Transport of dangerous goods by rail

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Abstract. Every day, products identified as dangerous goods are transported across the EU by road, rail, water and air. Currently, large quantities of different types of dangerous goods are transported by rail. The influence of random factors and events can lead to an accident resulting in a leakage of hazardous substances. These types of incidents not only threaten the safety of rail transport, but also life, environment and property. The paper defines legal framework of DGT (dangerous good transport), risks during the carriage of hazardous materials and the main advantages of the rail transport of dangerous goods, compared with other transport modes.

1 Introduction

In the last few years, traffic volume, especially of hazardous substances, transported by rail has increased. Safety is becoming an issue of major concern. Regulations and preventive measures present powerful tool for increasing the safety and efficiency of "dangerous transports". Currently, each mode of transport, used for carriage of dangerous goods, has its own regulations for proper and correct ways of manipulations, package, labelling and transportation of hazardous substances. [1]

These rules have to be primarily respected by the shipper and the transporter. It is not possible to ensure enough protection of the population and the environment without the population's active participation and responsibility.

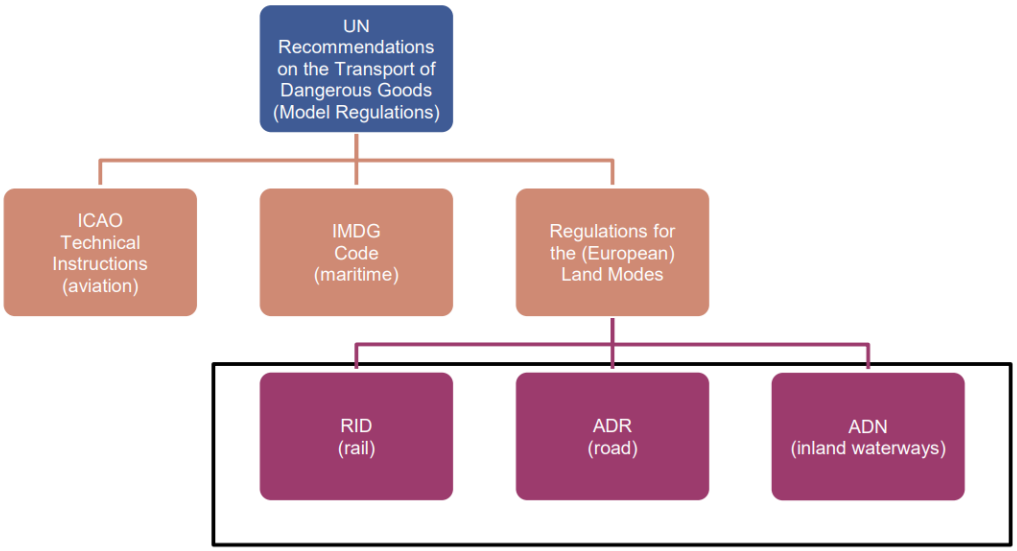

Fig. 1. Regulations for the international carriage of dangerous goods (Authors according to the Orange book)

2 Regulations for international transport of dangerous goods

2.1 International DGT by road

The international regulation of the carriage of hazardous substances by roads within the EU is achieved via the 'European Agreement Concerning the International Carriage of Dangerous Goods by Road' (known as ADR), drawn up by the United Nations Economic Commission for Europe (UNECE) in Geneva [2,3].

The provisions of ADR set out how producers, consignors and carriers should classify, package, label and transport dangerous goods. Specific vehicle and tank requirements and

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various other operational requirements such as driver training are also included.

2.2 International DGT by inland waterways

Carriage and manipulation of the hazardous substances in the terms of inland navigation are regulated by the AND Agreement. The agreement divides substances and materials into the classes (classification) according to the hazardous properties of the substances. It also sets uniform conditions for the labeling of dangerous goods and means of transport carried on waterways within the EU [4-6]. ADN was formed by grouping of two agreements – ADN-R (Agreement for the Rhine river) and ADN-D (for the Danube river). The agreement was established in 2006 in Geneva. The ADN consists of nine parts, which deal with the transport, handling and labelling of dangerous goods. [8,9]

2.3 International DGT by sea

The principal international rules for proper carriage of dangerous goods by sea are published in the IMDG code - 'International maritime dangerous goods code', which closely reflects the UN Model Regulations. Modifications of the IMDG code are the responsibility of IMO sub-committees. The carriage of goods in ships is covered by separate codes such as the 'International bulk chemical code' and the 'International gas carrier code'. The IMO is based in London; the UK's Maritime and Coastguard Agency, an agency of the Department for Transport (DfT), plays (in consultation with industry) a leading part in its deliberations [10].

2.4 International DGT by air

The International Civil Aviation Organization (ICAO) established the Technical Instructions for the Safe Transport of Dangerous Goods by Air (ICAO technical instructions), which are closely aligned with the UN Model Regulations, and cover the following: [11]

- classification of substances,
- proper packing,
- labelling and marking of packages, the documentation of consignments,
- the acceptance procedures to be used by air operators,
- the loading of dangerous goods on aircraft and the training of personnel involved in the transport of dangerous goods by air [12].

2.5 International DGT by rail

The international carriage of dangerous goods by rail within the EU is governed by annex I of the Convention Concerning International Carriage by Rail (COTIF).

Annex I is the 'Regulations Concerning the International Carriage of Dangerous Goods by Rail', more commonly known as 'RID'. RID is published by OTIF and updated every 2 years. Any amendments to the regulations are discussed and agreed by the RID Committee of Experts [11].

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The structure of Regulations RID is divided into seven parts, each of which is divided into chapters and then sections and paragraphs. In accordance with the conditions laid down in the RID dangerous goods are divided into nine hazard classes (table 1). [12]

Table 1. Classification of dangerous goods.

Class	Substance
1	Explosives
2	Gases
3	Flammable Liquids
4.1	Flammable Solids
4.2	Spontaneously Combustible Solids
4.3	Dangerous when Wet
5.1	Normal Oxidizing Agent
5.2	Organic Peroxide Oxidizing Agent
6.1	Poisons
6.2	Biohazard
7	Radioactive
8	Corrosive
9	Miscellaneous

3 Regulations for international transport of dangerous goods

Risk is commonly understood as the combination of the magnitude and likelihood of potentially harmful events (hazard), and the severity of their consequences (1). In this context risk is estimated as the product of hazard and consequences:

$$Risk = Hazard \times Consequences \quad (1)$$

The risk assessment process consists of several steps:

- identification of risks,
- risk analysis,
- risk evaluation,
- risk treatment [4].

The risk identification process includes the identification of main factors that may affect the occurrence of an emergency or accident in rail transport:

- **the state of the track** – level of rail quality,
- **line characteristic** – can depend on the interference deriving from the trains themselves (single or double track) and on the line alignment,
- **traffic system** – using of the automatic block signal (safer) or the telephonic signal (the least efficient), both require a visual check by or intervention on the part of the driver,
- **railway operation** – human error (accidental/no accidental),
- **wagon characteristics** – wagon defects (condition of a wagon – its age, the last maintenance, check),
- **probability of hazardous material release** – type of material transported, quantity of material, modality of transport, train speed [5].

Based on historical data, the most possible types of accidental events that should be considered in a Risk Assessment are: [13]

- **collision,**
- **derailment,**

- **grade crossing** .

Most of these accidents are caused by events resulting in impacts external to the mode of transport.
Monitoring the transport situation and subsequent communication and consultation may lead to risk treatment process (in the form of preventive measures and procedures that may eliminate the emergencies and risks to acceptable level). [14]

In accordance with the risk management the Commission of Experts OTIF (Working Group on Standardization of Risk Analysis) developed Generic Guideline for the Calculation of Risk due to Railway Transport of Dangerous Goods. This guideline is intended to assist in the implementation of basic principles that are used for risk assessment in Chapter 1.9 of the RID Regulations, "Transport restrictions by the competent authorities". [15] At the present guideline uses widely known and utilised procedures for analysis and risk evaluation (for example method Fault Tree Analysis FTA, Event Tree Analysis ETA or Quantitative Risk Analysis QRA)

4 Benefits of railway transport of hazardous materials

4.1 Safety

Reliable freight transport is the primary precondition for transport quality. In the comparison with other transport modes, the rail transport is certainly the most reliable traffic mode. The reliability does not result from a lower number of traffic accidents, but also lesser losses incurred from the accidents [16]. Accident rate of rail transport parties is almost zero, which is not true for car, neither air transport. The road transport carries along a direct danger for the safety of participants in every accident. In the rail transport, according to available statistics, the results of the investigation of accidents, the most common causes of the accidents are human error and equipment failure. The surroundings are also not negligible. Figure 2 shows the internal and external sources of threats, which are the causes of accident in rail transport.

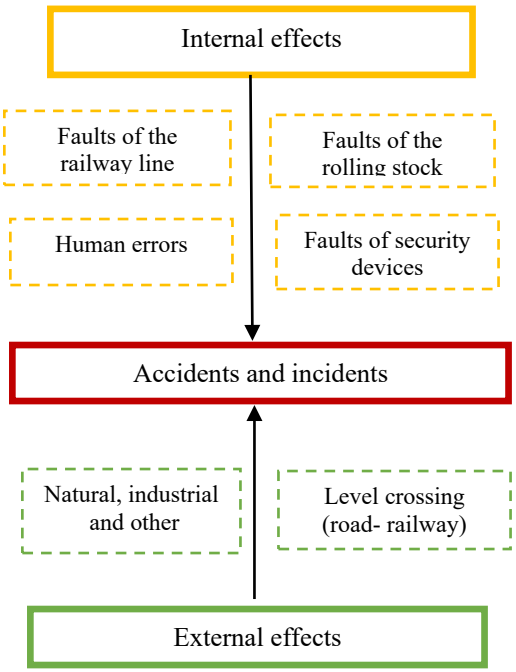

Fig. 2. Main causes of accidents in railway transport (Authors based on Verma)

Figure 2 shows that the causes of accidents can be defined according to the identified threats. Railway transport also disburdens overburdened network of highways and roads.

4.2 Ecology and environment

The high amount of transports and requirements on speed, reliability, punctuality and flexibility of transports increase every day. Millions of tons of goods transported each day by various modes of transport have an impact on quality of environment. Ability of meeting customer's requirements in an environment-friendly manner has become therefore one of the basic criteria for quality of transport services, as well as a significant competitive advantage of railway carriers. Railway transport is an efficient and environment-friendly transport system, as the large volume of goods can be transported on long distances quickly and with a minor impact on environment. Compared with road and air transport, railway transport produces the lowest amount of emissions and requires much lower costs on regeneration of damaged environment. From the total amount of costs on reduction of negative impacts of transport industry on environment, only 8% comes from railway transport, while up to 90% comes from road transport, even though its traffic performance is by 50% lower than the traffic performance of railway transport [9].

The most serious problem near railway lines is noise [10]. Noise produced by the railway transport on environment is lower than by the road transport. The intensity of the noise is influenced by several factors. Among the most significant factors there are means of propulsion of locomotives, inequalities of rails, base of ballast, speed, and different kinds of trains.

Measures to reduce noise can be implemented by means of suitable design of railway track and bearable construction of railway subgrade, including the imposition of tracks or construction of noise barriers. A very good solution is to lead the railway tracks parallel with the roads, motorways, i.e. to create transport corridors, and to protect the surrounding environment by ground mounds with higher vegetation [13].

4.3 Less restrictions

In the terms of transport of dangerous goods, road transport has many restrictions according to ADR (transport through the tunnels, amount of shipments etc.) In general, compared with road carriers, the important advantage of railway transport can also be lower transport restrictions, such as limitations in utilizing highways and primary roads, limitations in traffic peaks, or obligations to keep safety breaks. Advantage of railway transport out of the EU countries is also shorter waiting times on border crossings [8].

4.4 Optimisation of transport processes

Considering all transport claims a new trend of a combined transport is coming to the sphere of transports. The transport system lays stress on utilizing of railway transport supplemented by advantages of other traffic modes. It combines flexibility and fast transposition of goods with a reasonable consumption of energy and positive ecological aspect, minimizes impacts on environment and that way charges the society with rational ecological costs [3], [12].

5 Procedures to improve the safety of railway dangerous goods transport

Strict qualification, strengthening the training of practitioners

This objective can be reached by improving the professional trainings by qualified training institutions. The institutions should prepare every participant of the dangerous goods transport to guarantee the quality of training, so the operators and managers have a knowledge of proper respond on each type of emergency.

Implementation of security measures

Handling of dangerous goods must be strictly monitoring, and all the security procedures must be respected. Requirements on the proper labelling and marking of shipments, tanker filling and handling must be complied [7]. The loading operations of the hazardous materials must be monitor during the whole process. In the case of carriage of larger transport volume, the second and third category of dangerous goods, the measurements standards must be strictly enforcing to avoid the occurrence of the leakage. Mainly forwarders should conscientiously implement the system of tanker inspection according to current standards and procedures.

Contingency plans

Transport of dangerous goods represents big responsibility. In the case of an accident, not only significant economic losses, but also serious social impact can cause. To ensure the safety, in the case of leakage, fire or other accidents, prompt management should be made. This can be reached by establishing and improving the railway dangerous goods transport contingency plans. Plans should contain emergency procedures, methods, proper responding, information network etc [5]. Emergency plans should be situated at all handling stations, intermodal hubs and at the port terminals.

6 Design of minimising-risk model for railway transport of dangerous goods

The model of risk minimising during the transport of dangerous goods by rail consists of 3 steps. Hazard identification and risk estimation by using expert estimates; the second step is to reveal the risk sources based on the selection from the threat library; and the last part represents the decision-making process for the transport of dangerous goods by rail.

6.1 Hazard identification and risk estimation

In 2009, the European Railway Agency approved the Common Safety Method (CSM) as the basic model for managing rail transport risks. The first step of the proposal is to carry out the identification of risk sources according to the standard with respect to the CSM method. First, a system and the context have to be defined. The rail transport system can be divided into:

- transport infrastructure,
- means of transport and technology,
- management and information systems,
- human resource,
- repair capacities.

In the paper, the attention was paid in particular to the first three sections of the rail transport system. The context was mainly determined in relation to the likely occurrence of emergencies. Depending on the threat location, it may be:

- on the train,
- on the track and on the bridge,
- in the station,
- in the tunnel,
- in the vicinity of the track.

The second step of the model is to find out the threats that can endanger safe railway transport of dangerous goods. Based on data from the KISDIS Crisis Information Project, it is possible to divide the reactions to:

- human factor errors (fatigue, error, inattention, lack of communication, inadequacies in the organization, inappropriate repair, operator error, non-compliance with work procedures, non-compliance with occupational safety rules, etc.),
- extreme natural phenomena (avalanche, frost, constant frost, whirlwind, extreme drought, floods, long-lasting rain, torrential rain, snow calamities, etc.),
- technical failures (failure of safety systems, mechanical failure, failure of auxiliary equipment, failures of safety systems),
- criminal activity (individual and organized crime, sabotage, terrorism),
- Other (racial and religious conflicts, unauthorized demonstrations, unprofessional handling of dangerous goods, etc.).

The examination of the likelihood of risk consists of:

- operational failures,
- staff failure,
- threatening a person outside the system,
- the impact of floods,
- the influence of the vortex,
- impact of storm (lightning),
- the influence of high temperatures,
- impact of earthquake.

The risk categorization has been chosen according to the expert opinions on the transport of dangerous goods by rail.

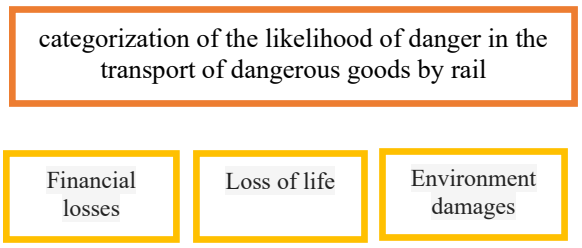

Fig. 3. Main causes of accidents in railway transport (Authors)

The second part of the model consists of three steps that help in the process of dealing with the crisis (Figure 3).

1. activation of the crisis staff

- receiving a report on the occurrence of an emergency and verifying the report
- initial evaluation of an emergency
- convocation of the crisis staff
- crisis staff starts up the realisation activities [13].

2. starting rescue work

- initiating activities under the crisis plan
- getting more detailed information from the place
- of emergency
- monitoring and evaluating the fulfilment of tasks
- according to the crisis plan

- convocation of the crisis staff
- performing rescue work
- logistics support on the place of emergency
- informing superiors about the progress of the emergency solution
- informing own employees
- informing customers
- informing the media
- conducting a crisis management meeting
- inviting experts to deal with emergency
- ending rescue work
- update the crisis plan
- the selection of workers and means for dealing with the emergency
- termination of rescue activities
- informing own employees about the current working regime.
- informing customers of the current provision of services
- informing the media about the state of the emergency response and its impact on society, the population and the environment
- calculating damages and losses
- termination of the crisis staff [17].

3. finishing rescue work and system recovery

The third part of the model is a sub model of the decision-making process for the transport of dangerous goods by rail. An important element is the establishment of a National Transport Information Centre (NTIC) to collect all transport data. In the case of emergencies, it provides information as required to individual agendas. NTIC has information about the railway lines and rail traffic. Among the components of the agenda are (in Slovakia): firefighters, police, emergency medical services, crisis management, railway administrations, Slovak hydrometeorological institute, infrastructure manager (ZSR), carriers and shippers. The information from the system should be available in addition to rescue services and distribution publishing systems such as systems of the Ministry of Transport and Construction, traffic portal, carriers, shippers, and to subjects of crisis management.

Adequate decision-making process for the occurrence of extraordinary events and accidents during the transport of dangerous goods by rail is aimed at implementing telematics applications [18].

7 Conclusion

In the rail transport there are several risks and threats which should be taken into consideration. Special attention must be paid to the transport of dangerous goods, which is very risky. Transport of hazardous substances could have disastrous consequences on people, as well as the environment and the property. Safety, as the most important element in the terms of the transport of dangerous goods, is reduced by the increasing the level of risk. Risk management allows to know the areas of greatest risk, identify individual risks, express their value and assess them using different methods and procedures. They enable proposing measures to minimize the risks to acceptable levels. It is crucial to recognize all potential threats and eliminate them to the acceptable level to ensure the safety and efficiency of railway transport in general.

References

1. R. Anderson, C. Barkan. Transportation Research Record. Pp. 88-98. (2004)
2. European Agreement concerning the International Carriage of Dangerous Goods by Road. UNECE (2017)
3. European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways. UNECE (2017)
4. A. Galierikova, J. Sosedova.*Communications : scientific letters of the University of Žilina*. **19**. **2** 80-85. (2017)
5. Gheorghe et al. Reliability Engineering & System Safety. **88**, **3**. 247-272. (2005)
6. International maritime dangerous goods code (IMDG Code). International Maritime Organisation. (2016)
7. O. Stopka, R. Kampf. Transport, 33, 280-290. (2018)
8. T. Kalina, et al. ALTA-Journal of Interdisciplinary Research.. **7**, **2**. 274-281 (2017)
9. Orange book: *Recommendations on the transport of dangerous goods*. United Nations. 17th edition. Vol. **I**. (2015)
10. I.A. Papazoglou *Final report to KOVERS, unpublished working paper*, Swiss Federal Institute of Technology, ETH, Zurich (2000)
11. P. Piala, et. al. *Communications : scientific letters of the University of Žilina*. **19**, **2**. 116-119. (2017)
12. P. Drizdziel, B. Bukova, E. Brumercikova. Transport problems **10, 4**, 5-13. 2015
13. *Regulation concerning the International Carriage of Dangerous Goods by Rail* (RID). Intergovernmental Organisation for International Carriage by Rail (2017)
14. *Technical Instructions for the Safe Transport of Dangerous Goods by Air* (ICAO technical instructions). Council of ICAO. (2016)
15. L. Černá, A. Dolinayová, J. Daniš. In: *Proceedings of the 20th International Scientific Conference Transport Means 2016*., Pages: 414-419. (2016).
16. L. Černá, J. Mašek. *Tranport Means – Proceedings of the International Conference*. 567-570. (2015)
17. M. Verma. Transportation Research Part C : Emerging technologies. **19**, **5**. 790-802 (2011)
18. Project KISDIS, 2012. Online. Available at <http://anakan.cz/soubory/**kisdis**/metodika-krizoveho-rizeni.pdf>