THE DANGEROUS FACTORS IDENTIFICATION FEATURES OF OCCUPATIONAL HAZARDS IN THE TRANSPORTATION CARGO PROCESS

Vitaliy Tsopa[1], Serhiy Cheberyachko[2], Yana Litvinova[2], Mariia Vesela[2], Oleg Deryugin[2,*], Ivan Bas[2]

[1]International Institute of Management, Kyiv, Ukraine
[2]Dnipro University of Technology, Dnipro, Ukraine

*E-mail of corresponding author: oleg.kot@meta.ua

Vitaliy Tsopa 0000-0002-4811-3712,
Serhiy Cheberyachko 0000-0003-3281-7157,
Yana Litvinova 0000-0003-2806-4076,
Mariia Vesela 0000-0001-9318-9110,
Oleg Deryugin 0000-0002-2456-7664

Resume

The article highlights the problem of occupational safety of a technological truck driver by improving the process of determining the level of occupational risk by studying the relationships between various external and internal hazards. A special algorithm is proposed, the main difference of which from the known ones is the procedure for analyzing and determining the causes of dangerous factors, for which it is proposed to use the "Decision-Making Trial and Evaluation" method (further - fuzzy Dematel). A cause-and-effect relationship has been established between dangerous factors that affect the work of a truck driver while driving a vehicle.

Article info

Received 3 April 2023
Accepted 20 June 2023
Online 28 June 2023

Keywords:

a driver
professional risk
fuzzy Dematel method
management decisions

Available online: https://doi.org/10.26552/com.C.2023.058

ISSN 1335-4205 (print version)
ISSN 2585-7878 (online version)

1 Introduction

With the industrialization spread in the world, the responsibility of employers for occupational safety has increased. This has led to necessity to introduce various legal acts both at the international [1] and national levels regarding occupational health and safety at work. In particular, the convention of the International Labor Organization (ILO) and the European Union (EU) 89/391/EEC "Framework directive on health and safety at work" has been adopted at the international level, and at the national level - the corresponding legislation on labor protection and [2-5], which contains requirements for both employers and employees, the basis of which is the occupational risk assessment (hereinafter -OR). It is considered that its introduction allows to significantly increase the level of labor safety, due to elimination of industrial hazards that affect employees during the professional activities' performance. The appropriate, high-quality assessment of occupational health and safety is a very important stage of the occupational safety and health management system.

The evaluation procedure of the assessing occupational risks, according to ISO 31000:2018, ISO 39001:2012, ISO 45001:2018 and others, consists of several main steps: identification of hazards and dangerous factors (hereinafter - DF), determination of the damage level and occurrence probability of a dangerous event, establishment of causal consequential links between danger, DF and dangerous event, on the one hand and dangerous event and consequences, on the other. Next, the value of OR is directly assessed, which is the basis for justifying the protective and preventive measures. The last step is to check the OR assessment. Despite the fact that all the steps are quite important, and a mistake made at any stage can nullify the entire procedure, it is considered that the most difficult and responsible step is the first one: the identification of hazards and DF. Ignoring any hazard or DF can lead to catastrophic consequences that no one has expected. Therefore, in each specific case, there is a necessity to process fairly significant volumes of information: processing the letters of incapacity for work, accident materials investigation, results of sanitary and hygienic, ergonomic analyzes of the workplace, maps of working conditions, results of monitoring the performance of production operations, questionnaires, employees surveys to find out, not only the presence of the dangers themselves, but the causes

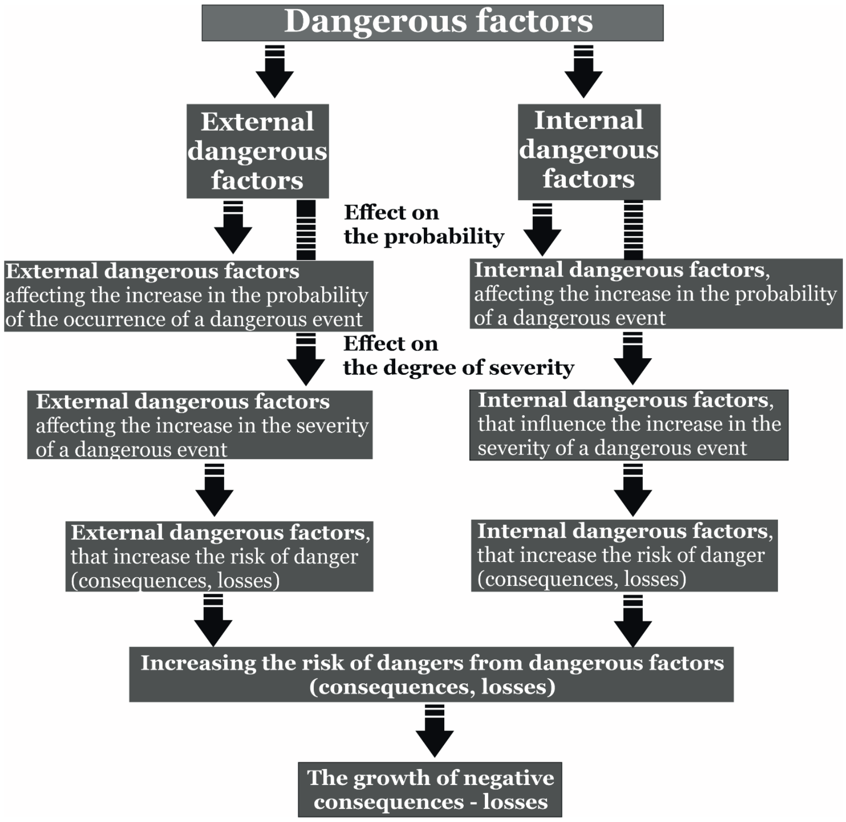

Figure 1 *Dangerous Factors' threat*

- DFs, as well, which lead to and have an impact on the increase in the occurrence probability and severity of incidents, emergency situations, traffic accidents (hereinafter - TA), accidents or emergency situations (Figure 1).

Also, it can be noted that this process is strongly influenced by the professional expert subjective opinion. A cohort of various cognitive biases (too much information, planning errors, optimism bias, fundamental attribution error, and others) quite often leads to incorrect evaluation decisions, calculations of the OR value [6-7] - neglect of obvious facts. At the same time, the processing of the entire set of the DFs would lead to a significant increase in the maps size for the OR assessment, the complexity of their understanding and reading, and most importantly, the selection of the most significant factors of incidents. Therefore, research aimed at improving this procedure, namely reducing the influence of the judgments subjectivity when calculating OR, is a rather urgent task [8].

2 Analysis of relevant literature

Several different approaches are proposed for evaluating the OR in transportation processes: qualitative, semi-qualitative (when the occurrence probability of a dangerous event and the severity of the consequences are set by experts based on their own experience) and quantitative. Experts indicate that the latter is the most appropriate, as it allows to assess reliably the level of the OR. However, a significant amount of statistical data is needed to determine the probability of the dangerous event occurrence. The issue raised in the case of road freight transportation (further - RFT) of hazardous substances that pose a significant threat to humans and the environment becomes especially relevant [9]. The author suggests that during the OR assessment, it is necessary to take into account the influence of the physical and chemical properties of the cargo being transported. However, the author, having disclosed in detail the consequences of such accidents and at the same time substantiating the need to take into account the type of cargo for the evaluation of the OR, does not indicate a specific procedure that would allow establishing the value of the OR. In the study [10], it is also suggested to pay attention to the type of cargo, the quality of the driver training and the influence of the environment, using the usual matrix system of the occupational risks evaluation. Moreover, they do not pay attention to the cumulative effect of the mentioned dangerous factors (PMs), but evaluate their impact separately from each other, which can lead to a significant error in the calculations of OR. In addition, no less important for reducing the level of professional risks is the construction of rational traffic routes, thanks to which a reduction in the distraction of the driver's attention during transportation is achieved [11]. In another publication [12], the authors cited the results of the influence of a large number of participants in the transportation process and their possible incompetent actions, which lead to an increase in random factors and the resulting OR. To identify the transportation risks, the authors suggest using the SWOT analysis, which does not allow for the ranking of OR, but only indicates the presence of a number of strengths and weaknesses with the identification of threats that affect the RFT. The interesting solution for the occupational risks assessment was proposed by the authors in [13], to identify the OR that appears in the transport chain. At the same time, for each step, it was proposed to determine, instead of the severity of the consequences, the quality of the cargo transportation process. The result is the amount of OR when performing the RFT of the corresponding type of cargo. At the same time, having proposed a good idea, the authors subsequently followed the path of semi-quantitative analysis, which requires appropriate preparation for conducting such an analysis. Another unusual approach to the assessment of transport risks was shared by the authors in [14], where it is proposed to carry out a OR assessment by the Functional Resonance Analysis Method (FRAM method), which allows to consider the influence on the final result of four factors, which are set by the functions of time, control, availability of preconditions and a sufficient number of resources. On the one hand, this approach allows for more thorough determination of the occupational risks of failure to perform the transport work, and on the other hand, it forces a qualitative assessment of the function variability, which can introduce additional errors into the transport process risk assessment.

The conducted analysis indicates the need to develop or improve the process of DFs identification, which increase the probability of a dangerous event to reduce the procedure subjectivity for the management of OR in road freight transportation.

The purpose of this study was to improve identifying the to improve the process of identifying the dangerous factors that increase the probability of a dangerous event occurrence and the severity of its consequences to reduce the subjectivity of judgments during the managing professional risks procedure ine implementation of the road freight transportation.

3 Materials and methods

For the above mentioned procedure it was planned to use the fuzzy Dematel method, which is based on paired comparison and decision-making tools based on the Graph theory [15-16], which would allow the causal relationships transformation in structural-visual models and together with verification of experts' assessments of emissions according to the Grubbs criterion to identify and understand the most relevant interdependencies between various DFs that cause human harm.

The fuzzy Dematel method is superior to other multi-criteria management decision-making methods, such as "Interpretive structural modeling" (ISM) and "Analytic Hierarchy Process" (AHP) methods, as it allows to assess the overall degree of influence of various factors or problems effectively, to identify the cause-and-effect groups and establish causal relationships [15-17]. The use of fuzziness in the fuzzy Dematel method allows to use imprecise information that is typical for ordinary human judgments. It includes four main stages [18-20].

Formation of data for analysis. To identify areas where the process improvement is possible, data relevant to the problem under consideration must be collected so that various quantitative and qualitative operations can be applied to refine the details.

Identification of received data. The information collected at the stage A is important for identifying the potential problems (PP) that prevent the normal operation of the technological (transportation) process under consideration. Based on the nature of the received information, the quantitative and qualitative data analysis is carried out. It is also possible to convert the qualitative (logistic statements) data into quantitative data and vice versa.

Analysis of relationships. The number of problems highlighted in this step can vary from a few units to very large values. It is believed that none of the problems exists by itself, without the connection to the others. In other words, each problem can drive others or depend on other problems. Therefore, it is important to analyze the interrelationships between problems.

Interpretation of the obtained results. At this stage, the results of the analysis carried out at the relationships analysis stage are interpreted.

The above four stages can be divided into several consecutive steps of the research (Figure 2), which will allow to obtain the appropriate result from the analysis of the impact of certain DFs on the efficiency of the technological (transportation) process.

At the first step, a group of experts-specialists in the relevant field is formed, who have theoretical and practical experience in the relevant field of activity to identify the DFs related to the professional activity of the driver and their consequences. Five experts were selected to carry out this procedure (Table 1).

At the second step, evaluation criteria are determined and the fuzzy linguistic scale is developed for expert evaluation. At this stage, various criteria and degrees of each problem's relative importance are determined, and presented in the linguistic classification terms: very high impact, high impact, low impact, very low impact and no impact. Answers of experts were transformed into the fuzzy numbers using a fuzzy scale (Table 2). Triangular fuzzy numbers were used; the triangular fuzzy number $\tilde{z}$ is defined as follows: $\tilde{z} = (l, m, u)$, where l, m and u are real numbers and $l \leq m \leq u$.

I Stage - Data formation for analysis

Step 1. Formation of a group of experts-specialists in the relevant field who have theoretical and practical experience in the relevant field of activity in order to identify dangerous factors related to the professional activity of the employee and their consequences.

Step 2. Determination of evaluation criteria and development of a fuzzy linguistic scale for expert evaluation.

II Stage - Identification of the received data

Step 3. Construction of the fuzzy normalized matrix of direct connection $\tilde{Z}_k$ based on the results of expert judgments of the problem under consideration.

Step 4. Analysis of the initial normalized fuzzy direct matrix and transformation of the scale of evaluation criteria into a scale of comparable values into triangular numbers of the developed evaluation criteria.

III Stage - Analysis of relationships

Step 5. Construction and calculation of the direct matrix of connections T of the normal relation.

Step 6. The values of the expressions $R_i + C_j$ and $R_i - C_j$ are defuzzified (transformation of a fuzzy set into a distinct number by the degree of membership) using the method of using the technique of defuzzification of the center of the value area (CVA).

IV Stage - Interpretation of the obtained results

Step 7. Construction of a causal diagram. Analysis of the obtained results.

Figure 2 *Algorithm of the fuzzy DEMATEL method*

Table 1 *Data from experts participating in research*

Information	Amount
Number of experts	5
Work experience in transport logistics positions	from 10 to 14 years
Education of experts	majored in transport technologies
Work experience	more 10 years
Availability of an auditor's certificate for the company's quality and safety management systems	Yes
Advanced training in risk assessment according to requirements ISO 45001	Yes

Table 2 *Word phrases and corresponding fuzzy numbers [21]*

Final equivalent	Description	A vague equivalent		
Very high impact	VH	0.75	1	1
High impact	H	0.5	0.75	1
Low impact	L	0.25	0.5	0.75
Very low impact	VL	0	0.25	0.5
No influence	NO	0	0	0.25

The membership function $\mu_{\tilde{z}}$ is defined as follows:

$$\mu_{\tilde{z}} = \begin{cases} \dfrac{x-l}{m-l} \; at \; l \le x \le m \\ \dfrac{u-x}{u-m} \; at \; m \le x \le u \\ 0 \; in \; all \; other \; cases \end{cases}. \quad (1)$$

The third step involves the construction of a fuzzy normalized matrix of direct communication based on the results of expert judgments of the problem under consideration. Fuzzy matrices $\tilde{z}_1, \tilde{z}_2, \tilde{z}_3, \ldots, \tilde{z}_p$ are formed. Triangular fuzzy numbers were generated according to the judgments of the experts who participated in the peer review. The initial direct matrix is the fuzzy matrix $\tilde{z}_k$:

$$\tilde{z}^k = \begin{bmatrix} 0 & \tilde{z}_{12}^{(k)} & \ldots & \tilde{z}_{n1}^{(k)} \\ \tilde{z}_{21}^{(k)} & 0 & \ldots & \tilde{z}_{n1}^{(k)} \\ \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots \\ \tilde{z}_{n1}^{(k)} & \ldots & \ldots & 0 \end{bmatrix}, \quad (2)$$

where $\mu_{\tilde{z}} = 1,2,3,\ldots,p; \tilde{z}_{ij}^{(k)} = \left(l_{ij}^{(k)}, m_{ij}^{(k)}, u_{ij}^{(k)}\right)$.

Without loss of generality $\tilde{z}_{u}^{(k)} = (i = 1,2\ldots n)$ was treated as a triangular fuzzy number $\tilde{z} = (0,0,0)$, when it is required.

In the fourth step, the normalized fuzzy matrix of direct connections is analyzed. Suppose that:

$$r_k = \max_{i=1}^{n}\left(\sum_{j=1}^{n} u_{ij}^{k}\right). \tag{3}$$

A linear transformation was used to transform the criteria scale into a scale of comparable values, and a normalized fuzzy matrix of direct relationships, obtained as a result of expert evaluation, has the following form given in Equation (4):

$$\tilde{x}^{k} = \begin{bmatrix} \tilde{x}_{11}^{(k)} & \tilde{x}_{12}^{(k)} & \dots & \tilde{x}_{1n}^{(k)} \\ \tilde{x}_{21}^{(k)} & \tilde{x}_{22}^{(k)} & \dots & \tilde{x}_{2n}^{(k)} \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ \tilde{x}_{n1}^{(k)} & \tilde{x}_{n2}^{(k)} & \dots & \tilde{x}_{nn}^{(k)} \end{bmatrix}, \tag{4}$$

where k = 1, 2, 3, ..., p.

$$\tilde{x}_{ij}^{(k)} = \frac{\tilde{z}_{ij}^{(k)}}{r^{k}} = \left(\frac{l_{ij}^{(k)}}{r^{k}}, \frac{m_{ij}^{(k)}}{r^{k}}, \frac{u_{ij}^{(k)}}{r^{k}}\right). \tag{5}$$

Similar to the conventional Dematel method, we assume that there is at least one value of i such that $\sum_{j=1}^{n} u_{ij}^{k} < \sum_{j=1}^{n} r^{k}$.

$\tilde{X}$ denotes the average value of the judgments of all the experts who participated in the evaluation of the technological process:

$$\tilde{X} = \frac{\tilde{x}^{1} + \tilde{x}^{2} + \dots + \tilde{x}^{p}}{p}. \tag{6}$$

$$\tilde{X} = \begin{bmatrix} \tilde{X}_{11} & \tilde{X}_{12} & \tilde{X}_{1n} \\ \tilde{X}_{21} & \tilde{X}_{22} & \tilde{X}_{2n} \\ & & \\ \tilde{X}_{n1} & \tilde{X}_{n2} & \tilde{X}_{nn} \end{bmatrix} \tag{7}$$

where $\tilde{X}_{ij} = \frac{\sum_{k=1}^{p} \tilde{x}_{ij}^{(k)}}{p}$.

The fifth step is to calculate the overall fuzzy matrix of connections $\tilde{T}$. It is known that $\lim_{W\to\infty} X^{W} = \Theta$, where Θ is the zero matrix. In addition, it is known that $\lim_{W\to\infty}(1 + \tilde{X} + \tilde{X}^{2} + \dots + \tilde{X}^{W}) = X \cdot (1 - \tilde{X})^{-1}$. Both of these relations are proved in [22-23]. The last matrix is a general fuzzy matrix of connections $\tilde{T}$.

The sixth step consists in calculating the general matrix of connections $\tilde{T}$. Significance and relative position vectors are calculated, as well.

In the seventh step, all the fuzzy numbers are converted to exact values. For this, the following variant of the CFCS method is used. Suppose there are triangular fuzzy numbers $\tilde{N}_k = (l_k, m_k, u_k)$; $k = 1, 2, \dots, n$. Provided that $L = \max(l_k)$; $R = \max(u_k)$; $\Delta = R - L$. That is, the usual value is calculated according to the following formula:

$$\tilde{N}_k^{def} = L + \Delta \times \\ \times \frac{(m_k - L)(\Delta + u_k - m_k)^2 \times \times (R - l_k) + (u_k - L)^2(\Delta + m_k - l_k)^2}{(\Delta + m_k - l_k)^2(\Delta + u_k - m_k)^2(R - l_k) + +(u_k - L)(\Delta + m_k - l_k)^2(\Delta + u_k - m_k)}. \tag{8}$$

Based on the results of the calculation carried out in step 7, a cause-and-effect diagram was built. Its feature is determination of the causal and consequential dangerous factors. As a result, $r + c$ indicates the importance of criterion i in the system and $r - c$ shows the effect of criterion i in the system. If $r - c$ is positive, the effect of criterion i belongs to the group of reasons, and if $r - c$ is negative, the effect of the criterion belongs to the group of "dependents", which allows establishing the most important (causal) ones, according to which the risks are determined when performing the road freight transportation.

4 Research results

To assess the risks in implementation of the RFT, one can use the "Bowtie" model [24], which is the most widespread, as it allows to clearly establish, by visualizing, the cause-and-effect relationships. Moreover, with its help, it is quite simple to show the effect of DFs, which increase the probability of the dangerous event occurrence (Figure 3). The latter, in accordance with the requirements of the international standards of the ISO 9000, ISO 14000, ISO 39000, ISO 45000 series, include all the external and internal threats, challenges, inconsistencies that are identified during audits, analyzes by management, investigation of incidents, accidents during implementation RFT [11-12].

Thus, the analysis of various literary sources [25-27], as well as familiarity with the main causes of traffic accidents, made it possible to establish the main dangers (Table 3) that lead to traffic accidents and represent any source with the possibility of causing injury and deterioration of driver health.

Considering that the dangerous event occurrence is significantly influenced by various factors that increase its occurrence and the severity of its consequences, there is a necessity to build an appropriate register that would take into account at least several different groups of factors: human, organizational, social, technical, climatic, ergonomic ones. In each of the groups listed in Tables 4 and 5, specific dangerous factors that belong to one or another organization are considered. They are formed from working conditions, economic situation, technology and other components of organizational culture, which includes common/individual language/knowledge, acceptable technical solutions, common values, views, explicit/implicit symbols, shared experience, social customs and social norms, "maps meanings" that make social life understandable for employees of a separate company.

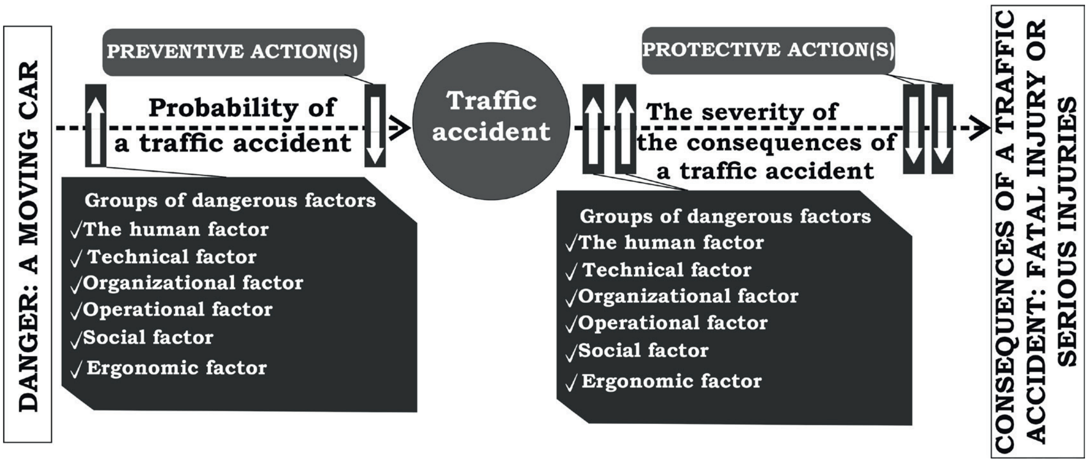

Figure 3 *The OR management model in the presence of DF in the external and internal environment of an organization*

Table 3 *Register of dangers affecting the motor vehicle driver*

Threat	Dangerous event	General DF		Consequences of a dangerous event
		Affecting the probability of the occurrence of a dangerous event	Affecting the degree of severity of the consequences of the occurrence of a dangerous event	
A moving car	Traffic accident	Organizational factors; the condition of the driver; technical condition of the car; climatic factor, social factor	The condition of the driver, the technical condition of the car, the condition of the water, operational and organizational factors	Serious injuries: broken bones, ruptured internal organs, skull fracture and brain contusion, etc.
Running car engine	Fire	Technical condition of the car, operational	Technical condition of the car, condition of the driver, operational, organizational factor	Serious injuries: burns and others
A working car engine in which fuel vapors have accumulated	Explosion	Technical condition of the car	Technical condition of the car, water condition, operational, organizational factor	Severe injuries: broken bones, ruptured internal organs, skull fracture and brain contusion, burns, etc.

As it has been already mentioned, a necessary condition for a successful occupational risks assessment is identification of all the potential hazards and their DFs, which is the basis of the first step in the OR assessment - hazard identification. The main complexity of the mentioned process includes the processing of a significant amount of information, that is, determination of the influence of one or another factor based on the establishment of cause-and-effect relationships, which would be carried out using the DEMATEL method, the algorithm of actions according to which is described above. A group of experts (Table 1) separately from each other, conducted pairwise comparisons of the determined dangerous factors (Table 4 and 5) and filled in the corresponding matrix-diagram (Figure 4) with pre-established criteria (Table 2). Unfortunately, this process is significantly influenced by the subjective judgments of experts, which are reinforced by possible cognitive distortions. Therefore, there is a necessity to apply various mathematical approaches to process the results received from experts and check their estimates for emissions, the Grubbs' criterion is used:

$$G_{\max} = \frac{X_n - \bar{X}}{S}, \tag{9}$$

where X_n is the proposed expert assessments, $\bar{X}$ is the sample mean and S is the mean square deviation.

Where it is necessary to calculate the mathematical expectation or the average value of the obtained results:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i. \tag{10}$$

It is also necessary to calculate the mean square deviation:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(X_i - \bar{X})^2}. \tag{11}$$

With help of the following formulas, one checks for outliers the maximum and minimum results of expert assessments, provided that the indicator exceeds the critical value:

$$\begin{cases} G_{\max} \geq G_{n,1-\alpha} \\ G_{\min} \geq G_{1,1-\alpha} \end{cases}, \quad (12)$$

Table 4 *An example of a low-risk register - a moving truck (when carrying out an RFT) - part 1*

A group of dangerous factors	Designation of the factor	Dangerous factor (DF)
Human	A_1	Distractions while driving - texting or talking on a cell phone
	A_2	Lack of system understanding skills and safe decision-making skills
	A_3	Aggressive behavior while driving a truck
	A_4	Negative physical state of health and psycho-physiological state of the driver
	A_5	Lack of regular and periodic training to improve professional skills
Technical	A_6	Non-compliance of the truck with the physical and chemical properties of the transported cargo
	A_7	Inconsistency of the carrying capacity of a vehicle with the amount of cargo being transported
	A_8	Operation of a technically defective truck and equipment
	A_9	Low-quality spare parts and untimely installation and replacement of units and assemblies according to the terms of maintenance and repair.
	A_{10}	Operation of the equipment after the warranty period of operation
	A_{11}	Untimely replacement of hydraulic fittings during maintenance
	A_{12}	Negligence in observing the technical condition of the truck's passive safety systems (airbags, safety belts, impact-absorbing bumpers, etc.).
	A_{13}	Lack of appropriate equipment of the truck to perform the RFT
	A_{14}	Lack of high-quality supervision and technical inspection of the technical condition of the truck

Table 5 *An example of a low-risk register - a moving truck (when carrying out an RFT) - part 2*

A group of dangerous factors	Designation of the factor	Dangerous factor (DF)
Organizational	A_{15}	Lack of emergency equipment (fire extinguisher, etc.), first aid kits
	A_{16}	Exceeding the standard working time of a truck driver (driver fatigue)
	A_{17}	Overloading of a truck when carrying out the RFT
	A_{18}	The cabin is dirty, there are foreign objects in the driver‘s seat
	A_{19}	Lack of regular diagnostics and appropriate maintenance
Operating	A_{20}	Inconsistency of tire pressure with the road conditions
	A_{21}	Unadjusted electronic driver assistance systems when driving a truck
	A_{22}	Lack of proper pre-race medical control of the driver‘s health
	A_{23}	Fog, rain, snow/night time - poor visibility of the road by the driver
Social	A_{24}	Lack of financial support in a difficult situation
	A_{25}	Low wages
	A_{26}	Absence of monetary supplements for the difficulty of performing professional functions
	A_{27}	Overtime work schedule
Ergonomic	A_{28}	Lack of ease of steering wheel adjustment
	A_{29}	Lack of sufficient and convenient visibility at the workplace
	A_{30}	Lack of adequate air conditioning/heating system

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}	A_{17}	A_{18}	A_{19}	A_{20}	A_{21}	A_{22}	A_{23}	A_{24}	A_{25}	A_{26}	A_{27}	A_{28}	A_{29}	A_{30}
A_1	1	VH	H	NO	H	VL	NO	L	VH	H	H	L	H	H	L	NO	H	NO	L	NO	L	VL	VH	H	L	NO	VL	VL	VH	H
A_2	VH	1	VH	L	VH	L	L	VH	VH	H	H	L	H	H	H	NO	H	NO	L	NO	L	NO	VH	H	NO	VL	VL	VL	VH	H
A_3	H	VH	1	H	VH	H	L	VH	VH	L	L	H	H	H	L	NO	H	NO	H	NO	L	NO	VH	L	L	VL	VL	VL	VH	VH
A_4	NO	L	H	1	L	VL	NO	NO	NO	NO	VL	NO	NO	NO	L	H	H	H	H	VH	H	L	NO	L	NO	H	VH	H	H	H
A_5	H	VH	VH	L	1	L	L	L	VH	H	VH	L	L	L	H	NO	L	VL	L	NO	VL	L	VH	L	L	NO	NO	L	VH	VH
A_6	VL	L	H	VL	L	1	VH	VH	H	VH	VH	VH	VH	VH	VH	H	H	L	H	VL	NO	VL	L	L	VH	NO	NO	VL	H	H
A_7	NO	L	L	NO	L	VH	1	VH	H	VH	VH	VH	VH	VH	VH	VL	VL	H	VH	NO	NO	L	L	VL	VH	H	H	NO	L	L
A_8	L	VH	VH	NO	L	VH	VH	1	H	VH	VH	VH	VH	VH	VH	H	H	H	VH	NO	L	L	L	L	VH	H	L	NO	L	L
A_9	VH	VH	VH	NO	VH	H	H	H	1	VH	VH	VH	VH	VH	VH	L	H	L	H	NO	L	NO	VH	NO	VH	VL	VL	NO	VH	VH
A_{10}	H	H	L	NO	H	VH	VH	VH	VH	1	VH	VH	VH	VH	H	L	L	L	VH	NO	L	NO	H	NO	VH	H	L	L	L	L
A_{11}	H	H	L	VL	VH	VH	VH	VH	VH	VH	1	VH	VH	VH	H	H	L	H	VH	NO	VL	NO	L	VL	VH	H	NO	VL	L	L
A_{12}	L	L	H	NO	L	VH	VH	VH	VH	VH	VH	1	VH	VH	H	H	L	H	VH	L	H	NO	L	VL	VH	H	NO	VL	L	L
A_{13}	H	H	H	NO	L	VH	VH	VH	VH	VH	VH	VH	1	VH	VH	H	H	L	H	VH	L	H	NO	L	VL	VH	H	NO	VL	L
A_{14}	H	H	H	NO	L	VH	VH	VH	VH	VH	VH	VH	VH	1	H	H	H	H	H	L	NO	NO	L	VL	VH	L	VL	L	H	H
A_{15}	L	H	L	NO	H	VH	VH	VH	VH	H	H	H	H	H	1	VL	VL	VL	L	NO	H	H	H	L	VH	H	NO	NO	H	H
A_{16}	NO	NO	NO	H	NO	H	L	H	L	L	H	H	NO	H	VL	1	VH	H	H	NO	VH	H	H	L	L	L	L	NO	NO	NO
A_{17}	H	H	H	H	L	H	L	H	H	L	L	L	VL	H	VL	VH	1	L	L	NO	VH	VL	L	VL	H	NO	VL	VL	H	H
A_{18}	NO	NO	NO	H	VL	L	H	H	L	L	H	H	NO	H	VL	H	L	1	VL	VH	VH	H	NO	VL	H	H	H	VH	VH	H
A_{19}	L	L	H	H	L	H	VH	VH	H	VH	VH	VH	H	H	L	H	L	VL	1	H	H	NO	L	NO	VH	L	VL	NO	NO	L
A_{20}	NO	NO	NO	VH	NO	VL	NO	NO	NO	NO	NO	L	VL	L	NO	NO	NO	VH	H	1	VH	VH	NO	L	NO	L	H	VH	VH	VH
A_{21}	L	L	L	H	VL	NO	NO	L	L	L	VL	H	NO	NO	H	VH	VH	VH	H	VH	1	VH	VH	VH	VH	VH	VH	H	H	H
A_{22}	VL	NO	NO	L	L	VL	L	L	NO	NO	NO	NO	NO	NO	H	H	VL	H	NO	VH	VH	1	H	VH	L	H	NO	L	L	H
A_{23}	VH	VH	VH	NO	VH	L	L	L	VH	H	L	L	L	L	H	H	L	NO	L	NO	VH	H	1	VH	VH	L	NO	VL	VH	VH
A_{24}	H	H	L	L	L	L	VL	L	NO	NO	VL	VL	VL	VL	L	L	VL	VL	NO	L	VH	VH	VH	1	L	H	NO	L	VH	VH
A_{25}	L	NO	L	NO	L	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	L	NO	H	VH	H	VH	L	VH	L	1	VH	VH	L	L	L
A_{26}	NO	VL	VL	H	NO	NO	H	H	VL	H	H	H	H	L	H	L	NO	H	L	L	VH	H	L	H	VH	1	VH	L	L	L
A_{27}	VL	VL	VL	VH	NO	NO	H	L	VL	L	NO	NO	NO	VL	NO	L	VL	H	VL	H	VH	NO	NO	NO	VH	VH	1	L	NO	NO
A_{28}	VL	VL	VL	H	L	VL	NO	NO	NO	L	VL	VL	VL	L	NO	NO	VL	VH	NO	VH	H	L	VL	L	L	L	L	1	VH	VH
A_{29}	VH	VH	VH	H	VH	H	L	L	VH	L	L	L	L	H	H	NO	H	VH	NO	VH	H	L	VH	VH	L	L	NO	VH	1	VH
A_{30}	H	H	VH	H	VH	H	L	L	VH	L	L	L	L	H	H	NO	H	H	L	VH	H	H	VH	VH	L	L	NO	VH	VH	1

Figure 4 *An example of the matrix of pairwise comparisons, which is filled out by experts*

where α is the level of significance, which is determined in accordance with the requirements [28].

In the case of non-fulfillment of the specified inequality, the results of evaluations will be considered as emissions that must be excluded. In addition, the experts who gave such an assessment are clarified to identify the reasons for e validity of their choices of points during the examination. Critical values of statistics are chosen based on the distribution law of a random variable. Those values can be found for a normal distribution according to the requirements of [28]. In the case of suspicion of two outliers, Grubbs' two-outlier statistic is used to evaluate the population of results.

The dimensions of the matrix-diagram are determined by the number of the DFs that affect the activity of drivers when performing the road freight transportation. In this case, an appropriate number (thirty) of DFs was proposed during the implementation of the RFT, although this list is far from complete. Each expert analyzes the causal relationship between a pair of DFs. At the same time, the connection can be absent, weak or strong, which is encoded by the corresponding symbols. The subjectivity of experts' judgments at this stage is reduced during the averaging of their results after steps 4, 5, when the general matrix of connections of the determined DFs is built. In this case, the judgment of experts is, as a rule, based on the OR control approach. In addition, to reduce the influence of subjectivity of judgments during the transformations of the values of the relationship between DFs established by experts, a threshold indicator (μ) at the level of 0.5 was introduced, which makes it possible to filter out rather insignificant connections in which the experts were not sure [25]. It is worth noting that to reduce the subjectivity of experts' judgments, when calculating the degree of importance and impact of the OR, the standard deviation σ was considered to determine the threshold indicator (μ), which was determined from the matrix of the overall impact. The threshold value is set by calculating the sum of the mean and standard deviation ($\mu + \sigma$). At the same time, it is considered that all the DFs from each group will lead to a dangerous event and, in general, cause harm to human life or disruption of the performance of the transport task during the implementation of the road freight transportation. In addition, when compiling a matrix-diagram, experts are invited to take into account the possibility of controlling the value of each factor. Next, processing of the results of the conversion is carried out, which allows obtaining the prioritization of DFs (Table 6 and 7) and conducting a detailed analysis to determine their impact on a dangerous event. So, in the given example, the largest indicator ($r + c$) is recorded in the DF numbered A_2, A_3, A_4, A_{11}, A_{12}, A_{14}, A_{15}, A_{16}, A_{15}, A_{17}, A_{18}, A_{20}, A_{21}, A_{22}, A_{23}, A_{25}, A_{26}, A_{27}, A_{28}, A_{29}, A_{30} (Figure 5), while taking into account only those dangerous factors in which the difference ($r - c$) had positive values.

Based on [26], the determined causal factors can be divided into decisive, that is, those that affect the probability of the dangerous event occurrence and secondary - those that have a less strong influence $\tilde{N}_k = (l_k, m_k, u_k); k = 1,2,...,n$. For this, used the condition that the level of influence, which is calculated as $r - c$, should be bigger than the average number of S_{cp}. matrices of general influence. The basis of this transformation is the combination of r and c criteria into a single matrix by transforming the "positive" indicator of the value of each factor into a "positive" one. Additionally, an alternative approach for determining the significant dangerous factors is presented. Thus, the causal dangerous factors are determined by fulfilling the condition $r_i / c_i > 1$ or $r_i - c_i > 0$. The next step is to establish the significance of the causal dangerous factor. For this purpose, it is proposed to determine the range for the indicator of the level

***Table 6** Prioritization of DFs based on degree of importance (r + c) and level of influence (r - c) - part 1*

DF	Calculated data		Degree of importance	Level of influence	Determination of the type of DF	Determining the significance of the impact of the causative DF	Definition of the DF used in risk calculations (if causal and significant)
	r	*c*	*r + c*	*r - c*			
A_1	28.44	28.73	57.17	-0.29	consequential	not considered	not used
A_2	32.53	28.28	60.11	3.65	causal	essential*	used
A_3	31.36	28.24	59.10	3.12	causal	essential	used
A_4	26.69	29.24	55.93	-2,55	consequential	not considered	used
A_5	28.02	28.39	56.41	-0.37	consequential	not considered	used
A_6	28.02	29.79	57.81	-1.77	consequential	not considered	used
A_7	29.26	28.10	57.36	1.16	causal	not essential*	used
A_8	27.71	29.21	56.92	-1.50	consequential	not considered	used
A_9	28.93	28.12	57.05	0.81	causal	not essential	used
A_{10}	27.72	28.53	56.25	-0.81	consequential	not considered	used
A_{11}	25.74	28.70	54.44	-2.96	consequential	not considered	used
A_{12}	30.55	28.48	59.03	2.07	causal	essential	used
A_{13}	27.77	28.93	56.70	-1.16	consequential	not considered	used
A_{14}	32.26	28.61	60.87	3.65	causal	essential	used

***Table 7** Prioritization of DFs based on degree of importance (r +c) and level of influence (r - c) - part 2*

DF	Calculated data		Degree of importance	Level of influence	Determination of the type of DF	Determining the significance of the impact of the causative DF	Definition of the DF used in risk calculations (if causal and significant)
	r	*c*	*r + c*	*r - c*			
A_{15}	31.14	29.31	60.45	1.83	causal	essential*	used
A_{16}	30.58	29.16	59.74	1.42	causal	essential	used
A_{17}	31.13	28.82	59.95	2.31	causal	essential	used
A_{18}	31.23	28.40	59.63	2.83	causal	essential	used
A_{19}	26.53	27.55	54.08	-1.02	consequential	not considered	not used
A_{20}	28.60	27.94	56.54	0.66	causal	not essential*	not used
A_{21}	27.08	27.82	54.90	-0.74	consequential	not considered	not used
A_{22}	31.49	29.33	60.82	2.16	causal	essential	used
A_{23}	30.61	29.20	59.81	1.41	causal	essential	used
A_{24}	28.72	29.14	57.86	-0.42	consequential	not considered	not used
A_{25}	26.00	27.86	53.86	-1.86	consequential	not considered	not used
A_{26}	25.85	28.05	53.90	-2.20	consequential	not considered	not used
A_{27}	30.09	28.51	58.60	1.58	causal	essential	used
A_{28}	27.77	27.63	55.40	0.14	causal	not essential	not used
A_{29}	26.18	27.87	54.05	-1.69	consequential	not considered	not used
A_{30}	26.91	28.39	55.30	-1.48	consequential	not considered	not used

Note* causative case at $r - c > 0$ *or* $r/c > 1$; * causative case at $r - c \leq 0$ *or* $r/c \leq 1$; *essential $S_{cp} > 1.2$ *or* $\max(r-c) \geq (r-c) > 0.2\max(r-c)$; *not essential $S_{cp} \leq 1.2$ *or* $0.2\max(r-c) > (r-c) > 0$.

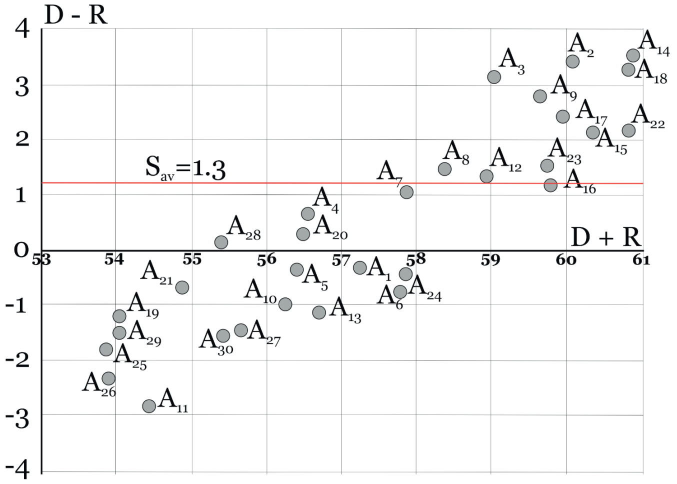

Figure 5 The connection map example between the measurements of DF (S_{av} average number of the matrix of general influence is 1.3)

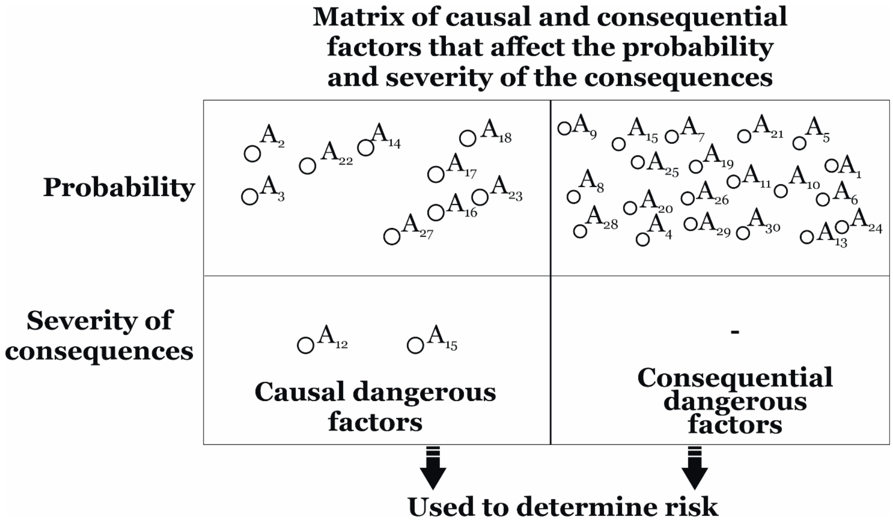

Figure 6 Division of consequential DFs into influential ones in terms of probability and severity of consequences according to criteria

of influence (r_i - c_i) from the principle "As low as reasonably practicable" (ALARP), that is, the residual level of risk should be reduced as much as it is practically possible. In this case, the following condition is provided: $\max(r-c) \geq (r_i - c_i) > 0.2\max(r-c)$, i.e., the level of influence is limited up to 80% of all the cases. As a result of the calculations, only 11 dangerous factors A_2, A_3, A_{12}, A_{14}, A_{15}, A_{16}, A_{17}, A_{18}, A_{22}, A_{23}, A_{27} would satisfy the given condition.

The obtained results would be divided into four zones in accordance with the recommendations [29] (Figure 6). The first zone includes the causal factors that affect the probability of the dangerous event occurrence, the calculation of which satisfied the above-mentioned condition - A_2, A_3, A_{12}, A_{14}, A_{15}, A_{16}, A_{17}, A_{18}, A_{22}, A_{23}, A_{27}.

The second level includes consequential factors that have an impact on probability of a dangerous event occurrence, as well. The third level allows to establish the causal factors that affect the severity of the consequences, which include A_{12}, A_{15}. In the fourth zone, there are also the consequential factors that affect the severity of the consequences, but they were not identified in this study.

In this study, it is assumed that for the further analysis of the occurrence assessment of a dangerous event, we select only dangerous factors that are the causes and form the corresponding impact on the dangerous event and the severity of consequences. Constructed prioritization of the dangerous factors, compatible with their ranking, makes it possible to obtain a map of connections from which it is clearly visible how the faults are related to each other and which of them are causal and which are consequential. If the first (causal) faults are eliminated, the second ones will disappear or at least weaken the influence, as well, however, experts still need to further analyze the results to identify possible inaccuracies.

The last step of the procedure is to clarify the cause-and-effect relationships between the hazard and the dangerous event and the consequences severity,

Table 8 *The form for determining the cause-and-effect relationship between a hazard, a dangerous event, DF and the consequences of an RFT*

Danger	DFs that affect the increase in the probability of a dangerous event occurring	Dangerous event	DFs that affect the increase in severity from the occurrence of a dangerous event	Consequences
Moving truck	A_2. Lack of system understanding skills and safe decision-making skills by a driver on the road A_3. Aggressive behavior while driving a truck A_{14}. Lack of high-quality supervision and technical inspection of the technical condition of the truck A_{16}. Exceeding the standard working time of a truck driver (driver fatigue) A_{17}. Overloading of a truck when carrying out RFT A_{18}. The cabin is dirty, there are foreign objects in a driver's seat A_{22}. Lack of proper pre-race medical control of driver's health A_{23}. Fog, rain, snow/nighttime - poor visibility A_{27}. Overtime work schedule	Traffic accident	A_{12}. Negligence in observing the technical condition of the truck's passive safety systems (airbags, safety belts, impact-absorbing bumpers, etc.). A_{15}. Lack of emergency equipment (fire extinguisher, etc.), first aid kits	Driver injuries (disability, death)

taking into account the established significant DFs. In particular, one can fill out the appropriate form (Table 8), which allows to further evaluate the OR when implementing the road freight transportation.

5 Discussion

The DFs' identification process involves the cause and sources of risk determination, as well as events and situations that may have general results regarding the objectives and nature of the OR. Taken together, this is the foundation for justification of the effective preventive and protective measures. From this example, six main DFs have been identified, which have the greatest impact on both the probability of an incident occurring, as well as six DFs that affect the severity of the consequences, which allows for a more thorough study of these factors' influence on the magnitude of the risk in the future. The specified DFs were determined based on determination of the cause-and-effect relationships, by evaluating pairwise comparisons to establish the most influential DFs on the occurrence probability of a dangerous event by degree of importance, and for the severity of consequences - by the level of influence, which are determined by transforming a vague set into a clear number by the affiliation degree, which occurs during the relevant calculations using the Dematel method. This conclusion is supported by the existing classic studies conducted using the fuzzy Dematel method [30-31], which can be classified into three types: the first type is relationships identification between factors or criteria; the second type is determination of the key factors based on cause-and-effect relationships and degrees of interrelationship between them; the third type is the weighting criteria determination by analyzing the relationships and levels of criteria influence. The last two types make it possible to transform the relationships between the factors into an understandable structural model of the system and divide them into a group of causes and a group of consequences [32]. For this, a threshold value, such as the mean of the total effect matrix, is set to filter out minor effects. Thanks to a detailed review of the Dematel methodology, there is an opportunity to reduce the influence of subjective judgments of experts through the uncertainty assessment in the decision-making process using the fuzzy sets to capture the relationships of mutual influence between quality attributes [33].

When determining the significant DFs, one should also pay attention to development of a dangerous event, evaluate the effectiveness of all the existing control measures, for example, design specifications, timeliness of providing medical assistance, and propose those that would significantly reduce the level of OR. This will make it possible to adjust the threshold indicator to avoid errors and reduce the subjectivity influence. It should be noted that most of the relevant DFs are interdependent, which also needs to be taken into account when establishing causal and consequential DFs. The higher the relationship weight is set, the better the score will be compared to others.

For example, certain limitations must be considered when interpreting the obtained results. First, the magnitude of established causal relationships cannot be established between variables. Yes, it cannot be ruled out that the frequent aggressive driving of the A_3 can be reduced with appropriate controls or better professional training. Secondly, the threshold indicator is set without distinguishing groups of factors, although it can be considered that the human factor has the greatest influence on the road accident occurrence [34-35]. In other words, in this study, DFs were assessed as a broad construct, and future studies could further focus on specific threats based on their occupational context.

6 Conclusions

To carry out the process of hazards and DFs identification, it is proposed to provide an appropriate ranking of the latter to identify the most important (causal) ones, according to which the OR is determined during the implementation of the road freight transportation.

A register of the DFs has been developed, which include six typical groups: human, organizational, technical, operational, social, ergonomic, which increase the probability of a dangerous event occurring during the implementation of RFT.

Based on the cause-and-effect relationships, using the fuzzy Dematel method, using the Grubbs criterion, the most influential variables that affect the probability of a dangerous event and the severity of consequences are determined to assess the risk of a road accident.

It is suggested that the most influential dangerous factors are determined by comparing the indicator of the influence level of DFs (c) to the average number of the matrix of total impact (S_{cp}), when the condition ($c_i \geq S_{cp}$) is fulfilled, and if the condition that r_i / $c_i > 1$ or $r_i - c_i > 0$ is fulfilled, followed by determination of the DF significance by limiting the exposure level indicator to a certain range, which is calculated based on the "As low as reasonably practicable" (ALARP) principle, i.e. the residual risk level should be reduced as much as it is practically possible.

It is proposed to reduce the subjectivity of experts' judgments, regarding the influence of DFs on probability of a dangerous event occurrence, when calculating their degree of importance and impact using the fuzzy Dematel method to adjust the threshold indicator that excludes weak relationships during a pairwise comparison of DFs, by taking into account the standard deviation, which was determined from the general influence matrix, using the Grubbs test.

An improved bow tie model, which visualizes the cause-and-effect relationship between danger and a dangerous event in the implementation of freight road transportation, which provides for the risk assessment to take into account dangerous factors that increase the probability of an incident and the severity of the consequences of its occurrence.

Grants and funding

The authors received no financial support for the research, authorship and/or publication of this article.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Conventions and recommendations - International Labour Organization (ILO) [online] [accessed 2023-02-15]. Available from: https://www.ilo.org/global/standards/introduction-to-international-labour-standards/conventions-and-recommendations/lang--en/index.htm

[2] On labor protection - Law of Ukraine [online] [accessed 2023-02-15]. Available from: https://zakon.rada.gov.ua/laws/show/2694-12/ed20110625#Text

[3] Order on the approval of the standard regulation on the procedure for conducting training and testing knowledge on occupational health and safety issues and the list of high-risk jobs [online] [accessed 2023-02-15]. Available from: https://zakon.rada.gov.ua/laws/show/z0231-05?lang=en#Text

[4] Resolution on approval of the procedure for investigating and recording accidents, occupational diseases and accidents at work [online] [accessed 2023-02-15]. Available from: https://zakon.rada.gov.ua/laws/show/en/337-2019-%D0%BF?lang=en#Text

[5] On the main principles of state supervision (oversight) in the area of commercial activity - Law of Ukraine [online]. [accessed 2023-02-15]. Available from: https://zakon.rada.gov.ua/laws/show/877-16?lang=en#Text

[6] STEPHENS, A., OHTSUKA, K. Cognitive biases in aggressive drivers: does illusion of control drive us off the road? *Personality and Individual Differences* [online]. 2014, **68**, p. 124-129 [accessed 2023-02-15]. ISSN 0191-8869. Available from: https://doi.org/10.1016/j.paid.2014.04.016

[7] TSOPA, V., CHEBERIACHKO, S., YAVORSKA, O., DERYUGIN, O., ALEKSIEIEV, A. Improvement of the safe work system. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu* [online]. 2022, **6**, p. 104-111 [accessed 2023-02-15]. ISSN 2071-2227, e-ISSN 2223-2362. Available from: https://doi.org/10.33271/nvngu/2022-6/104

[8] MAIREAN, C., HAVARNEANU, G., BARIC, D., HAVARNEANU, C. Cognitive biases, risk perception, and risky driving behaviour. *Sustainability* [online]. 2022, **14**(1), 77 [accessed 2023-02-15]. ISSN 2071-1050. Available from: https://doi.org/10.3390/su14010077

[9] STOLECKA, K. Hazards of the road transportation of hazardous materials. *System Safety: Human - Technical Facility - Environment* [online]. 2020, **2**(1), 237-246 [accessed 2023-02-15]. ISSN 2657-5450. Available from: https://doi.org/10.2478/czoto-2020-0029

[10] LI, H., WANG, Y. Research on the road transport risk of domestic hazardous chemicals. In: 3rd Annual International Conference on Management Science and Engineering MSE 2017: proceedings. Vol. 50. Advances in Economics, Business and Management Research. 2017. ISSN 2352-5428, p. 164-171. Available from: https://doi.org/10.2991/mse-17.2017.42

[11] LITVINOVA, Y. Finding ways of building sustainable trails cargo transportation using optimization methods and computational tools. In: 25th International Scientific Conference Transport Means 2021: proceedings. 2021. ISSN 1822-296X, eISSN 2351-7034, p. 514-519.

[12] DOROSH, A., DEMCHENKO, Y., MARKUL, R., BERDYCHEVSKA, T. Analysis of risks of international road cargo transportation. *Transport Systems and Transportation Technologies* [online]. 2020, **20**, p. 12-19 [accessed 2023-03-10]. ISSN 2222-419X. Available from: https://doi.org/10.15802/tstt2020/217388

[13] STAZNIK, A., BABIC, D., BAJOR, I. Identification and analysis of risks in transport chains. *Journal of Applied Engineering Science* [online]. 2017, **15**(1), p. 61-70 [accessed 2023-03-10]. ISSN 1451-4117. Available from: http://dx.doi.org/10.5937/jaes15-12179

[14] BAZALUK, O., KORIASHKINA, L., CHEBERYACHKO, S., DERYUGIN, O., ODNOVOL, M., LOZYNSKYI, V., NESTEROVA, O. Methodology for assessing the risk of incidents during passenger road transportation using the functional resonance analysis method. *Heliyon* [online]. 2022, **8**(75), e11814 [accessed 2023-03-10]. ISSN 2405-8440. Available from: http://dx.doi.org/10.1016/j.heliyon.2022.e11814

[15] MARTO, A., HAJIHASSANI, M., JAHED ARMAGHANI, D., TONNIZAM MOHAMAD, E., MAKHTAR, A. A novel approach for blast-induced flyrock prediction based on imperialist competitive algorithm and artificial neural network. *The Scientific World Journal* [online]. 2014, **2014**, 643715 [accessed 2023-03-10]. ISSN 2356-6140, eISSN 1537-744X. Available from: https://doi.org/10.1155/2014/643715

[16] TRIVEDI, R., SINGH, T., RAINA, A. Prediction of blast-induced flyrock in Indian limestone mines using neural networks. *Journal of Rock Mechanics and Geotechnical Engineering* [online]. 2014, **6**(5), p. 447-454 [accessed 2023-03-10]. ISSN 1674-7755. Available from: https://doi.org/10.1016/j.jrmge.2014.07.003

[17] CHAUHAN, A., SINGH, A., JHARKHARIA, S. An interpretive structural modeling (ISM) and decision-making trail and evaluation laboratory (DEMATEL) method approach for the analysis of barriers of waste recycling in India. *Journal of the Air and Waste Management Association* [online]. 2018, **68**(2), p. 100-110 [accessed 2023-03-10]. ISSN 1096-2247. Available from: https://doi.org/10.1080/10962247.2016.1249441

[18] PANDEY, M., LITORIYA, R., PANDEY, P. Application of fuzzy DEMATEL approach in analyzing mobile application issues. *Programming and Computer Software* [online]. 2019, **45**(5), p. 268-287 [accessed 2023-03-10]. ISSN 0361-7688, eISSN 1608-3261. Available from: https://doi.org/10.1134/S0361768819050050

[19] SEKER, S., ZAVADSKAS, E. Application of fuzzy DEMATEL method for analyzing occupational risks on construction sites. *Sustainability* [online]. 2017, **9**(11), 2083 [accessed 2023-03-10]. ISSN 2071-1050. Available from: https://doi.org/10.3390/su9112083

[20] SADEHNEZHAD, F., ZARANEJAD, M., GHEITANI, A. Using combinational method DEMATEL and ANP with fuzzy approach to evaluate business intelligence performance. *European Online Journal of Natural and Social Sciences* [online]. 2013, **2**(3), p. 1374-1386 [accessed 2023-03-10]. ISSN 1805-3602. Available from: https://european-science.com/eojnss/article/view/757

[21] TSOPA, V., CHEBERIACHKO, S., YAVORSKA, O., DERYUGIN, O., BAS, I. Increasing the safety of the transport process by minimizing the professional risk of a dump truck driver. *Mining of Mineral Deposits* [online]. 2022, **16**(3), p. 101-108 [accessed 2023-03-10]. ISSN 2415-3443, eISSN 2415-3435. Available from: https://doi.org/10.33271/mining16.03.101

[22] LIN, C., WU, W. A causal analytical method for group decision-making: under fuzzy environment. *Expert Systems with Applications* [online]. 2007, **34**(1), p. 205-213 [accessed 2023-03-10]. ISSN 0957-4174. Available from: https://doi.org/10.1016/j.eswa.2006.08.012

[23] CHEBERIACHKO, S., YAVORSKA, O., DERYUGIN, O., LANTUKH, D., BAS, I., KRUZHILKO, O., MELNYK, V. Improving safety of passenger road transportation. Transactions on transport sciences [online]. 2023, **14**(2), p. 1-10 [accessed 2023-02-08]. eISSN 1802-9876. Available from: https://doi.org/10.5507/tots.2023.003

[24] NECHAYEVA, I., DONCHIK, D. Use of BOWTIE tie technology in risk assessment practice. *Economy and Society* [online]. 2021, **33**, 51 [accessed 2023-03-17]. eISSN 2524-0072. Available from: https://doi.org/10.32782/2524-0072/2021-33-51

[25] SU, C.-M., HORNG, D.-J., TSENG, M.-L., CHIU, A.S.F., WU, K.-J., CHEN, H.-P. Improving sustainable supply chain management using a novel hierarchical grey-DEMATEL approach. *Journal of Cleaner Production* [online]. 2015, **134**, p. 469-481 [accessed 2023-03-17]. eISSN 2524-0072. Available from: http://dx.doi.org/10.1016/j.jclepro.2015.05.080

[26] WU, W.-W., LAN, L. W., LEE, Y.-T. Exploring decisive factors affecting an organization's SaaS adoption: a case study. *International Journal of Information Management* [online]. 2011, **31**(6), p. 556-563 [accessed 2023-03-17]. ISSN 0268-4012. Available from: http://dx.doi.org/10.1016/j.ijinfomgt.2011.02.007

[27] TSENG, M.-L. A causal and effect decision making model of service quality expectation using grey-fuzzy DEMATEL approach. *Expert Systems with Applications* [online]. 2009, **36**(4), p. 7738-7748 [accessed 2023-03-17]. ISSN 0957-4174. Available from: https://doi.org/10.1016/j.eswa.2008.09.011

[28] DSTU GOST ISO 5725-2:2005 (GOST ISO 5725-2-2003, IDT). Accuracy (correctness and precision) of measurement methods and results. Part 2. The main method of determining the repeatability and reproducibility of the standard measurement method [online] [accessed 2023-03-17]. Available from: http://online.budstandart.com/ua/catalog/doc-page?id_doc=84968

[29] WU, W.-W., LEE, Y.-T. Developing global managers' competencies using the fuzzy DEMATEL method. *Expert Systems with Applications* [online]. 2007, **32**(2), p. 499-507 [accessed 2023-03-17]. ISSN 0957-4174. Available from: https://doi.org/10.1016/j.eswa.2005.12.005

[30] LIANG, H., REN, J., GAO, Z., GAO, S., LUO, X., DONG, L., SCIPIONI, A. Identification of critical success factors for sustainable development of biofuel industry in China based on grey decision-making trial and evaluation laboratory (DEMATEL). *Journal of Cleaner Production* [online]. 2016, **131**, p. 500-508 [accessed 2023-03-17]. ISSN 0959-6526, eISSN 1879-1786. Available from: https://doi.org/10.1016/j.jclepro.2016.04.151

[31] ABDULLAH, L., ZULKIFLI, N. Integration of fuzzy AHP and interval type-2 fuzzy DEMATEL: an application to human resource management. *Expert Systems with Applications* [online]. 2015, **42**(9), p. 4397-4409 [accessed 2023-03-17]. ISSN 0957-4174. Available from: https://doi.org/10.1016/j.eswa.2015.01.021

[32] HUANG C.-Y., SHYU J. Z., TZENG G.-H. Reconfiguring the innovation policy portfolios for Taiwan's SIP mall industry. *Technovation* [online]. 2007, **27**(12), p. 744-765 [accessed 2023-03-17]. ISSN 0166-4972. Available from: https://doi.org/10.1016/j.technovation.2007.04.002

[33] AZADEH, A., ZARRIN, M., ABDOLLAHI, M., NOURY, S., FARAHMAND, S. Leanness assessment and optimization by fuzzy cognitive map and multivariate analysis. *Expert Systems with Applications* [online]. 2015, **42**(15-16), p. 6050-6064 [accessed 2023-03-17]. ISSN 0957-4174. Available from: https://doi.org/10.1016/j.eswa.2015.04.007

[34] MAIREAN, C., DIACONU-GHERASIM, L. Time perspective, risk perception on the road, and risky driving behavior. *Current Psychology* [online]. 2023, **42**, p. 5611-5620 [accessed 2023-03-17]. ISSN 1936-4733, eISSN 1046-1310. Available from: https://doi.org/10.1007/S12144-021-01921-2

[35] O'BRIEN, F., GORMLEY, M. Risk-perception and dangerous driving among adolescents: outcome- and behavior-focused questions yield opposite results. *Journal of Adolescence* [online]. 2016, **52**, p. 89-94 [accessed 2023-03-17]. ISSN 1095-9254. Available from: https://doi.org/10.1016/j.adolescence.2016.07.010