On the methodology for risk assessment in transport of dangerous goods by road

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Abstract. The general trend in the development of the technosphere implies a constant increase in the volume of transport of dangerous goods by road. The combination of "dangerous cargo and vehicle" is potentially dangerous because it can pose additional risks to road users, as well as to the environment (nature and population). For this reason, it is necessary to conduct appropriate risk analyses for the transport of dangerous goods by road, which makes it possible to assess such risks.

1. Introduction
Natural and man-made emergencies pose a threat to the life and health of the population, economy and ecology of the regions. The problem is justified by the growing threats of man-made and terrorist nature, and especially for those territories that are characterized by a high concentration of production facilities that receive, use, process, store and transport dangerous substances.

2. The relevance of the topic and the current state of the problem
Assessment and development of measures for the prevention and liquidation of emergency situations is carried out during the development of planning documents, including the safety data sheets of the territory, passports and safety declarations of potentially dangerous and critical facilities [1-3].

The safety data sheet contains the characteristics of the area and potentially dangerous facilities located on its territory; materials on the basis of which indicators of the degree of risk of emergencies are justified and confirmed. Also, in accordance with the requirements of the Order of the Ministry of Emergencies of Russia dated 25.10.2004 N 484, maps, plans with the zones of the consequences of possible emergencies, as well as the zones of individual (potential) risk, are applied to the safety data sheet of the municipality. In addition, routes for the transport of dangerous goods are plotted on the territory map.

At the same time, the complexity of developing a Safety Data Sheet, in terms of plotting routes for transporting dangerous goods and taking into account the risks associated with this, lies in the need for
a comprehensive review of various aspects that characterize not only all kinds of emergency situations at defense facilities, but also on routes for transporting dangerous goods.

All types of transport dangerous goods by road are subject to the ADR regulation [4,5]. The current legislation defines the requirements for the carrier, for the cargo owner, for container manufacturers, for rolling stock, as well as for traffic control authorities, however, there are no requirements for the route of transportation of dangerous goods [6,7].

The situation is aggravated by the difficulty of justifying a safe route due to the lack of official statistics on incidents related to the carriage of dangerous goods by road [8]. This is partly due to the fact that the requirements of sections 1.8.3 and 1.8.5.4 of ADR are not fully complied with in the Russian Federation. According to which, if an emergency occurs during loading, filling, transportation or unloading of dangerous goods, a report of the established form is compiled. However, the competent authorities of the Russian Federation have not established a procedure for the collection and analysis of this type of report.

All this allows us to conclude that the topic of identifying indicators and parameters that help to determine the risks on the studied route for the transportation of dangerous goods by road is relevant.

3. Information and methods

Quite often we see special tankers carrying various cargoes on the road. What are they carrying? Gas? Oil? Petrol? It is also worth considering how many “solid dangerous goods” are transported generally on roads in covered vehicles. For example, the most ordinary things, such as enamel paint, plastic film, rags, matches, fishmeal, cotton wool, sparklers and fireworks, household chemicals in aerosols - all this is classified as a dangerous cargo.

Everyone understands that the transportation of dangerous goods is a serious area of activity that requires special equipment, driver skills, permits and, most importantly, maximum caution when loading and unloading and transportation itself. At the same time, an analysis of media reports about incidents involving vehicles carrying dangerous goods (fuels and lubricants, oil, gases, alkalis, etc.) showed that 30 similar incidents occurred on Russian roads in January - February 2020, in which 14 people died, 10 were injured and in 14 cases there was a loss of cargo.

Obviously, compliance with the requirements of ADR does not exclude the likelihood of a man-made emergency, since a vehicle carrying dangerous goods can be subjected to mechanical impact (collision) from another vehicle. Thus, it is advisable to consider that the likelihood of a traffic accident with a vehicle involved in the transport of dangerous goods is identical to the likelihood of a man-made emergency [9].

However, is it possible to apply this approach in practice? Let us figure it out.

The task of analyzing the causes of an accident is to search for and systematize measures and actions aimed at preventing the accident, as well as determining the degree of guilt of those involved in it [10].

In practice, the state traffic Inspectorate of Russia distinguishes the following types of analysis:

- analysis of individual accidents, which can be deterministic, causal, legal analysis, accident expertise, etc.
- analysis of accidents as a mass phenomenon, as a variant of parametric, probabilistic, statistical, etc.

The analysis of single accidents is based on a detailed study of the causes of a particular accident and its consequences, and the analysis of accidents as a mass phenomenon using the data on accidents and other statistical data.

4. Analysis of a single accident

The general scheme of the causal approach to the analysis of a single accident, by definition, should be based on the construction of a certain model or mechanism of the incident, the analysis of the parameters of which should provide the possibility of preventing the accident [11]. However, in the practical activities of State Traffic Safety Inspectorate (STSI) units, the analysis of single traffic
accidents is limited to establishing links between the fact of the accident and violations of the rules and regulations in force in the field of road safety committed by the participants in the accident. The influence of other factors of the system “driver - car - road - environment” remains outside the field of analysis. This circumstance is due to the limited possibility of using probabilistic estimates of causal relationships, since the conclusions of the analysis, being the basis for criminal prosecution, must meet strict requirements of a high degree of reliability [12].

5. Analysis of accidents as a mass phenomenon

When analyzing information about numerous incidents, it becomes clear what are the trends in the indicators that characterize accidents, what factors are associated with the greatest risk of accidents and what should be the focus of efforts to prevent them [13]. At the same time, it is obvious that the initial data do not pretend to reflect causal relationships, but only to state the facts. However, even based on a comparison of various indicators, it is possible to obtain important estimates and, without penetrating into the mechanism of the accident, establish what factors, what conditions increase the likelihood of an accident and how much [14,15].

In the departments of the State Traffic Safety Inspectorate of the Ministry of Internal Affairs of the Russian Federation, the comparison method is used as the main accident analysis method, to use which it is necessary to clearly understand which objects, processes, factors should be compared with each other, according to what characteristics, properties, indicators, a comparison should be carried out, which specific calculation procedure should be the basis of comparison [16-18].

For the analysis of accidents, absolute, specific and relative accident indicators are used.

Absolute indicators are formed as a result of the accumulation of data on single accidents. The main purpose of the absolute indicators is the reflection of the accident rate, the assessment of damage from road accidents, the analysis of the accident dynamics. The absolute indicators include: the number of accidents, the number of fatalities, the number of injured, the number of accidents due to technical malfunction of vehicles and others.

For analysis, absolute indicators should also be used that characterize the conditions in which activities to ensure road safety are carried out. The set of indicators characterizing these conditions depends on the level of road safety management (federal, regional, enterprises engaged in transportation activities), the main ones are:

- characteristics of the socio-economic development of the region (territory, population);
- the size, condition and development of the fleet of vehicles;
- condition and development of the road network (length of various roads, traffic intensity, including along road sections and at various time intervals);
- the availability and effectiveness of the medical ambulance system, monitoring compliance with road safety requirements, the number of enterprises engaged in various types of transportation activities;
- operating conditions of transport organizations (number and structure of the fleet);
- data on transportation routes, number, length of service, age, qualifications of drivers, availability and organization of pre-trip medical examinations, etc.).

At the same time, absolute indicators are not suitable for comparative analysis of the level of road safety. For example, the absolute number of accidents, deaths and injuries cannot be compared with the level of traffic safety in different regions due to differences in the number of vehicles, the length of roads and other specific features that objectively affect these indicators.

Specific indicators are the percentage of one absolute accident rate from another. For example, the proportion of accidents committed by drunk drivers in the total number of accidents caused by drivers or the proportion of injured (dead, wounded) of various categories of road users in the total number of injured (dead, wounded), etc.

Relative indicators are formed by dividing one absolute indicator by another. The most commonly used relative indicators are the number of accidents, deaths or injuries per 1 million kilometers of
vehicle mileage, per 10,000 vehicles, per 10,000 drivers, per 100,000 population, per 100 kilometers of roads, and so on.

The main methods for analyzing accident dynamics include assessing changes in accident rates [19]:

- in relation to the previous period of time;
- in relation to the base time period;
- in relation to the average value for the previous few years.

The results of the analysis are presented in the form of tables, graphical dependencies, diagrams, maps.

Studying and comparing the dynamics of changes in accident rates is usually carried out to assess the results of activities to ensure road safety, to identify adverse trends, which are the basis for further analysis aimed at finding out the causes of these adverse changes, in order to take the necessary preventive measures.

In practice, the most common type of accident analysis is a calculation in relation to the previous period, the results of which are reduced to a statement of growth or decrease in accident rates.

At the same time, the growth of incidents is assessed as a sign of unsatisfactory activity, and a decrease or previous level of the number of incidents allows a positive assessment of the work on road safety. However, as noted in the works of various authors, including A.B. Chubukov [20], such assessment is not always fair.

Since it is incorrect to assume that the objective level of road safety is characterized by the values of indicators of the previous period, which is not always correct. An accident in nature is a random event, i.e. the observed number of incidents varies under the influence of random factors, this effect must be taken into account in order to get more correct conclusions about the change in accident rates.

More than 50% of all road traffic accidents occur in cities and towns of the Russian Federation. Studies have established that 20-40% of all accidents are concentrated on hazardous sections of roads, accident centers, the total length of which is 2-5% of the entire road network [21].

In this regard, one of the varieties of accident analysis, as a mass phenomenon, is the "accident analysis in the places of accident concentration". The order of the Ministry of Internal Affairs of the Russian Federation No. 380-15 and the decree of the Federal Highway Agency No. 853-r established criteria for determining the concentration of traffic accidents, as well as recommendations for their identification and analysis of the causes of education. According to these guidelines, an accident concentration area is a section of road that does not exceed 1000 m outside a settlement, 200 m in a settlement, or a road intersection where three or more accidents of the same type or 5 or more accidents, regardless of their type, have occurred in the past 12 months that killed or injured people.

In the practical activities of the departments of the State traffic inspectorate, methods for analyzing information about accidents in places of their concentration can be divided into quantitative, qualitative and topographic [22].

A quantitative analysis provides the actual indicators of the state of accident, their comparison (matching) by year and for other calendar periods in order to identify general trends. The simplest indicators of quantitative analysis are data on the total number of accidents, the number of dead and injured people, and the severity of the consequences of an accident.

The purpose of qualitative analysis of accident materials is to identify the causal factors and determine the degree of influence of each of them on the state of accident.

Topographic analysis consists of drawing on a map or diagram of the studied territory of the places where the accidents occurred.

The most common 3 types of topographic analysis of traffic accidents are:

- cartographic;
- in the form of a line graph;
- in the form of a situational plan.

A cartographic analysis of traffic accidents is a large-scale map of the area, at the corresponding points of which the symbols of road accidents are applied as they are recorded.
A line graph is compiled for an individual highway or road section and is a development of an accident map. The large-scale scheme is used for topographic analysis at the places of concentration of road accidents and is a development of the scheme of a separate road accident provided for by the road accident registration card.

6. Analysis of methodological approaches to assess the causes and conditions contribute to the commission of road traffic accidents

The analysis of literature sources allows us to identify three main areas of research: probabilistic and statistical analysis of data on accident arrays [23]; development of models for the mechanism of a single accident [24, 25]; and evaluation of the effectiveness of the control actions taken in the field of traffic accidents [26].

Obviously, in the framework of the issue under discussion “On identifying indicators and parameters that allow us to determine the risks on the studied route for the carriage of dangerous goods by road”, we are interested in questions of probability and statistical analysis of data on arrays of accidents and modeling of the mechanism of committing a single incident.

7. Probabilistic and statistical method for analyzing accidents

This type of analysis is carried out within the framework of the concepts inherent in the "analysis of accidents as a mass phenomenon", since accident characteristics obtained from a fairly large group of accidents are subject to statistical laws. The main purpose of the analysis is to determine the dynamics and trends of accident indicators depending on the component being studied, and the research methods are the practice of using mathematical modeling patterns, mainly analytical, surface and simulation ones.

It is characteristic for analytical modeling that the processes are described in the form of some functional relationships and the results obtained are reliable only for relatively simple systems.

The surface response model reflects the relationship between the output (response) and input (factor) parameters. The whole system or parts of it consist of approximating (replacing) equations, the coefficients of which are determined on the basis of directly or indirectly obtained information about the operation of the system. Surface response models are reliable in a limited area by a certain approximation and their advantage is a simplified structure.

In simulation models, the basic equations describing the behavior of the system are grouped into separate modules that describe the response of individual parts of the system to a change in its state. Simulation models make it possible to describe processes as they would in reality. Such a model can be “played in time” both for one test and for a given set of them. Moreover, the results will be determined by the random nature of the process, allowing us to get fairly stable statistics.

In general, the choice of model type is determined by the quality of the available information about the system and the degree of understanding of the processes. It is also important that the accident characteristics obtained from a sufficiently large group of accidents are subject to statistical laws.

8. Models of a single incident mechanism

This is a comprehensive scientific and technical study of the circumstances of the accident (in fact, the examination of an accident), the main purpose of which is to determine the availability of technical capabilities to prevent the accident and, as a result, to determine the degree of its participants’ guilt. At the same time, the circumstances of the occurrence of an accident are a description of the mechanism for the occurrence of an accident in time, that is, the actions (inaction) of road users, other persons involved in the accident, as well as other events that took place before and during the accident.

According to current statistics, in 80-90% of cases, the causes of accidents are human-related, in the remaining 10-20% - are man-made. This division is based on the dominant assumption that the road user must adapt to any situation that occurs on the road, compensate for failures that occur in the driver–vehicle–road–environment (DVRE) system. As a result, approaches to analyzing the causes of
accidents are formed by the paradigm - the accident is the result of traffic violations committed by a person. And the conditions of occurrence of an accident — the totality of characteristics of the road, vehicles, driver and environment at the time of the incident - remain outside the scope of the analysis.

This rule is also fixed by the regulations of the Ministry of internal Affairs of the Russian Federation, so according to clause 3.6.21. instructions "On recording information about an accident using an Automated information and control system" for each participant of the incident, up to three traffic violations (causes) that are directly related to the mechanism of occurrence of the accident and in strict accordance with the existing classifier are indicated. For example, driving into the oncoming lane, speed mismatch with specific traffic conditions or violation of the rules for overtaking.

As a result, the analysis of the accident’s mechanism models is based solely on the findings of the circumstances of the accident, without taking into account the causes and conditions.

At the same time, a number of specialists in the field of road safety, including A. Lutsk and S. Rubinstein, believe that in investigating an accident it is necessary to find out the causes of each event in all personality and specificity, without allowing a pattern and bindings [27, 28]. Since accidents that are completely identical at first glance can have various causes, and their investigation on the basis of similar cases can lead to erroneous conclusions. Therefore, along with the nature of the violation that led to the accident (established in accordance with the classifier), it is necessary to establish factors related to road conditions, the condition of the vehicle, as well as the internal mood of the road user to comply with moral and legal standards. Moreover, the causes of the accident are defined as “a set of conditions and circumstances, the elimination of which would have made the occurrence of this incident impossible”.

The above definition is consistent with the opinion of modern experts in the field of road safety, including reflected in the works of R.N. Minnikhanov, V.V. Lukyanov, A.B. Rotenberg, A.B. Chubukov, Yu.I. Molev, Yu.A. Ryabokon and others who believe that a large number of simultaneously occurring factors leads to an accident.

9. Conclusion
Firstly, accidents during the transport of dangerous goods by road are qualified by the traffic police as traffic accidents that is, an event that occurred during the movement of a vehicle on the road and with its participation, in which people were killed or injured, vehicles, structures, cargo were damaged or other material damage was caused [29, 30]. However, only information about road accidents in which people died or were injured are included in the state statistical reporting. For this reason, incidents, the consequences of which are only damage to the vehicle or the loss of dangerous goods, are not included in the state statistical reporting. As a result, the statistics on accidents during the transport of dangerous goods by road do not reflect the real situation and cannot be used for analysis and forecasting.

Secondly, it was found that there is no need for a separate classification and accounting for accidents involving motor vehicles transporting dangerous goods, since the essence and mechanism of the incident depends on many factors related to the process of driving a vehicle under the influence of the environment (route) and the least way with nature of transported cargo.

Thirdly, this paradigm allows identifying approaches to the analysis of incidents involving motor vehicles involved in the transport of dangerous goods with common approaches to the analysis of road traffic accidents. In this case, the analysis of the probability of an accident during the carriage of dangerous goods by road must be considered on the proposed route as an accident analysis in the places of an accident.

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