance of functions, and from 2 to 4 it indicates unsatisfactory performance of functions, i.e. there is a significant probability of loss of system reliability and failure to perform the transportation task in time and quality.

Step three. Determination of functional resonance. At this stage, there is a problem in establishing a list of the most influential factors on the reliability of the TR transport process in the conditions of the mining enterprise to perform functions that are determined from the general conditions of productivity. Analysis of the data from Table 1 revealed that the reliability of TR is influenced by three main aspects: organizational (training and education of employees, administrative control over the performance of work); technological (ergonomics of the workplace, duration of work, complexity of professional functions, physical and psychophysiological workload) and psychological, social (support and control of enterprise management, organizational culture) [17, 19–21].

To estimate the variability of functions or their resonance from certain factors through functional relationships we use the formula [17]

$$IFA_m = \frac{\sum_{k=1}^m CP \cdot \sigma_1}{m-1},$$

where IFA is variability of functions; CP is the coefficient of influence of transport process factors on function variability; σ_1 is the coefficient of reinforcement (depending on the experience of the expert: in the case of an experienced expert, we take a value of 1, in other cases we choose indicators from the range of 0.9–0.5), m is the number of factors that affect the reliability of the transport process of cargo transportation.

The coefficient of influence of the factors affecting the reliability of the transport process was determined on a five-point scale from four evaluations made by experts, which were then averaged for further calculations. In this case, five points char-

Table 3

The results of determining the variability of the elements of functions

Element of function	Indices	Preparation of trucking	T delivery for loading	T loading	Transportation of cargo to the destination	Unloading of cargo at the destination
Output	V_j^T	4	2	2	4	2
	V_j^P	3	3	2	4	2
	a_{ij}^T	0.3	0.4	0.4	0.4	0.4
	a_{ij}^P	0.4	0.3	0.4	0.4	0.4
CV		1.44	0.72	0.64	2.56	0.64

acterize the significant dependence of the function on the specified factor, while one point characterizes low one. The list of these factors that affect the reliability of the transport process is not limited to those listed in Table 4 and can be increased in the case of a detailed analysis of the transport activities of the TR in the conditions of the mining enterprise.

Analysis of the results showed that the greatest variability are the functions of the TR transport process: transportation of cargo to the destination and preparation of TR, characterized by differences in expert assessments of the impact of certain factors that determine the reliability of the transport process and their non-compliance with international regulations of current legislation for TR in the conditions of a mining enterprise.

Note that the “FRAM” model allows you to combine functions through six different aspects. That is, the end result will depend on the performance of the entire TR transport system, so it is important to determine the function that has the least predictable output due to high changes and variability. At the same time, the presented study is focused on the identification of critical factors that may lead to untimely performance of the transport task due to the occurrence of, for example, an accident or incident involving changes in the state of the “DARE” system and, consequently, the system “DARE” will lose reliability. The results of calculations for determining the probability of the transport process as a product between changeability and variability of functions are given in Table 5, and a graphical representation of the “FRAM” analysis of cargo transportation are shown in Fig. 2.

As a result of the assessment, we can see that the least predictable are the functions of preparation and transportation of cargo to the destination. This is most likely due to the large number of

Table 4

The results of determining quantitative estimates of the variability of the functions of the TR transport process

No.	Function	Professional experience of T driving r	Administrative control	Ergonomics of the workplace	Duration of work	Complexity of technological process	Workload, stress	Level of support of enterprise management	Variability (IFA)
1	Preparation	4	3	4	3	5	4	4	0.31
2	T delivery for loading	1	3	2	2	2	1	1	0.15
3	T loading	2	3	1	2	2	2	2	0.16
4	Transportation of cargo	3	5	4	5	3	4	3	0.33
5	T Unloading	2	3	1	2	2	2	2	0.16

Table 5

The results of the calculation of the probability of performing the function of the TR transport process

No.	Function	Changeability of CV	Variability (IFA)	Probability of performance	Rank
1	Preparation	1.44	0.31	0.46	2
2	T delivery for loading	0.72	0.15	0.11	3
3	T loading	0.64	0.16	0.10	4
4	Transportation of cargo	3.2	0.33	1.06	1
5	T Unloading	0.64	0.16	0.10	4

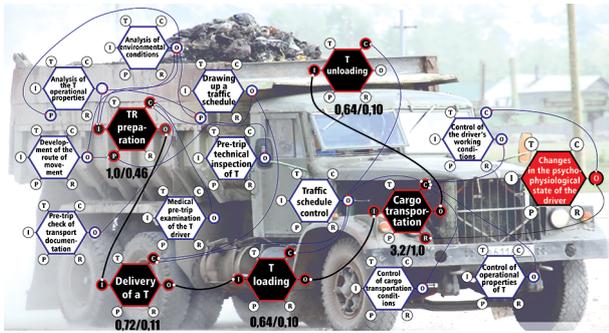


Fig. 2. The elementary transportation process of cargo transportation in the conditions of the mining enterprise from the point of departure to the point of unloading is modelled by means of the “FRAM” analysis, the designations: in the numerator is value of variability of function, in denominator is value of probability of performance)

production tasks to prepare for transportation and high regulatory requirements for the transportation of goods, which unfortunately in most cases are not supported by the appropriate level of control and support from the management of the mining company.

Step four. Change management. The numerical values of the “IFA” indicator, which represent the influence of factors affecting the reliability of the transportation process, on the input data of the relevant functions of the transportation process require appropriate changes in the organization of TR. In particular, changes in the system of driver training, selection of appropriate vehicles, which was characterized by ergonomics and minimal stress.

To control the driver’s psychophysiological state, it is possible to introduce checklists that take into account ergonomic, psychosocial, individual working conditions and health indicators of the driver. Thus, the data for the analysis can be received in an automatic mode, by means of modern systems of control of a physical condition of the driver, and on change in a physical condition of the driver.

The result of supplementing the developed model of the transportation process of cargo transportation in the conditions of the mining enterprise with various control systems is shown in Fig. 3.

The results of calculating the changeability and variability of functions obtained in accordance with the presented algorithm and presented in the updated model (Fig. 3), were determined taking into account the increasing timeliness and accuracy of their implementation through the introduction of control at each stage of the TR transport process. Numerical results can provide a more accurate and inter-subjective representation of the magnitude of the variability of the functions of the transportation process.

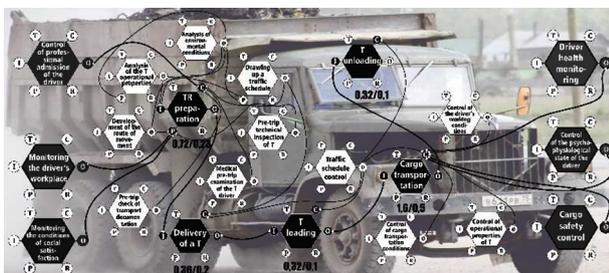


Fig. 3. The improved model of elementary transportation process of cargo transportation in the conditions of the mining enterprise from the point of departure to the point of unloading is modelled by means of the “FRAM” analysis, (numerical values according to each stage of transportation process; the designations: the value of variability of function is in the numerator, value of probability of performance is in denominator)

Discussion. The largest number of road accidents according to statistics (94 % of accidents) is due to exceeding the driver’s own capabilities while driving T [7, 8]. This reason is a consequence of changes in the psychophysiological state of the driver due to the peculiarities of the conditions of production activities. The psychophysiological state of the driver is influenced by several factors: the symptoms of fatigue, loss of attention to monitoring the road conditions. This leads to erroneous actions when driving T : speeding, making mistakes when maneuvering during overtaking, violation of traffic rules with traffic lights and violation of the rules of road markings, incorrect choice of distance, etc.

Of course, it can be argued that not all drivers are the same. Each driver has his own psycho-physiological temperament, has his own characteristics of physical health, the appropriate level of responsibility when driving a vehicle, and others. It is necessary to create a control system that would allow more effective control of the psychophysiological state of the T driver before the start of transportation work on the transportation of cargo throughout the route. The control of the driver’s psychophysiological condition can be done with the help of a checklist, which takes into account ergonomic, psychosocial, individual factor, considering the main indicators of the driver’s health and discomfort factor. The proposed checklist allows you to quickly identify the main risks associated with the psychophysiological state of the driver and based on the results, you can decide whether to allow the driver to drive T or not. The proposed measure is aimed at improving the reliability of the transportation process, traffic safety, aimed at reducing the risk of occupational diseases in T drivers, which arise as a result of professional activities, etc. [16].

To increase TR safety, many T manufacturers are now mass-producing vehicles equipped with state-of-the-art driver health and psychophysiological control systems. Among such technical devices are the following: steering wheel with built-in sensors that monitor blood pressure and heart rate of the driver, control system of facial expressions of the driver, eye blink control system, and control system for T changing rectilinear motion, etc. They are connected via GPS navigation sensors to the dispatcher, who monitors the process of T movement on the route and when the relevant indicators are changed to critical values, the dispatcher can decide in time to stop the vehicle or to change the driver.

Conclusions.

1. The transport process of TR in the conditions of the mining enterprise is represented by five main functions: preparation of trucking, supply of T , loading, transportation and unloading of cargo at the destination. For each function, its variability is determined based on the accuracy and timeliness of performance and factors are identified that affect the reliability of the transport process (experience, control, time, complexity of the process, stress, level of support) that may worsen the output result, i. e. the reduction or loss of reliability of TR transport process.

2. It was found that the least predictable functions of the TR transport process at the mining company are the preparation and transportation of cargo, due to their significant changeability and variability, as well as a significant number of production tasks for shipments and high customer requirements for transportation services.

3. With the help of the “FRAM” analysis the system of elementary TR transport process in the conditions of the mining enterprise from the loading point to the unloading point with the introduced elements of control over the psychophysiological condition of the driver during transportation work on cargo transportation is modelled.

4. It is proposed to strengthen control over the psychophysiological condition of the driver to increase the reliability and safety of the transportation process and reduce the likelihood of road accidents by introducing electronic checklists, checklists to automatically determine both physical, psychophysiological parameters of the driver’s health and professional conditions.

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Підвищення надійності вантажних автомобільних перевезень в умовах гірничодобувного підприємства

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Мета. Підвищення ефективності вантажних автомобільних перевезень (ВАП) в умовах гірничодобувного підприємства за рахунок розробки рекомендацій, спрямованих на підвищення надійності транспортного процесу.

Методика. Для визначення факторів впливу на надійність ВАП застосовано метод «Functional Resonance Analysis Method» (далі – метод «FRAM»), що базується на дослідженні функцій автомобільного транспортного процесу перевезення вантажу, виходячи з шести різних аспектів: час, контроль, вихід, ресурс, передумови та вхід.

Результати. Транспортний процес ВАП в умовах гірничодобувного підприємства представлено за допомогою п'яти основних функцій: підготовки ВАП, подачі вантажного автомобіля під завантаження, завантаження вантажу, перевезення й розвантаження вантажу в місці призначення. Для кожної функції транспортного процесу ВАП визначено: її мінливість, виходячи з показників точності та своєчасності виконання транспортної операції; фактори, що впливають на надійність транспортного процесу – професійний досвід водія, адміністративний контроль, час виконання транспортної операції, складність транспортної операції, ергономіка робочого місця, навантаження та стрес, рівень підтримки керівництва, які можуть погіршити кінцевий результат – доставки вантажу до місця розвантаження. Встановлено, що найменша надійність функції транспортного процесу ВАП – це підготовка та транспортування вантажу до місця призначення, що пов'язано зі значною їх мінливістю й варіабельністю, великою кількістю виробничих завдань і високими змінними нормативами транспортної роботи. Запропоновано для підвищення надійності ВАП в умовах гірничодобувного підприємства та зменшення ймовірності відмов при виконанні транспортної роботи посилити контроль за психофізіологічним станом водія.

Наукова новизна. Полягає у встановленні взаємозв'язку між функціями й факторами транспортного процесу ВАП в умовах гірничодобувного підприємства, що дозволяє провести оцінку рівня надійності виконання поставленого завдання у визначений термін.

Практична значимість. Полягає в кількісній оцінці впливу факторів транспортного процесу на надійність ВАП в умовах гірничодобувного підприємства.

Ключові слова: надійність, транспортний процес, водій, психофізіологічний стан, метод «FRAM», безпека

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