VÉDELEM TUDOMÁNY
KATASZTRÓFAVÉDELMI ONLINE TUDOMÁNYOS FOLYÓIRAT

Andrea Majlingova, Péter Pántya

KOCKÁZATKEZELÉSEK A VESZÉLYESÁRU-SZÁLLÍTÁS KAPCSÁN – ÁTTEKINTÉS

Absztrakt

A veszélyesáruszállítás a kockázatos tevékenységekhez tartozik. Ezt az is indokolja, hogy nem lehetséges pontosan, előre meghatározni a veszélyesanyag kiszabadulás helyszíneit. A veszélyes áruk szállításával kapcsolatos kockázatok felmérésének és kezelésének kérdése a tudomány és a kutatás aktuális témái közé tartozik még európai szinten is. Jelen cikk összesíti az ismereteket a kérdéskörben - a veszélyesáru szállításásban és annak biztonsági biztosításában - valamint javaslatokat fogalmaz meg arra, hogyan fejleszthető a terület az ADR járművek ellenőrzése és felügyelete kapcsán, amikor is azonnali információk nyerhetőek a kérdéses járművek pontos pozíciójáról az esetleges baleset helyének meghatározásához. Felmerül ugyanígy a legyakrabban használt veszélyesáruszállítási útvonalak meghatározásának lehetősége a kapott felügyeleti adatok által.

Kulcsszavak: veszélyesáruk, ellenőrzés, kockázatértékelés, útvonal tervezés, szállítás

MANAGEMENT OF RISKS ASSOCIATED WITH DANGEROUS GOODS TRANSPORTATION – REVIEW

Abstract

The transportation of dangerous goods belongs among the risky activities, mostly because it is not possible ahead precisely to identify the localities which are most susceptible to occurrence of an accident connected with dangerous substance leakage / release. The issue of assessment

and management of risks associated with dangerous goods transportation belongs among actual topics of science and research even at European level. This paper compiles the information, knowledge on current trends in solving the issue dangerous goods transportation safety ensuring, the assessment of risks associated with it and proposes the ways how to enhance the current situation in monitoring the ADR vehicles, when transporting the dangerous goods to get prompt information on their position in any time, to localise it precisely in case on an accident, as well as to identify the accident most susceptible localities based on commonly used transportation routes evaluation using the monitoring data.

Keywords: dangerous goods, monitoring, risk assessment, route planning, transportation

1. INTRODUCTION

Transportation of goods carries the risk of accidents. Particularly, in the case of dangerous goods, there is the risk of fire, explosion, chemical burns, poisoning or environmental damage. To reduce this risk, strict rules are applied to the transportation of dangerous goods**.**

To transport the dangerous goods, the several ways of transportation are used: road, rail, air, ship transportation and transportation by pipelines.

To prevent the occurrence of accidents in road and rail transportation, the European Agreements Concerning the International Carriage of Dangerous Goods by Rail (RID) and by Road (ADR) were developed and signed.

The main task of the ADR Agreement since its conclusion was to ensure safe transport of dangerous goods. The individual provisions of the ADR are updated every two years in the terms of scientific and technical progress in order to increase the safety of the transport of dangerous substances and articles.

Dangerous substances within the meaning of the ADR Agreement are substances and articles which are dangerous to humans, animals or the environment by their properties, such as

explosiveness, flammability, toxicity, possibility of induction of infections, radioactivity, corrosivity or environmental contamination.

To minimise the risks associated with dangerous goods transportations by roads several solutions have been developed, e.g. risk assessment tools, vehicles monitoring systems, and route-planning systems based on network analyses performance. Some of those solutions are introduced in this paper.

2. RISKS ASSOCIATED WITH TRANSPORTATION OF DANGEROUS GOODS

Transport plays an important role in national economies and impacts on economic development. The scale of the transportation of goods that may be dangerous to humans and the environment is expanding every year. Overall, transport is dangerous for the environment and road users, causing the increased emission of pollutants, accidents and traffic collisions. The rise in demand of basic materials, such as petrol and diesel, has led to a growth in the transport of dangerous goods, which in turn has increased the risk of road accidents.

Adamec et al. (2016) consider the transportation of goods and supplies to be an essential part of maintaining a functioning urban infrastructure. This type of transportation may especially in the urban areas signify a high risk that may significantly damage the critical infrastructure of the city, if there is an accident and leakage of dangerous chemical substances. The aim is therefore, to minimize the risk and its consequences. The effective instruments are through the identification, analysis and assessment of these risks, searching for critical areas in cities and ensuring the application of prevention and safety measures.

Novacki et al. (2016) focused the threat assessment of dangerous goods in transportation of the European Union and the Republic of Poland. According to their findings, they stated that the dangerous goods in the European Union are carried by inland waterways, rail and road. In Poland 87.5% of dangerous goods have been carried by road and 12.5% by rail in 2014.

Dangerous goods can cause an accident and lead to fires, explosions and chemical poisoning or burning with considerable harm to people and the environment. There is not any monitoring system in Poland to control in real time road transportation of dangerous goods. They proposed the National System of Monitoring Dangerous Goods in Poland. They pointed out the implemementtaion of this kind of system to be significantly contributing to improving safety of people and environment.

In 2009, in Portugal, the transport of dangerous goods by road was 10% of the total, which corresponds to 10 million tons annually. About 70% of these goods were flammable. Since 1961, 80% of accidents with flammable products come from GPL. Patricio et al. (2013), in this context and given the importance of this issue, characterized the accidents with flammable gases in Portugal, based on official statistics of the Portuguese National Institute of Statistics and the National Authority for Civil Protection, as well in a bibliographic review performed through Metalib (FEUP). Between 2001 and 2005, 66 incidents were reported, 15 of which corresponded to propane, butane and other hydrocarbon gas liquefied mixture, having been recorded one dead.

Lukasik et al. (2017) developed and introduced a research method involving an analysis of the inspection rates regarding the transport of dangerous goods by road in the European Union (EU) and related Polish legal documents.

To prevent the accidents during the transportation of dangerous goods, there were specified the rules and technical conditions for organization of road transport of dangerous goods, especially in reference to conveying information and co-operation with emergency services and their readiness to undertake rescue operations.

Smal et al. (2016) presented the issues concerning legal and technical conditions, as well as marking of vehicles on the chosen examples.

3. RISK ASSESSMENT TOOLS

The issue of risk assessment is an important phase of the risk management process. To know the most susceptible localities to occurrence of accidents dangerous goods vehicles is important for planning and implementation of effective preventive measures. To know the vulnerability of those locatities, i.e. the potential consequences of the accident, is necessary to plan and ensure the sources and resiurces ti minimize the consequences ofthe accident and to increase the level of the community, environment and economic resilience.

There are introduced several risk assesment tools which were implemented to minimize the risk of dangerous goods transportation abroad.

Bogaert et al. (2013) introduced new Flemish approach for risk dangerous goods transport risk analysis system. The risk analysis system for the transport of dangerous goods was developed by the Flemish government. The system covers external safety of people for the transport modalities roads, railways, inland waterways and pipelines. It has to be seen as the technical tool for a Flemish safety policy to obtain the external risk of new developments of transport routes at an acceptable level, to detect and remediate existing bottlenecks over time and to clearly communicate about transport risks with the other involved authorities and the citizens. The risk analysis system is based on an approach of two steps. The first step consists of the determination of the general risk of a transport route, the second is a more profound calculation of a local risk at certain specific parts of the transport route. For the first step a general probability of an accident with loss of containment is calculated from statistical data resulting from reports of accidents in neighbouring countries or from international reports. The first step has to be done mainly because of lack of statistical data in Flanders. In a second step a fine tuning is done by determining a local probability of an accident. This local probability is based on accident data and on expert parameters (infrastructure and traffic parameters) for a specific part of the transport route. For each transport modality expert parameters are listed. The calculation of the effects and consequences is the same for the two steps in the risk analysis system. To indicate the consequences of a possible accident with dangerous substances, the

number of people within the 1% lethality distance is determined. This is done for the different transport modalities and for four classes of dangerous goods (flammable liquids and gases and toxic liquids and gases) based on representative substances. The results are presented on geographical maps. For each transport route maps of probabilities, consequences and risks give a visual representation. With the risk analysis system comparisons can be done for different routes of the same transport modality to look for the most save route. The method allows also to compare different transport modalities for transporting dangerous goods between two points. The risk analysis system can support decision making as well as for the construction of new routes as for improvements of existing routes. The system is also to be seen as a tool to take into account safety matters in the policy of land use planning. The risk analysis system is also applicable in other countries.

Borghetti et al. (2014) introduced the DESTINATION project as an instrument for the protection of the territory through the knowledge of the risk associated to transport of dangerous goods on road. The DESTINATION Project, "Monitoring the transport of dangerous goods as a means of protecting the territory" started in 2010 with the aim to quantify and manage the risk related to the transport of dangerous goods by road, considering both anthropic and environmental vulnerabilities. To achieve this goal the GIIS - Global Integrated Information System - was developped to collect territorial data as well as data coming from the monitoring activity of Dangerous Goods Transports. The GIIS processes these data by elaborations and simulations in order to create risk maps.

Bu et al. (2013) analysed the existing problems in dangerous chemicals transportation. Through combination of domestic and foreign advanced technology and national conditions, control strategies and measures for safe transportation of dangerous chemicals they studied in depth to propose the preventive measures need to be taken. The preventive measures include establishing a management system, risk early warning mechanism and transport information platform which are based on modern information technology, establishing transport industry standard, ensuring good security propaganda work, setting emergency and consultation service system, carrying out special rectification work for transportation safety, so as to ensure

scientific, reasonable and effective control of dangerous chemicals transport, reduce and avoid related accidents.

Caliendo and De Guglielmo (2017) introduced a quantitative risk analysis regarding dangerous goods vehicles running through road tunnels. Peak hourly traffic volumes, percentage of heavy goods vehicles, and failure of the emergency ventilation system were investigated in order to assess their impact on the risk level. The risk associated with an alternative route running completely in the open air and passing through a highly populated urban area was also evaluated. The results in terms of social risk, as F/N curves, show an increased risk level with an increase the peak hourly traffic volumes, the percentage of heavy goods vehicles, and a failure of the emergency ventilation system. The risk curves of the tunnel investigated were found to lie both above and below those of the alternative route running in the open air depending on the type of dangerous goods transported. In particular, risk was found to be greater in the tunnel for two fire scenarios (no explosion). In contrast, the risk level for the exposed population was found to be greater for the alternative route in three possible accident scenarios associated with explosions and toxic releases. Therefore, one should be wary before stating that for the transport of dangerous products an itinerary running completely in the open air might be used if the latter passes through a populated area. The quantitative risk analysis may help decisionmakers both to implement additional safety measures and to understand whether to allow, forbid, or limit circulation of dangerous goods vehicles.

Forigua and Lyons (2016) presented results of a case study in Colomia. They pointed out the fact that in recent years, the accident rates of freight transportation in the towns of Colombia have increased. The risk related to the transport of dangerous goods and its impact on transport chain is not well-known for the companies or the national authorities. Municipalities do not have a specific legislation for the transportation of these materials inside urban areas and is the Ministry of Infrastructure and Transportation that regulates this type of freight movements in road national network, including roads across urban areas. The main objective of their research was to develop a methodology focused on identifies the key variables that would allow us to propose a set of strategic and operational indicators to integrate road safety in the transport chain of major dangerous products transported by road in Colombia. The methodology assessed

the degree to which road safety is within the strategic and operational planning by the stakeholders of the transport chain as well as the identification of compliance with the law by freight generators, carriers and drivers carrying HAZMAT in urban areas in Colombia. The research is aimed to contribute to the analysis to integrate road safety into strategic and operational planning of transportation chain and to implement public policies in order to improve the transport chain of HAZMAT in Colombian cities, along with specific indicators to enhance the performance of the transport chain by the organizations involved.

Garbolino et al. (2013) dealt with assessment of vulnerability and resilience of the territory concerning risk of dangerous goods transportation. Among the territories concerning risk of dangerous goods transportation were included especially road and rail transportation systems. These features cross the territories that gather dense urbanized places, critical infrastructures (highways, tunnels, bridges etc.) and organizations (hospitals, police and firemen centres, rail stations etc.), and protected areas (national, regional and departmental natural reserves and parks). According to the definitions of vulnerability and resilience, the authors proposed a spatial model based on two indices in order to characterize the level of vulnerability and resilience of the territory induced by the dangerous goods transport. Those two indices are implemented into a Geographical Information System (GIS) in order to define a Spatial Decision Support System (SDSS) dedicated to the decision-makers (infrastructures managers, public authorities and transport companies). As a conclusion, the authors discussed the levels of vulnerability and resilience of the territory according to the different kind of transportation systems, i.e. rail and road in order to underline recommendations for dangerous goods transportation route planning.

Kanj and Flaus (2015) described a generic approach to use agent-based modeling to modeling systems comprised of autonomous and interacting agents, for risk analysis. It presents a novel generic model facet for representing risk analysis and fault tree propagation in an agent model, where the goal is to analyze the risk related to a system and to simulate its behavior in normal and degraded mode by using multi-agents systems. This approach is used to analyze the risks related to dangerous goods transportation and to minimize these risks by using agent-based model (identifying the best road that having the minimum risk level for transport).

Kasrim et al. (2017) proposed a model for calculating the risk exposure of the transport of hazardous materials trajectories using the Gaussian stochastic travel time. The transport of hazardous materials trajectory meta-model was extended to take into account the risk management dimension. The storage of the transport of hazardous materials trajectories was used for discovering risk patterns on the urban space by means of the mesh of Voronoi. The proposed analytical solution was deployed in an interoperable infrastructure using intelligent transport systems architecture.

Krejci et al. (2018) introduced a risk assessment approach related to the transport of ammonia and chlorine in urban areas. A mathematical and a simulation approach for a model leakage of these substances in road accidents were compared in their study. The synergistic use of both approaches proved to be the most appropriate - the mathematical one to evaluate the preventive and mitigation measures, while the simulation to determine the extent of the affected area. Measures to be taken were suggested to reduce the risk associated with the transport of hazardous substances.

Landucci et al. (2017) presented HazMat transportation risk assessment in form of a revisitation in the perspective of the Viareggio LPG accident. Their study was aimed at the analysis of reference procedures and tools available for the analysis of the risk in the transportation of dangerous substances. The Viareggio accident represents a paradigmatic event involving the transportation of dangerous substances. The accident, that took place in Italy in 2009, was analyzed in the perspective of current approaches to the analysis of risk in the transportation of hazardous materials. The results pointed out that the Viareggio scenario, although of particular severity, is comprised within those accounted in quantitative risk analysis.

In recent years, heavy traffic accidents of hazardous chemicals road transport in China have occurred sometimes, both the loss of dangerous goods itself and the damage to the vehicle, to bring considerable property damage to the enterprise, but also a threat to the people who live in the place where the accident happened and ambient environment.

Li and Wang (2017) in their study first collected data of 61 cases of road safety accidents in the past three years, and identified the factors that affect the risk control of hazardous chemicals road transport from five aspects: man, machine, material, method and environment and draw a

Fishbone Diagram. Then carried out a risk assessment and make a risk matrix. Finally, some suggestions and measures on risk control were given to establish a simple and easy to understand and effective risk control system for enterprises.

Mlynczak (2014) proposed a model of risk assessment concerning road transportation of dangerous goods. Vehicle transporting dangerous goods produces "moving" risk due to dangerous loads moving through areas of different exposures what gives at each point of the road (short segment) changeable value of the risk. Model is based on the concept of road risk profile which takes into account road segments of various population densities, natural environment and engineering installations. Author ptrovided also an example of calculation of proposed risk profile for a given road segment and a tanker. Road transportation of dangerous goods was analyzed to identify all important elements and processes. Advantage of the proposed method consists in systemic dividing of all distinguished objects dealing with goods transportation (dangerous goods, truck, driver), road infrastructure (road geometry, construction, roadside, land development), natural environment. Objects are divided in active and passive ones. Active objects may produce risk, while passive are exposed to catastrophic events. The general model proposes an idea of hazard identification and risk matrix for a given road segment and is summarized with an example.

Janno and Koppel (2017) pointed out the fact that when packaged dangerous goods are transported by road, it is critical to follow both legal requirements as well as meet suggested safety regulations in order to prevent accidents during activities with chemicals that are harmful for man, assets and environment. Due to the fact that there are multiple parties involved into handling and transportation procedures, plenty of different risks can occur during these activities with dangerous goods. As the importance of human factor has been underestimated, they focused in ntheir paper on analysing different types of risks within a dangerous goods transportation chain related to specific participant. By analysing and prioritising risks, the most critical of them are identified and evaluated upon possible harm to entire chain. They presented a combined overview study based on theoretical aspects which is supported by results of previous studies regarding risk assessment of dangerous goods transport in practice. Additional results of research regarding how involved parties in Estonia evaluate possible harms resulted

by their activities while handling and transporting dangerous goods confirm the main finding that human factor is one of the crucial factors why accidents occur. Despite the limited study group generalisations of research results are applicable widely in Europe due to the universal features of risks as well as common legal requirements. In scope of further research, results of present study are milestones to focus on managing risks affected by human factor in road transport of dangerous goods.

According to European Commission statistics on dangerous goods transport there are up to 80 percent of accidents that are caused by a human error, 8 percent of accidents are caused by technical failure.

Janno and Koppel (2018) described operational risks in dangerous goods transportation chain on roads. The author stated that due to the fact that there are multiple parties involved in handling and transportation procedures, plenty of different risks can occur during these activities with dangerous goods. In their paper, they focused on identifying and analyzing of operational risks within a dangerous goods transportation chain related to the specific participant. By identifying and evaluating risks, the most critical of them are identified and evaluated upon possible harm to the entire chain. Their paper presents a combined overview study based on theoretical aspects which are supported by results of previous studies regarding risk assessment of dangerous goods transport in practice. By implementing semi-quantitative risk assessment method, it finally allows differentiating operational risks according to their levels into acceptable, tolerable and unacceptable operational risks when transporting dangerous goods on roads.

Rada et al. (2017) described the safety state in the Varese district (an area of northern Italy with a very high population density and industrial activities), with the aim at comparing the current situation (considering the risks due to the transportation of hazardous materials on the main motorways and main national roads) with a potential scenario that introduces a few mitigating interventions, such as a partial conversion from road haulage to rail transport. This comparison can be accomplished by developing the existing intermodal platforms and implementing new ones in strategic areas.

Razga et al. (2017) focused the issue of safety in road tunnels. They considered the safe operation of tunnels to be very important, because tunnels are specific engineering structures constructed in order to shorten transport routes and improve road safety. In 2015, they introduced introduced an extension of risk analysis model for road tunnels for the first time Razga et al. (2015). They calculated the risk analysis of road tunnels, built Tunnel Traffic & Operation Simulator and they were working on adding of risk analysis model by risk analysis of transport of dangerous goods through road tunnels model (DG QRAM), which was developed under the joint OECD/PIARC. Model of risk analysis examines the personal risk of tunnel users and evaluates statistically the expected number of victims per year. They considered the Tunnel Traffic & Operation Simulator at the University of Zilina in combination with unique software to be conducive to research of the possible operating conditions during normal service and model emergency situations. The Simulator manages technological equipment of a virtual two-tube highway tunnel interconnected with simulation of vehicle tunnel traffic.

Roncoli et al. (2013) proposed a risk-based approach to control dangerous goods transport flows by roads, solving a real-time flow assignment problem. The model takes into account the planned scheduling of the dangerous goods fleets. The objective is to readapt the schedule in real time, controlling the dangerous goods flow to minimize both the risk on the network and the gap between the proposed modified delivery and the planned one. The innovative aspect of the proposed approach is to balance the social objective of a national authority, thus minimizing the risk on the road infrastructures, with the economical objective of the dangerous goods distribution companies that have to minimize the actual time, as defined by the planned deliveries. The proposed dangerous goods transport model is defined according to a system of systems view. Each subsystem represents either a regional area or, more commonly, a segment of a road. The proposed approach provides a useful tool for evaluating the optimal speed for dangerous goods vehicles in each subsystem and the optimal amount of dangerous goods flow that should transit from one subsystem to another, following the planned delivery schedule. The problem has been tackled in two different formulations. First, a nonlinear mathematical programming formulation is defined. Then, according to simplifying assumptions, the problem is solved as a discrete-time finite horizon linear quadratic optimal control problem with a state

feedback control. An exemplificative case study is used to show a comparison between the two formulations, as well as the effects of a risk sudden change in the overall dangerous goods routing.

Salmane et al. (2014) considered improving safety of people and road-rail facilities to be an essential key element to ensure a good operating of the road and railway transport. For this purpose, road and railway safety professionals from several countries have been focused on providing level crossings as safer as possible. Many actions are planned in order to exchange information and provide experiments for improving the management of level crossing safety and performance. Authors in their paper aimed to develop a video surveillance system to detect, recognize and evaluate potentially dangerous situations in level crossing environments. First, a set of moving objects are detected and separated using an automatic clustering process coupled to an energy vector comparison strategy. Then, a multi-object tracking algorithm, based on optical flow propagation and Kalman filtering correction with adaptive parameters, was implemented. The next step consisted of using a Hidden Markov Model to predict trajectories of the detected objects. Finally, the trajectories were analysed with a particular credibility model to evaluate dangerous situations at level crossings. Real data sets were used to test the effectiveness and robustness of the method.

Adamec et al. (2016) introduced the issue of the risks associated with the transportation of hazardous substances in the cities and to propose measures that are in accordance with the concept of Smart Cities, in order to contribute to create of functional communication network, traffic flow in cities and increasing the security of critical infrastructure.

4. DANGEROUS GOODS VEHICLES MONITORING

In last years the interest in transportation security has increased significantly, in particular with respect to road transport safety of dangerous goods.

When speaking about dangerous goods movement, traceability and monitoring are not only a matter of an intelligent and efficient logistics. They also imply aspects related to security and

safety, being a concern common to involved industries and authorities. For this reason, tracking and tracing the shipment of dangerous goods requires an efficient collection of timely and precise information about the various operations.

Besides, reliability is a fundamental requirement, especially in the case of intermodal transport where different operators and modalities are involved. About 85% of the shrinkage in the overall supply chain occurs while materials, components or finished goods are in transit. In this respect, the satellite navigation technology is a key element, as it enables: the continuous localization, control and monitoring of goods traffic during transport; the collection of data to be further analysed for statistical reporting and incident prevention.

Systems based on the use of satellite positioning are today widely adopted in the transport of dangerous goods operations. Tracking & tracing devices (installed on board of the asset transporting the goods) can also integrate sensors to enable the monitoring of the status of the goods and different telecommunication means (satellite and/or terrestrial) for positions/data transmission.

Various past and on-going European initiatives are also introducing the use of the European satellite navigation (EGNSS, European Global Navigation Satellite System), starting from EGNOS (European Geostationary Navigation Overlay Service) and in view of Galileo. Among these initiatives, the project SCUTUM (SeCUring the EU GNSS adopTion in the dangeroUs Material transport) concluded in 2011, exhaustively and successfully demonstrated that EGNOS provides precise and reliable localization and tracking, and thus it is particularly suitable for monitoring the transport of dangerous goods. Today, thanks to SCUTUM, EGNOS is used to monitor around 1,200 road tankers transporting dangerous goods by road in Europe (Italy, France, Austria, Slovakia, Hungary, Romania, Czech Republic).

Capitalizing on SCUTUM's achievements, the on-going project CORE, started in 2014 and with a duration of 4 years, is extending the use of EGNOS to the intermodal transport of dangerous goods, and analysing the advantages of the introduction of Galileo. As done in SCUTUM, also CORE is expected to launch an operational best practice in Europe. Moreover, similarly to SCUTUM, the project's results will feed the on-going UNECE OTIF WG (United Nations Economic Commission for Europe Organisation Intergouvernementale pour les Transports

Internationaux Ferroviaires Working Group) on Telematics in relation to the use of telematics for the transport of dangerous goods, specifically for what the EGNSS is concerned. (Di Fazio et al., 2016)

Today, there is a growing attention paid also to implementation of automotive sensors monitoring systems, in order to make them an effective and valuable aid in situations of danger, improving transportation safety. The main limitation of visual aid systems is that they do not produce accurate results in poor weather conditions (such as fog, rain) and in presence of smoke. This limitation can be overcome by using radar sensors.

Baselice et al. (2014) introduced 3D automotive imaging radar for transportation systems monitoring. In particular, imaging radar are gaining interest in the framework of Driver Assistance Systems (DAS). Radar monitoring system can be effectively used for the safety dangerous goods transportation. At present most of radar focusing techniques are not able to discriminate multiple targets on the same line of sight. Authors in their paper introduced a novel radar signal processing technique, based on Compressive Sensing (CS) theory, to perform the detection of two or more targets on the same line of sight, greatly improving the performances of a radar DAS. After a brief description of the proposed methodology, case studies were presented in order to evaluate the performances of the technique.

Li and Gu (2016) introduced an application of IC card license for road transportation in commercial vehicles supervision and service. IC card electronic license for road transport includes the IC card commercial vehicle's certificate and IC card practitioner's qualification certificate. In China, the IC card electronic license for road transport is the electronic ID card, which must be carried by each commercial vehicles and practitioners. Authors in their paper briefly introduced the basic situation, data format and security keys architecture of IC card electronic license for road transportation of China. In order to strengthen the supervision and service of commercial vehicles, they put forward the overall application framework of IC card electronic license for road transport. The application examples of IC card license in the supervision of passenger station, dangerous goods transport management, governance overload and logistics park and port area management were discussed, too. The practical application results showed that the application of IC card electronic license for road transport is an

important technical means to improve the supervision ability and service quality of the road transportation industry.

Liu et al (2012) introduced a dangerous goods dynamic monitoring and controlling system based on Internet of Things (IOT) and Radio Frequency Identification (RFID). In their study they first analyzed the conditions of road transport of the dangerous goods, including the causes of accidents, situation monitoring and technologies. Then a dynamic RTDG monitoring system was proposed which is based on the IOT and RFID technology. This system is a four-layer framework including basic information collection, data transmission, information process, and application. Cooperating with the highway infrastructure and information sharing system databases, the proposed system can get more information of RTDG and timely prevent/deal accident.

Malekian et al. (2016) addressed the implementation of a smart vehicle navigation system capable of using radio frequency identification (RFID) based on information about navigation paths. For prediction of paths and accurate determination of navigation paths in advance, predictive algorithms have been used based on the hidden Markov model. At the core of the system there is an existing field programmable gate array board and hardware for collection of navigation data. A communication protocol and a database to store the driver's habit data have been designed. From the experimental results obtained, an accurate navigation path prediction is consistently achieved by the system. In addition, once-off disturbances to the driver habits have been filtered out successfully.

Tang et al. (2014) proposed a complete monitoring and tracking system, which is able to check at the same time the position and real-time status of dangerous goods of the ship, as well as the conditions in the cargo bay. The system exploits battery-powered environmental sensors (temperature, humidity, pressure, gas concentration and liquid level), connected by a ZigBee-based Wireless Sensor Network. This approach guarantees flexibility, ease of deployment and low power consumption. Collected data is then sent from the ship to a fixed server via a GPRS link. The GPS positioning system is integrated by the use of Navigation System, which also guarantees a precise estimate of the position when the GPS signal is weak or temporarily lost. When dangerous goods of the ship start leaking, the system can develop a plan to solve the

accident, according to the situation at that time. The proposed solution has been deployed in a real environment, and some performance evaluation tests have been carried out.

Xie et al. (2016) introduced a Hazmat Transportation Monitoring System Based on Global Positioning System/ BeiDou Navigation Satellite System and RS485 bus. It is a real-time system, which can monitor the state of Hazmat during the transportation by using Global Positioning System (GPS)/BeiDou Navigation Satellite System (BDS) technology and sensor acquisition modules, which is based on RS485 bus technology. Combination of the above technical schemes with General Packet Radio Service (GPRS) radio transmission, Radio Frequency Identification (RFID) and Geographic Information System (GIS) technology, allows the system monitor the position information and provides crucial state information of the dangerous goods during the transportation. The system can fundamentally solve the safety issues of Hazmat transport.

Vehicle location devices only based on GPS technology have played an important role on the current market. However, there are obvious shortcomings by using a simple GPS method in the aspect of positioning accuracy and coverage. In the blind area of GPS, a vehicle's route could not be detached in real time, which will lead to manage and follow the tracks of vehicle difficultly.

To solve this problem, Ye et al. (2016), applied a hidden Markov model combined with RFID-based sensors for accurate vehicle route prediction. Their approach is based on building the probabilistic model through observation of the driver's habits from a map database involving RFID information. Before they predict a vehicle's route, they firstly compute the shortest path from starting point to destination point. Then through this path they are able to filter some redundant data. Finally, experiments demonstrated the high prediction accuracy under different periods of traffic conditions by training the HMM.

5. ROUTE PLANNING TOOLS

To improve road traffic safety is one of the most important objectives for transport policy makers in contemporary society, and represents a strategic issue for enhance life quality. Recently ISO 39001 (Road Traffic Safety Management Systems) introduced the guidelines of safety-based activities aimed to decreasing road accidents, in agreement with the Quality Management Systems (ISO 9000). Such guidelines are intended for infrastructure managers, administrators, and private entities, and defines a standard management for reduction of road risk. In this context, the risk arising by dangerous goods transport represents a particular threat which needs strategies and tools to reduce risk rate of society, property and environment. Several decision making solutions for transport managers and public administration are defined, but two open points still exist. Firstly, there are not applications supporting for dangerous goods carriers in tactical and operational planning. The second point is related to impacts of traffic congestion on road accidents frequency: there is not a common approach for study and assessment these relationships.

One of the effective way to solve the problem of dangerous goods transportation risks is the planning of the dangerous goods transport routes as well as the rest areas. This issue was focused by several authors.

Caro-Vela et al. (2013) introduced a DEA-inspired approach to selecting parking areas for dangerous-goods trucks. They developed a procedure for selecting the subgroup of the most suitable service areas for modification in order to provide a service to dangerous-goods transporters. Under multiple criteria, a new DEA-inspired model was developed that uses the main characteristics of the problem under study with the goal of selecting the best locations. Through the application of this model to Spanish territory with the help of Geographical Information Systems, various solutions were suggested. The final decision on the number of areas to be located depends on corresponding authorities, whose main priority is to satisfy economic criteria.

Caro-Vela et al. (2015) proposed design of an efficient algorithm to determine a near-optimal location of parking areas for dangerous goods in the European Road Transport Network. In their study, they dealt with the problem of locating the minimal number of parking areas being necessary for dangerous goods in the European Road Transport Network. To obtain a near-optimal solution for this problem, they introduced the design of a new graph-based algorithm to locate parking areas in such a way that drivers can obey the regulations related to driving and resting times. This restriction is imposed to the problem as follows: each point in the European Road Transport Network has to be at a distance lower than 200 km from a parking area in the Network.

Rongrong et al. (2013) introduced a a multiobjective genetic algorithm (MOGA) for the determination of optimal routes for dangerous goods transportation under conflicting objectives. Implemented within the geographical information system environment, the MOGA approach was applied to the transportation of liquefied petroleum gas in the road network of Hong Kong. Experimental results in this case study substantiated the conceptual arguments and demonstrated the good performance of the proposed approach.

Cera and Fedriani (2016) described an advance in infinite graph models for the analysis of transportation networks. Their study extended to infinite graphs the most general extremal issues, which are problems of determining the maximum number of edges of a graph not containing a given subgraph. It also related the new results with the corresponding situations for the finite case. In particular, concepts from 'finite' graph theory, like the average degree and the extremal number, were generalized and computed for some specific cases. Finally, some applications of infinite graphs to the transportation of dangerous goods were presented; they involved the analysis of networks and percolation thresholds.

Conca et al. (2016) analyzed the interactions between road traffic flow and frequency of accidents. They proposed an integrated approach for the study of routing problems considering safety. The new approach to analyze a road accident involving a dangerous goods is focusing on the reason which lead to a leakage of hazardous materials. In their paper, they presented an upgrade of a minimum cost routing problem for a road carrier considering also the risk related to dangerous goods. After a description on how computing risk concerning dangerous goods

transportation in a routing choice problem, the paper describes a solution aimed at providing a tactical and operating decision-making tool. The aim was to enable the carrier that transport dangerous goods to calculate the quantification of the risk for each specific trip in addition to operating cost for each specific transport. The added value of risk quantification could be used by transportation carrier in ISO 39001 to numerically prove his own safety-decisions to the control authority. The analysis developed has provided good results. The approach defined, albeit simplified, is a useful tool, especially when ISO 39001 standards will strengthen road safety.

Dolia and Englez (2015) analysed the methods of conflict situations assessment and stated that the main shortcoming is the disregard of the probability of occurrence of the RTA involving an individual road user. Based on the factor analysis conducted, the non-linear model of the probability of the RTA occurrence in the transport network segments was developed. Also, the model of the probability of the RTA occurrence in transport junctions was improved. It will enable, if using respective optimization algorithms, working out the optimal routes for dangerous goods transportation by the minimum of the RTA occurrence probability.

In the case of determining routes and locations for constructing distribution centers on hazardous materials (Hazmat) transportation, risk and cost are considered as the main attributes for developing mathematical models. Since, Hazmat transport risk may be defined as a chaotic factor, using dynamic risk changes the selected routes and optimized locations for constructing distribution centers.

Mahmoudabadi (2015) proposed an an iterative procedure to determine the best routes and optimized locations of distribution centers for transporting hazardous materials based on the concept of chaos theory in which hazmat transport risk is defined as a dynamic variable. A mathematical model has been developed for solving Hazmat routing and locating problems, simultaneously. Daily transport risk, defined as a chaotic variable, was iteratively updated using one-dimensional logistic map equation over the time period (year). An experimental road network, consisted of eighty nine nodes and one hundred and three two-way edges, had been selected for analytical process and model validation. Results revealed that although different amounts of risk and cost priorities change optimized locations of distribution centers and their

associated supplies, but the most frequent set of optimized centers remains independent. Therefore, the proposed procedure was capable to determine the best routes and optimized locations for distributing hazardous materials. While risk was iteratively updated over a specific time period, results showed that the main property of chaos theory known as dependency upon initial condition are not a serious concern for decision makers who are dealing with Hazmat management.

Zero et al. (2016) solved bi-objective shortest path problem with one fuzzy cost function applied to dangerous goods transportation on a road network. As authors stated in their paper, the shortest path problem is a very well-known network problem, whose complexity sensibly increases from polynomial complexity to become a NP-hard problem when a multi-objective function is taken into account. In their paper, an algorithmic approach to a bi-objective problem was described, where one objective had a fuzzy value, which made even harder to get a solution. This kind of approach found an applicative use in the case of dangerous goods transport by road, where a trade-off between the minimum cost and the minimum (or minmax) risk had to be solved in the delivery from a depot to petrol stations.

6. CONCLUSIONS

Accidents related to dangerous goods transportation present a significant risk as for human, environment as for economy. The development of new technologies such as geographic information systems (GIS), global satellite navigation systems (GNSS), General Packet Radio Service (GPRS), Radio Frequency Identification (RFID) allow to enhance the situation with localisation and monitoring the position of the vehicles transporting the dangerous goods, to localise the position of a vehicle in an emergency and promptly to inform rescue services about the emergency. The tools of GIS allow to model the potential consequences of dangerous goods substances release or leakage and this way to determine the extent of contamined area to calculate the number of sources and resources to minimize the consequences of the emergency in shotest time and keeping the safety of the intervening personnel. Except it it provides the

whole set of tools for risk assessment procedures and well as the network analysis tools to optimize the route planning process.

As introduced in the paper, there were developed several risk assessment systems, models, methodologies, approaches to identify the dangerous goods transportation risky objects, activities, that were successfully implemented in national systems of risk analysis. There are several systems to monitorin the dangerous goods transporting vehicles and to plan the best route to transport the dangerous goods, avoiding the risk to humans and environment.

It depends on every country whether it will develop its own system of risk assessment, monitoring and route planning for dangerous goods transportation or it will adopt one of the already developed and in the practise verified systems. The only important thing for every country is to implement such systems to control the situation with dangerous goods transportation inland. However, this is not only a problem of a country, but it should be solved also at European level. In previous years there have been done many activities in this field at European level, but there is still a need to find solution how to enhance current situation with dangerous goods transportation in Europe because it is still not under control.

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REFERENCES

1. Adamec, V., Schullerova, B., Adam, V. 2016. Issues of Hazardous Materials Transport and Possibilities of Safety Measures in the Concept of Smart Cities. Smart City 360, V 166, P 790-799.

2. Baselice, F., Ferraioli, G., Matuozzo, G. et al. 2014. 3D Automotive Imaging Radar for Transportation Systems Monitoring. *Ieee Workshop on Environmental Energy and Structural Monitoring Systems*, Sep 17-18, 2014, Naples, Italy, p. 7-11. ISBN 978-1-4799-4988-5.

3. Bogaert, M., Imbrechts, K., Grooten, L. 2013. New Flemish Approach for Risk Analysis System for the Transport of Dangerous Goods. *Chemical Engineering Transactions*, 31: 19-24.

4. Borghetti, F., Gandini, P., Seminati, P. et al. 2014. DESTINATION project a instrument for the protection of the territory through the knowledge of the risk associated to transport of dangerous goods on road. Geomedia, 18(2).

5. Bu, Q., Wang, Z., Tong, X. 2013. Research on Cause Analysis and Safety Management for Road Transportation Accidents of Dangerous Chemicals. In Applied Mechanics and Materials. Sustainable Cities Development and Environment Protection, Pts 1-3, Vol. 361-363, p. 2282.

6. Caliendo, C., De Guglielmo, M.L. 2017. Quantitative Risk Analysis on the Transport of Dangerous Goods Through a Bi-Directional Road Tunnel. Risk Analysis, 37(1): 116-129.

7. Caro-Vela, M.D., Fedriani, E.M., Tenorio, A.F. 2015. Design of an Efficient Algorithm to Determine a Near-Optimal Location of Parking Areas for Dangerous Goods in the European Road Transport Network. Lecture Notes in Computer Science, Computational Logistics. Vol. 9335, p.617-626.

8. Caro-Vela, M.D., Paralera, C., Contreras, I. 2013. A DEA-inspired approach to selecting parking areas for dangerous-goods trucks. European Journal of Transport and Infrastructure Research, 13(3): 184-200.

9. Cera, M., Fedriani, E. 2016. An advance in infinite graph models for the analysis of transportation networks. International Journal of Applied Mathematics and Computer Science, 26(4):855-869.

10. Conca, A., Ridella, Ch., Sapori, E. 2016. A risk assessment for road transportation of dangerous goods: a routing solution. Transportation Research Procedia, Vol. 14, p. 2890-2899.

11. Di Fazio, A., Bettinelli, D., Louette, E. et al. 2016. European pathways to introduce EGNOS and Galileo for dangerous goods transport. Transportation Research Procedia, Vol. 14, p. 1482-1491.

12. Dolia, V., Englezi, I. 2015. Determine the safe transport of dangerous goods route. Transport Problems, 10(1):31-44.

13. Forigua, J., Lyons, L. 2016. Safety analysis of transportation chain for dangerous goods: A case study in Colombia. Transportation Research Procedia, Vol. 12, p. 842-850.

14. Garbolino, E., Lachtar, D., Sacile, R. et al. 2013. Vulnerability and Resilience of the Territory Concerning Risk of Dangerous Goods Transportation (DGT): Proposal of a Spatial Model. Chemical Engineering Transactions, 32: 91-96.

15. ISO. 2015. ISO 9000:2015 - Quality management systems. 2018. [Cit. 08.12.2018]. Available online: https://www.iso.org/standard/45481.html

16. ISO. 2012. ISO 39001:2012 - Road traffic safety (RTS) management systems -- Requirements with guidance for use. 2018. [Cit. 08.12.2018]. Available online: https://www.iso.org/standard/44958.html

17. Janno, J., Koppel, O. 2017. Human factor as the main operational risk in dangerous goods transportation chain. Proceedings of 17th International Scientific Conference Business Logistics in Modern Management, Oct 12-13, 2017, Osijek, Croatia p. 63-78

18. Janno, J., Koppel, O. 2018. Operational risks in dangerous goods transportation chain on roads. Logforum, 14(1)_33-41.

19. Kanj, H., Flaus, J.-M. 2015. An Agent-based framework for mitigating hazardous materials transport risk. IEEE Conference on Evolving and Adaptive Intelligence Systems, Dec 01-03, 2015, France.

20. Karim, L., Boulmakoul, A., Mabrouk, A. et al. 2017. Deploying Real Time Big Data Analytics in Cloud Ecosystem for Hazmat Stochastic Risk Trajectories. Procedia Computer Science, Vol. 109, p. 180-187.

21. Krejci, L., Schullerova, B., Adamec, V. 2018. Risk Assessment of the Transport of Ammonia and Chlorine in Urban Areas. Chemicke Listy, 112(4):232-236.

22. Landucci, G., Antonioni, G., Tugnoli, A. et al. 2017. HazMat transportation risk assessment: A revisitation in the perspective of the Viareggio LPG accident. Journal of Loss Prevention in the Process Industries, 49:36-46.

23. Li, H.-H., Wang, Y.-J. 2017. Research on the Road Transport Risk of Domestic Hazardous Chemicals. AEBMR-Advances in Economics Business and Management Research, Vol. 50, p. 164-171.

24. Li, W., Gu, J. 2016. Application of IC Card License for Road Transportation in Commercial Vehicles Supervision and Service. MATEC Web of Conferences, Vol 81.

25. Liu, W., Zheng, A., Li, H. et al. 2012. Dangerous Goods Dynamic Monitoring and Controlling System Based on IOT and RFID. Proceedings of the 2012 24th Chinese Control and Decision Conference, May 23-25, 2012, Taiyuan, Peoples R China, p. 4171-4175

26. Lukasik, Z., Kusminska-Fijalkowska, A., Kozyra, J. 2017. Transport of dangerous goods by road from a European aspect. Scientific Journal of Silesian University of Technology-Series Transport, 95:109-119.

27. Mahmoudabadi, A. 2015. Developing a chaotic pattern of dynamic risk definition for solving hazardous material routing-locating problem. Journal of Loss Prevention in the Process Industries, 37:1-10.

28. Malekian, R., Kavishe, A.F., Maharaj, B.T. et al. 2016. Smart Vehicle Navigation System Using Hidden Markov Model and RFID Technology. Wireless Personal Communications, 90(4): 1717-1742.

29. Mlynczak, M., 2014. Risk assessment of the road transportation concerning dangerous goods. Proceedings of 22nd Annual Conference on European Safety and Reliability (ESREL), Sep 29-oct 02, 2013, Amsterdam, Netherlands, p. 2275-2280.

30. Nowacki, G., Krysiuk, C., Kopczewski, R. 2016. Dangerous Goods Transport Problems in the European Union and Poland. Transnav-International Journal on Marine Navigation and Safety of Sea Transportation, 10(1): 143-150.

31. Patricio, P., Santos B.J., Bateira, C. 2013. Transport of dangerous goods by road - Accidents involving flammable Gases (class 2.1) in Portugal. Proceedings of the 9th International Symposium on Occupational Safety and Hygiene (SHO), Feb 14-15, 2013, Guimaraes, Portugal, p. 389.

32. Rada, E.C., Ferronato, N., Torretta, V. 2017. Individual risk evaluation and interventions for mitigation in the transportation of hazardous goods: a case study. Proceedings of the 8th International Conference on Manufacturing Science and Education, Jun 07-09, 2017, Sibiu, Romania.

33. Razga, M., Jancarikova, E., Danisovic, P. 2017. Research of selected factors of safety in road tunnels for practice. 2nd International Conference on Engineering Sciences and Technologies (ESaT), Jun 29-jul 01, 2016, Slovakia.

34. Razga, M., Danisovic, P., Polednak, P. 2015. Extension of risk analysis model for road tunnels. Proceedings of the 24th Russian-Polish-Slovak Seminar on Theoretical Foundation of Civil Engineering, Aug 24-28, 2015, Samara, RUSSIA, Vol. 111, p. 687-693.

35. Roncoli, C., Bersani, Ch., Sacile, R. 2013. A Risk-Based System of Systems Approach to Control the Transport Flows of Dangerous Goods by Road. Ieee Systems Journal, 7(4): 561-570.

36. Rongrong, l., Yee, L., Bo, H. et al. 2013. A genetic algorithm for multiobjective dangerous goods route planning. International Journal of Geographical Information Science, 27(6):1073-1089.

37. Salmane, H., Ruichek, Y., Khoudour, L. 2014. A novel evidence based model for detecting dangerous situations in level crossing environments. Expert Systems with Applications, 41(3):795-810.

38. Smal, T., Kopczewski, M. 2016. Transportation of Dangerous Goods - Legal and Technical Conditions and Marking of Vehicles. Proceedings of the 20th International Scientific Conference Transport Means 2016, Oct 05-07, 2016, Juodkrante, Lithuania, p. 191-196.

39. Tang, L., Zhang, Y., Ying, X. 2014. Sensor-Based Real-Time Monitoring Hazardous Chemical Cargo. Proceedings of the 3rd International Conference on Green Power, Materials

and Manufacturing Technology and Applications, Dec 27-30, 2013, Wuhan, Peoples R China, Vol. 484-485, p. 311.

40. UNECE. 2017. European Agreement concerning the International Carriage of Dangerous Goods by Road. 2018. [Cit. 08.12.2018]. Available online: https://www.unece.org/trans/danger/publi/adr/adr_e.html

41. Xie, Y., Yu, M., Fu, J. et al. 2016. A Hazmat Transportation Monitoring System Based on Global Positioning System/ BeiDou Navigation Satellite System and RS485 bus. Proceedings of the 9th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI), Oct 15-17, 2016, Datong, Peoples R China, p. 1059-1063.

42. Ye, N., Wang, Z., Malekian, R. et al. 2016. A hidden Markov model combined with RFID-based sensors for accurate vehicle route prediction. International Journal of Ad Hoc and Ubiquitous Computing, 23(1-2):124-133.

43. Zero, L., Bersani, Ch., Sacile, R. 2016. Bi-objective shortest path problem with one fuzzy cost function applied to dangerous goods transportation on a road network. Proceedings of the 11th IEEE System of Systems Engineering Conference (SoSE), Jun 12-16, 2016, Kongsberg, Norway.

Assoc. Prof. Andrea Majlingova, PhD., Habil., Technical University in Zvolen, Department of Fire Protection, Slovak Republic
e-mail: majlingova@tuzvo.sk

orcid.org/ 0000-0002-7450-4004

Assist. Prof. Péter Pántya, PhD. Habil., National University of Public Service, Institute of Disaster Management, Department for Fire Prevention and Rescue Control, Hungary

e-mail: pantya.peter@uni-nke.hu

orcid.org/ 0000-0003-2732-2766