Risk assessment of transport dangerous situations

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Abstract. Transport safety assessment plays a huge role in theory and practice of implementation of transport management systems. It should be noted that ensuring the transport safety is inextricably linked to identification of potentially dangerous transport situations and their risk assessment. To better manage transport risks we propose to apply a new integrated approach which allows to take into account the source of the threat, the degree of objects' protection, kinds of threats, extent of damage in the event of dangerous situations, magnitude of the dangerous situation. This approach is anchored to systematic analysis of causes and conditions of formation of dangerous situations. Also, it provides timely forecasting of their development and consequences. Therefore, it is necessary to develop a new approach to transport risk assessment which will be able to effectively evaluate occurrence of dangerous transport situations. In this paper we present components of transport safety and provide a list of typical objects of transport infrastructure. Transport safety model and algorithm for identification of potentially dangerous transport situation is proposed. Also, we consider a new integrated approach based on transport risk assessment method. It is worth highlighting that the proposed method of transport risk assessment allows taking into consideration the uncertainty linked to the occurrence of dangerous transport situations and their conditions. The specified method can be widely used in modern geographic information systems for analysis of transport emergencies.

1. Introduction

To apply the risk assessment methods in different subject domains in major hazard industries has become more apparent in recent years. Especially, this problem is very relevant for transport domain where number of dangerous situation is growing from year to years. Generally, rules of behaviour in hazard transport situation are regulated by different specification documents (rules, orders, recommendations and others). However, in practice it is quite hard to monitor compliance with the specification documents. Development of the novel automated system for vulnerability assessment of transport objects in dangerous situations is therefore necessary.

Risk assessment is now proven technology which allows to significantly reducing the risk level up to safe (appropriate) level with minimum expenses. Transport hazards are diverse in nature, and can be defined as any potential accident on a transport object connected with its interface with the transport environment. They include:

– natural transport hazard situations
– technogenic transport hazard situations.

Generally, natural hazard situations can be grouped on geophysics (earthquakes, volcanoes, etc), geologic (dust storms, landslides, mudslides, etc), meteorological (windstorms, tornado, hurricane,
heavy rain, frost, hot weather, etc), hydrologic (floods, etc), maritime hydrologic (strong gale, typhoon, tsunami, etc), hydrogeological (high levels of water table, etc) hazard phenomena, wildfire (forest, peat, prairie, etc). Technogenic hazard situations include transport accidents, fire and explosions, accidents connected with emission of chemical substances, emission of biological materials, sudden the building collapse, accidents at the power plant and transport networks, accidents on sewerage, heating networks, electricity and clean water infrastructure, accidents on treatment plants, hydrodynamic accidents (break of dam, dike, gate).

The great number of publications concerning the risk studies were introduces between the 1960s and 1980s [3, 5, 11]. It is of great interest to explore the notion of risk on various subject domains. From psychological perspective, according to [7], the people’s reaction to the technogenic hazard situations is much higher then to the natural hazard situations. Most of publications on risk problem have been done in context of informing on occurrence of the risk [6] as a basis for future decision making [8].

Large majority modern publications are discussed the methods and tools of transport safety assessment for concrete subject domains. Usually researchers applied different methods for transport risk assessment including statistical analysis, failure tree analysis, analyzing the forms, causes and consequences of transport dangerous situations (TDS) and others. In [12] was presented research of assessment of the potential threats on existing and new roadways. There are presented analytical tools for planning events in case of emergency transport situations on roadways. These tools allow comparing different alternatives, to evaluate the costs of danger situations.

For prediction and presentation of air accidents the standard of European Aviation Safety Agency defines approach based on event tree and risk factor tree methodology. These methodologies are presented in the literature [4, 10] and display the process of adverse event development as graphic models. According [10] event tree consists of one main event (specific danger situation) and set of following relevant events (for example, crew error, influence of unfavourable events, extreme weather conditions). For each nods of the tree are assigned to the conditional probability which allows to calculate the danger situation probability of occurrence. This methodology is applied for analyse possible reasons of happening specific danger situations.

In this paper we study how the transport industry seek to reduce the security risks of transport hazards by including transport safety model and algorithm for identification of potentially dangerous transport situation. Also we propose a new integrated approach based on transport risk assessment method.

2. **Major components of transport safety**

Traditionally, there are three parts of the transport safety:

- objects of the transport infrastructure;
- transport;
- passenger or cargo.

Typical objects of transport infrastructure are

- railway stations, railways;
- bus terminals, underground, subways, scaffold bridges, viaducts, street networks, flyovers, vehicular traffic tunnels, paved areas;
- marine terminals, seaport waters, ports which are located on the inland waterways, transshipment zones for dangerous goods, marine terminals for drop-off/pick-up passengers, artificial islands, plants, facilities which are located on the inland waterways and territorial waters, embankments;
- airports, airfields, communication, navigation systems, traffic control systems;
- road sections, railway and inland waterway, heliports, landing pads.

Level of the transport danger is defined by group of the threat sources. There are three groups of the threat sources:

- internal (ageing equipment, dynamic loads, vibrations etc.);
– external (natural and technological threats);
– human factor.

3. Model of transport safety
Transport safety model is model defined system structure and composition, cause-and-effect relations associated to concrete transport system. Transport safety model includes information about objects of transport infrastructure, about activities which can occur with these objects, information on the time and place of the occurrence of every activity. In order to do transport safety value, we need to know structure and components of transport safety such as transport danger, transport vulnerability. Let’s introduce the concept “vulnerability of the transport infrastructure objects” for assessment of degree of protection of the transport infrastructure objects and transport from dangerous and act of unlawful interference.

The classification of potentially TDS should be implemented in assigned area which is called potentially dangerous area. This area is characterized by directly its coordinates (latitude and longitude), the coordinates of objects of transport infrastructure and coordinates of location of the forces to eliminate TDS. In addition, it is necessary to determine the components of each potentially dangerous situation (object of transport infrastructure, type of threat, the magnitude of damage, and the scale of situation). Accurate definition of potentially dangerous area boundary will allow for better assessment of possible developments that proceeded of this situation, to assess the transport risk at the moment ant to predict its development in the future. The classification of potentially TDS in assigned potentially dangerous area is the key problem in situation analysis in order to decision-making about class of dangerous situation.

The major factor of classification of potentially TDS is decision-making time. Because in order to reduce decision-making time it is necessary to develop library including the most typical patterns of dangerous situations. Initial sets of typical patterns of dangerous situations should be defined by
– using subject domain expert opinions;
– using different statistical criteria;
– using theoretical knowledge.

It is important to note that the library of typical patterns of dangerous situations should include not only information about situations, their parameters, but also way of resolve these situations.

The identification process of potentially dangerous situations includes the following steps:
– determination of threats. On this step it is necessary to define types of transport object infrastructure and classes of transport;
– risk assessment;
– decision-making and providing recommendations of decision maker. On this step it is necessary to prepare plan for the elimination of dangerous transport situation, to accomplish modelling of this situation in the near future in order to reduce a response time and cost of losses from dangerous situations.

4. Transport risk assessment method
Risk assessment in the event of an emergency includes three stages:
1. definition of the dangerous transport situation sources;
2. definition of the development phases of dangerous transport situation;
3. impact assessment of dangerous transport situation on environment.

It should be noted that each concrete dangerous situation correspond to own probability of dangerous situation occurrence. With that the emergence of concrete TDS is characterized by event occurrence time distribution density.

Risk assessment related to occurrence of TDS expected to be implemented by applying method which includes following steps.
1. Dividing the set of the possible types of TDS into groups according to their parameters. Building groups is based on available statistics for these groups as well as on initial states of TDS for the
potentially dangerous area. Groups are used in order to define matching probabilities of the events’ occurrence.

2. Calculation of dangerous situation parameters and characteristics for each designated group of TDS.

3. Assessing risks for each variant of the TDS type in regard to the potentially dangerous area.

4. Calculating the mean value of possible risks for potentially dangerous area in a given time range taking into account uncertainty of event time.

Definition of density functions of \( i \) TDS occurrence time \( f_i(t) \) can be carried out in advance and in future they are only improved. For recognition of TDS current conditions on the basis of registered data analysis known methods [1] can be used.

For calculation of TDS parameters and characteristics the statistical and probabilistic models and methods can be applied [9]. Statistical values are described by physical values or their relationships. These values are accumulated in the process of long-term observations for dangerous transport situations. The main advantage of statistical values is their objective. For definition of probabilistic values the methods of probability theory are used. These values reflect regularities of emergence, outcome and development of dangerous transport situations in space and time.

Risk as assessment of each TDS at time instant \( T \) provides accounting its properties as well as accounting the characteristics of the inflicted transport, objects of transport infrastructure and passengers or cargos involved in given dangerous situation. In the interests of such assessment taking into account TDS event time uncertainty \( B_i(T) \) – mean values for parameters of \( i \)-th dangers at time instant \( T \) are calculated as:

\[
B_i(T) = \int_0^T B_i(T-t) f_i(t) dt.
\]

It is suggested to calculate conditional risks \( W_{ij}(B_i(T)) \) of \( i \)-th dangers at time instant \( T \) for specific \( j \)-th objects of transport infrastructure depending exactly on the parameters \( B_i(T) \). These especial conditional risks can be, for instance, determined by experts or using simulation modelling and technologies of advanced geographic information systems. Among these problems are the assessment of the environmental threat occurrence, spills of petroleum products and others.

The resulting predicted risk from TDS at time instant \( T \) taking into account previous conditions and probabilities \( P_i \) of \( i \)-th TDS are calculated using the following equation:

\[
W_\Sigma(T) = \sum_{i=1}^g \sum_{j=1}^m W_{ij}(B_i(T)) P_i,
\]

where \( m \) is the number of analysed objects of transport infrastructure.

Risk \( W_\Sigma(T) \) according to (2) is a current risk. Risks’ prediction for specified time intervals is possible using integral estimates derivation. Unlike the known methods the proposed approach allows to predict the risks from TDS in the current situation under a significant uncertainty of risk emerging time. The new method can be successfully implemented in advanced geoinformation systems. However, the method application is associated with a number of features.

Application of GIS-technologies for the solution of risks assessment problems of TDS assumes application of effective methods of gathered geophysical data visualization, results of their modelling and forecasting. Use of the risk assessment method allows operatively to reflect in geoinformation systems risk dynamics and to estimate damage values depending on type of TDS or their set. The spatial analysis performed by GIS tools allows:

– to represent the results of risk prediction as a series of thematic maps. On these risk maps taking into account spatial accessory to specific region zones that are defined by specific values \( W_\Sigma(T) \) both separated objects and groups of objects can be displayed. Creation of the thematic maps assumes development of qualitative scale for \( W_\Sigma(T) \) values that reveals the relation between risk level and
level of destruction. On the basis of the developed dynamic maps the decisions aimed to decrease risks and to plan actions for coasts protection against disasters can be made.

– to classify potentially dangerous area by hazards level for each of disasters variants for specific infrastructure objects and for specific life environment.

– to carry out adoption of the rational and operational decisions directed on timely realization of actions complex, directed on reduction of risk, preservation of life and human health, decrease of damage from catastrophic. Using intelligent GIS allows to improve decision support on alarm, to predict possible consequences and to carry out offers on protection actions.

5. Conclusion
The transport industry is facing increasing security demands. Practical application of the developed transport risk assessment method will allow:

– to increase the likelihood of identifying sources of dangerous transport situations;
– to reduce the resulting predicted risk from a dangerous transport situation;
– to ensure acceptable levels of transport safety risks;
– to ensure the efficient distribution of investments, to reduce the costs of ensuring the specified safety indicators in transport.

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