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Improving Safety of Passenger Road Transportation

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ABSTRACT: The objective is to increase the passenger road transportation safety by developing an improved model of the transport process with minimal risks of incidents. The Functional Resonance Analysis Method (FRAM) was used to determine the factors influencing the reliability of transportation, which is based on the study of the functions of the process of passenger road transportation based on six different aspects: time, control, output, resource, prerequisites, and input. It was clarified that the main reason for violation of traffic rules by drivers of passenger buses is the psycho-physiological state of the driver, which depends on the experience, duration of the work shift, duration of operation of the passenger bus, speed of movement, stress load. The most important criteria among those mentioned are professional work experience and speed of movement of a passenger bus. It is the combination of these criteria with the time of execution of a production task without the introduction of appropriate control over it that leads to a high probability of an incident. In addition, the human factor, directly the specialists' professional experience (the transportation organization manager, the mechanic checking a passenger bus before starting work, doctor, driver), also significantly affects the safety of the transportation process. The analysis of the causes of road traffic incidents confirmed the close connection between the probability of an undesirable event and human error, and the strengthening of control over the psycho-physiological state of the driver increases the reliability of passenger road transportation and reduces the probability of failures in the performance of transport work. The originality of the research lies in the established relationship between functions and criteria that have an impact on the safety of the transport process, which makes it possible to assess the level of reliability of the performance of the assigned task within the specified time; the practical significance lies in the quantitative assessment of these criteria and the provision of recommendations for monitoring the psycho-physiological state of the driver at all stages of the process of passenger road transportation.

KEYWORDS: Safety; Reliability; Passenger road transport; FRAM method; Risk

1. MAIN TEXT

Passenger road transport meets the needs of the population for movement in space, from the point of departure to the destination. They occupy a large segment in the transport infrastructure of large cities; play an important role in the transportation of passengers in regional and international connections. The growing demand for this type of passenger transportation intensifies the probability of the risk of road traffic incidents (RTI). Unfortunately, this is evidenced by sad statistics (World Health Organization, 2021; National Center for Injury Prevention and Control; The Wandering RV; Statystyka patrul'noyi politsiyi Ukrayiny, 2020).

Every year, in the countries of the European Union, approximately 20,000 passenger buses fall into RTI. The consequences of these RTIs are - 30,000 victims, 150 of whom die (Deryuhin & Cheberyachko, 2015). In Ukraine for the period 2018-2020, there were 420 RTIs with deaths or injuries due to the fault of passenger bus drivers (Table 1). It should also be noted that in 2021, as of 06/30/21 (compared to the same period in 2020), 56 RTIs occurred due to the fault of passenger bus drivers (+21.7%), in which 6 people died (-50%). 126 passengers were injured (+15.6%) (Statystyka patrul'noyi politsiyi Ukrayiny, 2020).

The main causes of RTI of passenger buses are mistakes made by drivers when driving vehicles as a result of exceeding their own capabilities. That is, when professional experience does not correspond to the decisions he makes when manoeuvring, when choosing the speed of passenger buses, when evaluating his own actions in conditions of limited time in intensive road traffic, etc. Special working conditions of a driver of passenger buses while driving vehicles - in fact, an unchanged working posture with the same type of limb movements, which he uses to influence the control bodies of vehicles over a long period of time leads to a change in his physical or psycho-physiological state of health, which is characterized by: the manifestation of fatigue from long-term driving of passenger buses; deterioration of psychomotor reactions when driving passenger buses due to stressful changes in traffic intensity, manifestation of fatigue from monotonous movements and finding a monotonous working posture; a change in emotional mood; loss of concentration; showing aggression towards passengers or other road users; dissatisfaction with the comfort conditions at the workplace, etc. (Deryuhin & Cheberyachko, 2015; Deryugin et al., 2018; Golinko et al., 2020; Borodina et al., 2021).

Year	Number of RTIs	Number of persons injured in RTIs	Number of persons who died in RTIs
2018	163	427	28
2019	149	346	28
2020	108	230	30
Total	420	1003	86

Table 1. RTI statistics with deaths and/or injuries caused by the fault of passenger bus drivers for the period 2018-2020 (Statystyka patrul'noyi politsiyi Ukrayiny, 2020).

Figure 1 shows the grouped main reasons for committing RTI in Ukraine for the period January 1-December 31, 2020 (Statystyka patrul'noyi politsiyi Ukrayiny, 2020).

The technical condition of passenger buses is also a very influential factor in the occurrence of RTI. Use of technically defective or outdated vehicle that does not meet the current legislation requirements on safety and comfort of passenger movement is prohibited. At the legislative level in Ukraine, there is no clear definition of the acceptable period of operation of passenger buses. And as a result, buses with a high degree of wear and tear are used on the streets of many cities (European Commission, 2015).

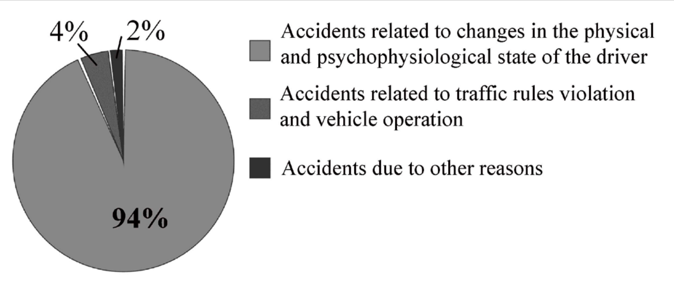

Figure 1. Grouped main reasons for committing RTI in Ukraine for the period 01.01-31.12.2020 (Statystyka patrul'noyi politsiyi Ukrayiny, 2020).

The safety of transportation is a global problem (Ministry of Infrastructure of Ukraine, 2016), which is why a significant number of various publications are devoted to it, from a comprehensive study of the impact of various factors of the activity of a motor vehicle enterprise (European Transport Safety Council, 2003) to a detailed study of a certain negative factor (Transit Advisory Committee for Safety, 2017). Thus, in the work (Tubis & Werbińska-Wojciechowska, 2014), the authors tried to approach the solution of the specified problem comprehensively, considering the operation of the system of passenger road transportation taking into account the aspects of meeting the needs of customers and carriers, which allowed to propose a classification of safety measures during transportation in accordance with the requirements and policy of the carrier. However, the question arises as to how effective the proposed measures will be, especially when conditions change.

A rather interesting study was conducted by specialists from the University of Minnesota regarding the impact of the intensity of transportation on accidents. The authors also for the first time linked the achievement of the travel goal with the ability to respond to disruptions in the logistics system. This allowed them to develop recommendations to improve reliability and safety through quick solutions to correct difficult situations on the roads (Bureau of Transportation Statistics, 2017). However, in this work, the authors did not take into account the interrelationships between various indicators, which can lead to the occurrence of an undesirable event in their combined action. It was the comparison between different safety indicators to find the correlation between system efficiency and safety measures that were carried out by the specialists of the Iranian University of Science and Technology, in which for the first time precautionary measures were systematized to determine their effectiveness based on different operating modes of buses (Baratian-Ghorghi & Ahmadianyazdi, 2017). However, the paper considers only three main safety indicators that allow transit agencies to find weak points in their system in terms of safety.

The objective is to increase the passenger road transportation' safety by developing an improved model of the transport process with minimal risks of incidents.

2. METHODOLOGY

In order to manage the risks of danger in passenger road transportation, a detailed study of the impact of various cause-and-effect relationships of the transport process of passenger transportation at each of its stages is important. This will make it possible to reveal a possible functionally resonant effect, when the system is unable to work in a normal mode of operation due to changes in its daily performance, which is determined by the influence of variable functions in complex systems, to which the process of passenger road transportation can be attributed, on the probability of the manifestation of certain factors, which may increase the risks at the relevant stages of the transport process under consideration.

We will use the FRAM method (Erik, 2017; Hollnagel, 2016; Hollnagel, 2018) to study the process model of passenger road transportation. As you know, the main element of the FRAM method is the functional hexagon (Figure 2), which reflects the relationship of six functions: "I" - initial data; "T" - time; "C" - control; "R" - resource; "P" - prerequisites; "O" - output data. These functions are considered as systemic interactions between each component system aimed at identifying potential sources of resonance. The basis of the FRAM method is that the result of one function can be an input parameter, a prerequisite or a mandatory control aspect of another function or its basic element (Table 2). A specific action (activity) can also lead to the identification of possible attenuation sources for unwanted variability.

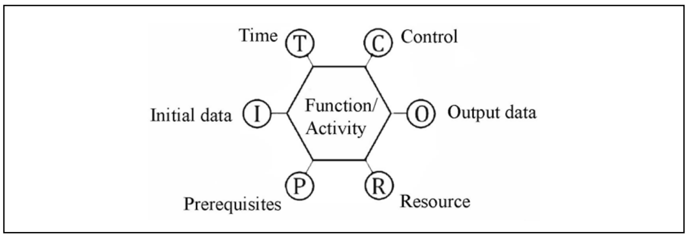

Figure 2. Functional hexagon of the FRAM method.

Function designation	Function name	Function description
"I"	initial data	characterizes the function in the process of functioning of the system; is a link from previous functions; trigger the execution or action of a function
"O"	output data	displays the function execution result; provides links to further functions; represents the result of a change in the technical state of system elements
"T"	time	the time period necessary for the maintenance of system elements, data processing, preparation or diagnostic processes; is a functional element or subsystem
"C"	control	restrictions, control methods and procedures; defines how a function communicates technical data and/or is controlled
"P"	prerequisites	system conditions that define the operating conditions and that must be satisfied before the function is executed
"R"	resource	resources that are required or used during the processing of a function or operation of system elements

Table 2. Characteristics of the functional elements of the FRAM method.

For example, if the resources for a certain function are rated as "adequate", this will somewhat provide a buffer in the event of any inconsistency in the functions presented. This feature is an important element for building a model of the process of passenger road transportation, as it allows establishing criteria that will allow assessing the safety level of passenger road transportation. Another important element of the system is the instance (immediate proximity), which reflects the possible relationships between functions, which allows you to identify both potential unwanted sources of variability and barriers.

When applying the classic FRAM method, the analysis consists of four main steps.

Step one. Description of the stages of the transport process in accordance with the six aspects of this method. For each component of the process of passenger road transportation, we find out what is the input element that starts the function, the prerequisite for its operation and the necessary resources for its execution.

Step two. Determination of functions variability. The characteristics of the variability of the functions are determined by the output results (performance), which can be variable in time and accuracy of execution.

Step three. Definition of functional resonance. At this stage, the problem of assessing the risk of failure of each function is solved, taking into account the influence of the defined aspects of the hexagon.

Step four. Change management. The performed calculations allow us to understand which factors have the greatest influence on the process of passenger road transportation, which allows us to find appropriate solutions to reduce the risk of dangerous events.

3. RESULTS

We will present the process of passenger road transportation in the form of five main functions: preparation and delivery of a passenger bus, boarding, transportation and disembarkation of passengers at the destination. We consider that the output of each function is the input of another. For example, the preparation of a passenger bus is completed by the selection of the technical task of the corresponding passenger capacity, route features, travel time, time of year, etc., which are initial data for the next function "passenger bus delivery". At this stage, we also find out the influence of other factors on the initial data (Table 3).

The description of functions allows you to find weak elements of the process of passenger road transportation, which as a result can lead to an undesirable result (incident), which will lead to non-fulfillment of passenger transportation. Each of the above functions is characterized by the interaction between human, transport and organizational factors and is recognized by several criteria that affect the safety of passenger road transport as a whole.

In accordance with regulatory requirements, they include:

- professional driver experience, regulated (Fomenko et al., 2014) – at least 5 years;
- the time of operation (driving) of passenger buses by the driver on the route is regulated (Nakaz Ministerstva transportu ta zv"yazku Ukrayiny, 2010) – no more than 4.5 hours;
- term of operation of passenger buses, regulated (Nakaz Ministerstva finansiv Ukrayiny, 2015) – 10 years;
- the permitted speed of passenger buses is regulated (Fomenko et al., 2014) in city conditions – 50 km/h, on highways – 90 km/h.
- load (stress) is regulated (Nakaz Ministerstvo okhorony zdorov"ya Ukrayiny , 2014).

The specified criteria will, of course, affect the variability of functions, which consists in untimely and inappropriate performance of the assigned task - delivering passengers to their destination exactly on time. For example, an inexperienced driver who drives passenger buses has longer idle times at bus stops, and the average speed of passenger buses is slower (Buylenko et al., 2017) compared to drivers with more experience. The general impact of the specified criteria on the variability of the function will be determined through the ratio of real indicators to the established regulatory requirements, taking into account the impact on each element of the function according to the formula

$$(1)\quad K_i = \frac{H_i}{H_i^{reg}} E_i^w ,$$

where K_i – variability value of the function; H_i – quantitative characteristic of a criterion that affects the safety of passenger road transport at a motor transport enterprise; H_i^{reg} – regulated value of the criterion by the relevant legislative acts; E_i^w – weight coefficient of the specified function.

The indicator of variability of the function is calculated for two possible scenarios of passenger road transport:

No. 1 Script: Transportation of passengers is carried out in violation of the rules of organization and implementation of the process of passenger automobile transportation: the professional experience of employees who organize, control and directly manage passenger buses is less than regulated by job instructions and current legislation; the operating period of passenger buses exceeds the standard of operation of the corresponding type of vehicle, which is regulated by current legislation; the process of passenger automobile transportation is carried out in violation of traffic rules, which regulate the permissible speed.

No. 2 Script: The transportation of passengers is carried out without violating the rules of organization and implementation of the process of passenger automobile transportation: the professional experience of employees who organize, control and direct management of passenger buses meet the standards regulated by job instructions and current legislation; the operational term of passenger buses does not exceed the standard of operation of the corresponding type of vehicle, which is regulated by the current legislation; the process of passenger road transportation is carried out without violating the traffic rules that regulate the permissible speed.

To determine the weighting coefficients E_i^w, which are one of the main elements of the proposed model, we will consider possible scenarios of the development of events taking into account each element of the hexagon. This is a typical decision-making task under uncertainty. To determine them, we will apply the method of analysis of hierarchies by T. L. Saati (1993). The basis of which is the decomposition of the task into simple components and making expert decisions about the components on the basis of so-called pairwise comparisons. Let us introduce a matrix of preferences (or pairwise comparisons) of size n = 5, corresponding to five functions.

$$(2)\quad W = \begin{bmatrix} w_{11} & w_{12} & w_{13} & w_{14} & w_{15} \\ w_{21} & w_{22} & w_{23} & w_{24} & w_{25} \\ w_{31} & w_{32} & w_{33} & w_{34} & w_{35} \\ w_{41} & w_{42} & w_{43} & w_{44} & w_{45} \\ w_{51} & w_{52} & w_{53} & w_{54} & w_{55} \end{bmatrix},$$

where w_{ij} - the importance criteria of matrix components.

The matrix is formed in the following way. The over-diagonal elements of the matrix W are determined by pairwise comparisons in such a way that the criterion in the row i = 1, 2, ..., n is evaluated with respect to each of the indicators

Functional elements	Functions				
	Preparation	**Delivery**	**Boarding**	**Transportation**	**Disembarkation**
Input	Operating properties, climatic conditions of transportation, route, timetable	Type, passenger capacity of passenger buses	Placement of passenger buses at the point of departure	Passenger bus, filled in accordance with the passenger capacity, transport documentation is available	Delivery of passengers to the destination in accordance with the timetable
Output	Type, brand of passenger buses	Maneuvering of passenger buses and waiting for passengers to board at the departure point	Accommodation of passengers in passenger buses, available transport documentation	Delivery of passengers to their destination	Manoeuvring passenger buses and waiting for passengers to drop off at the point of departure
Time	Standard time determined by the instructions of the motor transport company	According to the route passport schedule	According to the schedule of the route passport	According to the schedule of the route passport	According to the schedule of the route passport
Control	Inspection of transport documentation, technical condition of passenger buses, driver's state of health	Downtime, transport documentation	Placement of passengers and luggage in passenger buses	Movement speed, performance indicators, movement schedule	Disembarkation of passengers at the destination
Preconditions	Passenger buses, technically suitable for transporting the appropriate number of passengers, based on climatic conditions; instructions on the professional admission of a driver to drive passenger buses; job description of a mechanic; job description of the doctor performing the pre-flight medical examination of the driver	The place for boarding passengers must satisfy the possibility of manoeuvring passenger buses	Passenger capacity of passenger buses corresponds to the number of passengers transported; the volume of the luggage compartment corresponds to the safe placement of luggage in the appropriate volume	Favourable climatic conditions; efficient transport infrastructure; quality fuel; compliance with the traffic schedule	The place for disembarking passengers must satisfy the possibility of manoeuvring passenger buses
Resources	Manager for the organization of passenger road transportation, mechanic for the release of passenger buses to the line; a doctor performing a pre-trip medical check-up of a passenger bus driver	Competences of the driver, dimensions of the platform for boarding passengers	The platform is equipped for boarding passengers in the cabin of passenger buses	Professional experience; stress resistance; appropriate physical and psycho-physiological condition of the driver	Competences of the driver, dimensions of the platform for boarding passengers

Table 3. Description of functions that characterize the process of passenger road transportation.

presented in the columns $j \geq i$. The criteria are expressed as integers from 1 to 9 according to the data in Table 4.

Value	Condition
$w_{ij} = 1$	if criterion *i* is equally important compared to *j*
$w_{ij} = 3$	if criterion *i* is more important compared to *j*
$w_{ij} = 5$	if criterion *i* is clearly more important compared to *j*
$w_{ij} = 7$	if criterion *i* is significantly more important compared to *j*
$w_{ij} = 9$	if criterion *i* can be neglected in comparison with *j*
$w_{ij} = 2,4,6,8$	in intermediate cases

Table 4. Criteria comparison scale.

Taking into account the possible scenarios of the development of events and influencing factors, we will present a matrix of advantages in numerical form:

$$W = \begin{bmatrix} 1 & 1 & 3 & 1 & 3 \\ 1 & 1 & 1 & 1 & 1 \\ 0,33 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 4 \\ 0,33 & 1 & 1 & 0,25 & 1 \end{bmatrix} \cdot , \quad (3)$$

Where rows and columns correspond to the order given in table 5:

Row (column) number	Function elements
i = j = 1	Time
i = j = 2	Resource
i = j = 3	Prerequisites
i = j = 4	Control

Table 5. The order of correspondence of rows and columns of the matrix.

Vector of weighting coefficients $E_i^W = [E_1\ E_2\ E_3\ E_4\ E_5]^T$ was found from the formula

(6) $E \cdot W = \lambda_{max} E$,

where λ_{max} - the maximum eigenvalue of the matrix.

Equation (6) coincides with the definition of the maximum eigenvector. Therefore, the vector *a* is the maximum eigenvector of the matrix *W*:

(7) $a = W = [w_1, w_2, w_3, w_4, w_5]^T$,

The resulting vector must be normalized by dividing each of the values by the sum of the elements of the vector:

(8) $$a_i = \frac{a_i}{\sum_1^4 a_j} .$$

It is obvious that the vector now satisfies the normalization condition and can be used to calculate the magnitude of the risk of danger at each stage of the process of passenger road transportation

(9) $$\sum_1^4 a_i = 1 .$$

The results of the calculation of the weighting coefficients are summarized in Table 6, and the results of the calculation of the function variability indicator are in Table 7.

We will present the assessment of the risk of non-fulfillment of the production task as an exponential dependence on the general variability of the functions of the transport process:

(10) $R = 1 - \exp(-K_{total})$,

where K_{total} - the total variability of the function:

(11) $$K_{total} = \frac{\frac{K_{k1}}{2} + K_{k2} + K_{k3} + K_{k4} + \frac{K_{k5}}{2}}{n-1} ,$$

It is necessary to take into account the fact that there are indicators, the increase of which minimizes risks at the relevant stages of the process of passenger road transportation (professional experience). And vice versa - there are indicators, the reduction of which minimizes risks at the relevant stages of the transport process (vehicle service life, driving time, etc.). According to their content, they are calculated according to the following formulas (Fatkhutdinov, 2000):

The results of the calculations (Table 7) made it possible to determine that the most influential criteria that affect the efficiency of passenger road transport are the work experience of employees and the speed of movement, which, in combination with the time of execution of a production task without the introduction of appropriate control, leads to a high probability of an incident or inconsistencies that will lead to unforeseen losses or an undesirable event (Fig. 3). The analysis carried out (Tables 3, 7) shows that the transport process depends most on the professional experience of a specialist: a manager of the organization of passenger road transport, a mechanic who releases passenger buses on the line, a doctor, a driver. Therefore, the probability of the occurrence of an undesirable event is closely related to human error, which is confirmed by the most common causes of road accidents, which are associated with exceeding the driver's own capabilities, which requires additional research.

At the same time, from the given decision, it is possible to establish the nature of "human error" - a one-time act, or a systemic inconsistency caused by the organizational culture at the enterprise: the lack of certain resources, prerequisites, control or limited deadlines. In the presented version, the system error consists in the lack of proper control over the activities of both operators and drivers. Therefore, in order to reduce the probability of the occurrence of an undesirable event during the transport process, it is necessary to strengthen the specified elements of the functions (Table 8).

At the last stage of Change Management, an improved version of the transport process is proposed, which allows reducing losses due to the manifestation of nonconformities, incidents or emergency situations. Fig. 4 shows the relationship between the improved process of passenger transportation and the implemented elements of control over the health and psycho-physiological state of the participants in the transport process. The difference between the proposed transport processes of transporting passengers is that four new control measures have been introduced into it: control of the driver's professional permit; passenger safety control; control of the psycho-physiological state of the driver; control of the driver's physical state of health. To propose a strengthening of the control over the performance of the function was done on the basis of the analysis of the impact on the risk value of each element (input/output, time, control, resources and prerequisites), thanks to the change of weighting coefficients: in turn, each was given a priority of 40%. From fig. 5 it is clear that the greatest amount of risk, all other conditions being the same, is observed in the case of increased attention to the fulfilment of prerequisites and provision of resources. The lowest level of risk is observed when taking care of only the original data. The obtained result is explained primarily by the value of the variability of the functions, which depends on the number of criteria that do not correspond to the normative values. It is clear that the introduction of enhanced control over the performance of the transport task will lead to an additional reduction of the determined amount of risk. However, the task of influencing the final result - the driver's working conditions, his level of health, stress resistance, which also has a certain effect on the variability of functions - requires further research.

Therefore, the proposed measures allow monitoring changes in the psycho-physiological and physical state of health of the driver of passenger buses and the fulfillment of elementary safety conditions by passengers at all stages of the transportation process. This makes it possible to intervene and make management decisions, which are aimed at replacing the driver during the performance of transport work for the transportation of passengers without waiting for him to reach the destination. This control practice is already used by European carriers, as well as in Asian and American countries.

Function	Criterion					The value of the weighting factor
	Output	Time	Control	Preconditions	Resources	
Preparation	1	1	3	1	3	0.30
Delivery	1	1	1	1	1	0.17
Boarding	0.33	1	1	1	1	0.14
Transportation	1	1	1	1	5	0.27
Disembarkation	0.33	1	1	0.2	1	0.12

Table 6. Weighting coefficients.

Criterion	Criterion components	The function variability indicator	
		in violation of the regulations	without violating the regulations
Preparation of passenger road transport K_{k1}			
Professional experience, years	manager of the organization of passenger road transport	0.92	0.20
	mechanic	0.92	0.32
	doctor	0.88	0.40
	driver	0.88	0.28
Working time (management), h	manager of the organization of passenger road transport	0.19	0.13
	mechanic	0.06	0.04
	doctor	0.04	0.03
Load (duration) / Stress, %	manager of the organization of passenger road transport	0.50	0.50
	mechanic	0.50	0.50
	doctor	0.50	0.50
Service life (technical condition) of passenger buses, years		0.50	0.50
The total indicator of the function variability		**5.88**	**3.10**
Provision of passenger buses for passenger boarding K_{k2}			
Professional experience, years	Driver	0.92	0.28
Working time (management), h		0.63	0.125
Load (duration) / Stress, %		0.50	0.50
Service life of passenger buses, years		0.50	0.50
Permitted speed of passenger buses, km/h		0.90	0.90
The total indicator of the function variability		**3.45**	**2.05**
Transportation of passengers K_{k3}			
Professional experience, years	Driver	0.92	0.28
Working time (management), h		0.63	0.56
Load (duration) / Stress, %		0.50	0.75
Service life of passenger buses, years		0.50	0.50
Permitted speed of passenger buses, km/h		0.50	0.50
The total indicator of the function variability		3.70	2.73
Disembarking passengers at the bus stop K_{k4}			
Professional experience, years	Driver	0.92	0,28
Working time (management), h		0.10	0,063
Load (duration) / Stress, %		0.50	0,50
Service life of passenger buses, years		0,50	0.50
Permitted speed of passenger buses, km/h		0,90	0.90
The total indicator of the function variability		**2.92**	**2.05**
Return of passenger buses to the enterprise K_{k5}			
Professional experience, years	Driver	0.92	0.28
Working time (management), h		0.63	0.56
Load (duration) / Stress, %		0.75	0.56
Service life of passenger buses, years		0.50	0.20
Permitted speed of passenger buses, km/h		0.90	0.94
The total indicator of the function variability		**4.00**	**2.73**

Table 7. Calculation results of functions variability.

Function	The total indicator of the function variability	Weighting coefficient	The value of the indicator of non-fulfillment of any criterion that ensures the safety of passenger road transport	The magnitude of the risk of non-fulfillment of the work task when carrying out passenger automobile transportation
The process of passenger road transportation in violation of regulations				
Preparation	3.10	0.30	0.144	0.65
Delivery	2.05	0.17	0.100	
Boarding	2.73	0.14	0.096	
Transportation	2.05	0.27	0.125	
Disembarkation	2.05	0.12	0.080	
The process of passenger road transportation without violation of regulations				
Preparation	5.88	0.30	0.083	0.42
Delivery	3.45	0.17	0.053	
Boarding	3.70	0.14	0.074	
Transportation	2.92	0.27	0.083	
Disembarkation	4.00	0.12	0.038	

Table 8. The calculation results of the risk of production task non-fulfillment.

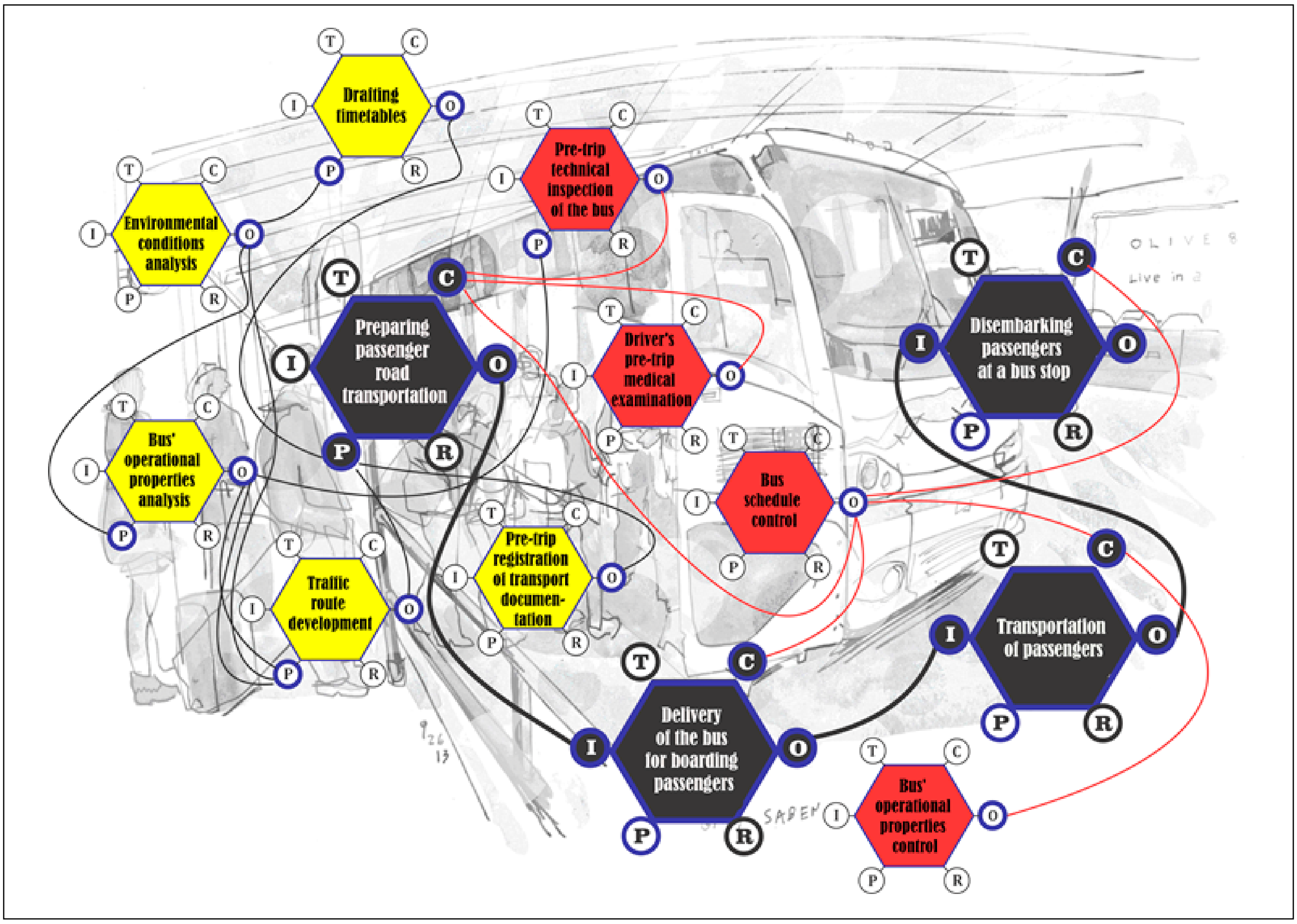

Figure 3. The view of the interrelationships of the process of passenger road transportation is built using the FRAM method.

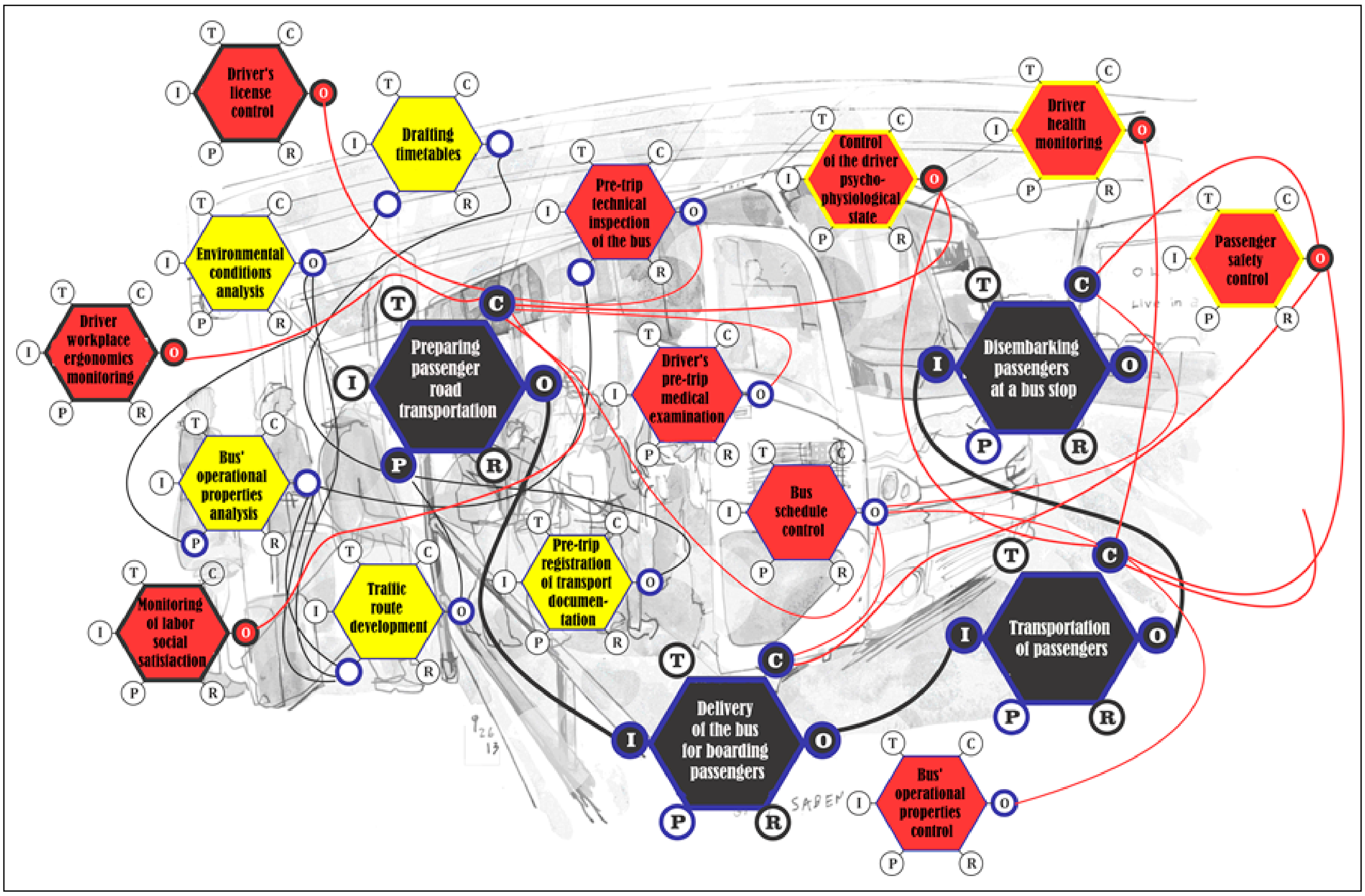

Figure 4. The view of the relationships of the improved process of passenger road transportation is built using the FRAM method.

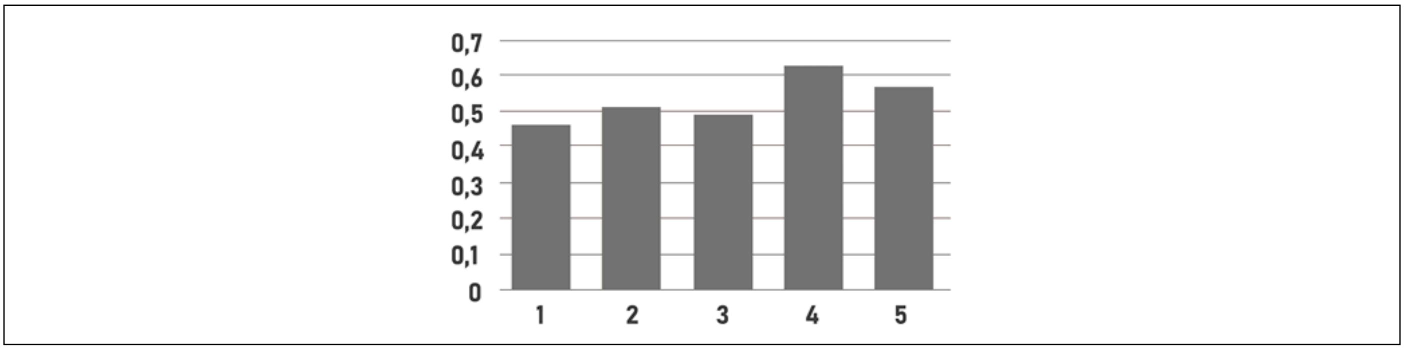

Figure 5. The magnitude of the risk of a failure or an incident at different priorities (weighting factors), which is determined by increasing attention to 40% on the elements of the function: input/output (1); time (2); control (3); prerequisites (4); resources (5).

4. DISCUSSIONS

Consequences of a change in the driver's psycho-physiological state during transport are fatigue, loss of attention to monitoring the road situation. This leads to erroneous actions that are manifested when driving passenger buses: exceeding the speed limit, making mistakes when overtaking, violating traffic lights and road markings, choosing the wrong distance, etc. It can definitely be said that not all drivers are the same. However, the calculations show that it is the lack of proper preparation and the increase in the complexity of transportation that leads to an increase in the number of failures (Fig. 6). This process is especially influenced by the psycho-physiological state of the driver, who is responsible for making decisions while driving the vehicle with minimal input data.

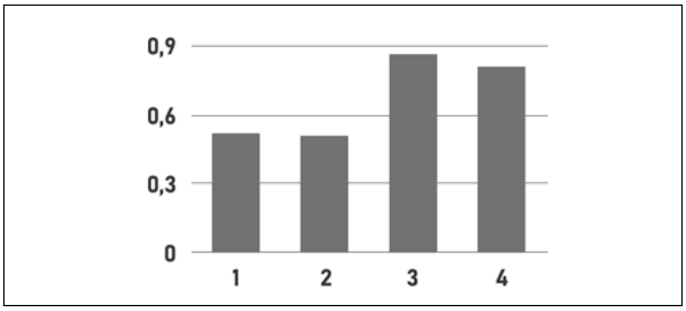

Figure 6. The magnitude of the risk of a failure or an incident at different priorities (weighting factors), which is determined by increasing attention to 40% on functions without violating the regulations: transportation (1); preparation (2); and on functions in violation of the regulations: transportation (3); control (4).

Additional control of the psycho-physiological state of the driver can be carried out with the help of a special checklist (Borodina et al., 2021), which takes into account: ergonomic, psychosocial, individual factors, which take into account the main indicators of the driver's health and the discomfort factor. It allows you to quickly identify the main risks associated with the psycho-physiological state of the driver using the survey method, and based on the results, you can make a decision to allow the driver to drive passenger buses or not. The proposed measure is aimed at improving traffic safety, aimed at reducing the risks of occupational diseases among passenger bus drivers, which arise as a result of performing professional activities, etc.

In order to increase the safety of passenger road transportation in the future, many manufacturers of passenger buses are serially producing vehicles that are equipped with modern systems for monitoring the health and psycho-physiological state of the driver. Among such technical devices, one can note a steering wheel with built-in sensors that monitor the driver's pulse and heartbeat, a driver's facial expression control system, an eye blink control system, a system for controlling the input of passenger buses from straight-line traffic, etc. They are connected via GPS - navigation with the dispatcher who monitors the process of passenger bus movement on the route and when the relevant indicators change to critical values, the dispatcher can make a timely decision to stop the vehicle or replace the driver.

Strengthening control over the driver's admission to driving passenger buses is to ensure accident-free driving experience over a long period of time (at least 10 years of professional experience in passenger transportation). Unfortunately, attention is not paid to this issue in the future. By and large, the main criterion is the admission of drivers with the appropriate category of driver's license, which gives the right to drive passenger buses. Accident-free driving experience should also be incentivized by wages and monetary rewards.

Unfortunately, there are facts of flying accidents of drivers while driving passenger buses in the process of movement. And this creates a great danger for passengers who are in the cabin of passenger buses. Therefore, the problem under consideration is relevant and important in the matter of improving traffic safety during passenger road transportation.

5. CONCLUSIONS

1. The variability of the functions of the process of passenger road transportation was determined based on five measurable criteria: professional experience, duration of the work shift, speed of movement, duration of operation, stress load taking into account four elements: time, control, prerequisites and resources.

2. It is proposed to determine the high-quality and timely execution of passenger road transport to determine the risk of an incident or failure at the appropriate stages of the transport process using the exponential distribution law, which well models the sequential execution of operations taking into account the probability of failure-free operation, which characterizes the product of the variability of functions and weights priority coefficients.

3. It was determined that for the worst case, when the criteria do not meet the values regulated by the normative legislation, the risk of an incident is 65%, while with full compliance it is 42%. The difference in indicators is explained primarily by the inconsistency of elements of control functions and prerequisites, which as a result increases the risk during transportation.

4. Proposed measures that allow control, which shows the influence of the psycho-physiological state of the driver on road safety. Among them, the following can be noted: a steering wheel with built-in sensors that monitor the driver's blood pressure and heartbeat, a driver's facial expression control system, an eye blink control system, a system for controlling the input of passenger buses from straight-line traffic, etc. They are connected via GPS - navigation with the dispatcher who monitors the process of passenger bus movement on the route and when the relevant indicators change to critical values, the dispatcher can make a timely decision to stop the vehicle or replace the driver.

5. It has been proven that in order to improve road traffic safety, it is necessary to strengthen control over the driver's psycho-physiological parameters.

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