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Development of the Infocommunication System for the Intelligent Rail Transport System of Dangerous Goods in Hungary

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Abstract. Through the examples of recent accidents in Hungary and abroad, we will reveal the possible reasons for the release of dangerous goods into the environment, and, considering these accidents, we will draw conclusions for the safety of rail transport of dangerous goods. While examining the situation of the rail transport of dangerous goods in Hungary, we will present the fundamental concepts and regulations of the transport of dangerous goods in Europe. Today the system of the transport of dangerous goods greatly relies on manual recording and identification methods. Our aim is to provide the ICT bases for tracking the transport of such goods and monitoring their storage conditions, by making suggestions for the development of a monitoring and tracking system to increase the safety of the rail transport system, provide protection for the critical rail infrastructure and ensure the safety of the transport of dangerous goods.

Keywords: ICT, transport of dangerous goods, railway safety, RID, accidents

1. Introduction - Incidents and examples of recent accidents in Hungary and abroad

1.1. Problem statement

“In the EU-28 in 2013, 48 accidents occurred involving the transport of dangerous goods. In 67 % of them there was a release of dangerous material. Austria reported the highest number of accidents (23, 16 of which included the release of dangerous material), followed by Lithuania (10, none of which included the release of dangerous material).” [1] Throughout Europe, these accidents cause significant material damage and an increased risk for society, therefore all efforts must be made to prevent such accidents or to minimise the damage if such accident happens.

In Europe, according to Tokody et al. on the basis of Safety Database Report [2] “77.2 % of railway accidents (2013, UIC) are caused by a third party (external reason), and secondly, in 7.3 % of the cases, the human factor is responsible for these accidents (2013, UIC) (internal reasons from the point of railway). According to the safety report of the UIC, external reasons mean that the accident was caused by a third party, or by the weather or the natural environment. These factors cause more than 80 % of the accidents. In case of accidents caused by a third party, 47.1 % is the result of unauthorised trespassing, while in 24.8 % of the cases the train hits a vehicle (this is higher rate, 17.2 %) or a pedestrian (7.6%) in level crossings. Among the internal reasons, the infrastructure, the rolling stock, the human factor (only the railway personnel) and the users of the railway (passengers) are mentioned. Internal reasons are responsible for approximately 20% of accidents. The highest rate is caused by the human factor (7.3 %), then by the rolling stock (4 %), the users of the railway (3.9 %) and finally the infrastructure (3.4 %).

From the above data it can be stated that 88.4 % of railway accidents are directly caused by human activities (unauthorized trespassing, ignoring signposts, etc.). In 7.4 % of the cases, accidents are due to some technical (indirectly human) reasons, when inadequate human activities cause the problem (problems in planning, implementation or maintenance, etc.). The lowest rate (3.5 %) of accidents is caused by chance or vis major events (weather and environmental conditions).

In our opinion, by reducing the human factor, the statistics of accidents can be improved for the whole transport process. Our study does not discuss third-party accidents, as this issue is addressed by transport safety experts. Our investigations focus on the human resource operating the railway system and the technical part of the railway system (infrastructure, rolling stock and safety equipment).” [3]

This problem also exists outside Europe. According to Erkut et al. about 36% of rail incidents in the USA (in 2013) were caused by human error, 33% were due to the failure of the storage or packaging material used for dangerous goods, and 30% happened because of the accidents of vehicles, (the remaining number of incidents were caused by other reasons) [4]

Our hypothesis is the following. The safety of the transport of dangerous goods depends on human activity, the condition of the technical systems and the safety of railway transport, as well as the quality and quantity of the transported material and the appropriate way of its storage [5].

“Member States shall ensure that railway safety is generally maintained and, where reasonably practicable, continuously improved, taking into consideration the development of Community legislation and technical and scientific progress and giving priority to the prevention of serious accidents.” [6]

1.2. Example of an accident abroad

In the following section, we will present several examples, and by examining these incidents we will determine the way of making the rail transport of dangerous goods safer through the use of ICT. During our research we will try to find the possibilities of increasing the safety of dangerous goods by using information systems, communication and computer networks, embedded systems and robotics. So far, the accidents in the transport of dangerous goods in Hungary have not been listed among the major events in international records. Accident situations in Hungary may be assessed in comparison with the following incident which happened abroad.

Recently, a very serious rail accident has taken place in a foreign country during the transport of dangerous goods. On 27 December 2015, one of the freight trains of the Queensland Rail Company consisting of 26 tank cars with a cargo of sulphuric acid was derailed at Julia Creek (Australia). The estimated amount of the transported sulphuric acid was between 200 000 and 820 000 litres. Two days after the accident, local authorities talked to ABC News about the release of 310 000 litres of dangerous substances into the environment.[7] [8]

In case of such an accident, besides the release of the transported goods, the diesel used by the rail locomotive can also escape into the environment. In many cases, the damaged train set creates a hazard of fire and explosion, and the release of dangerous substances could cause serious harm to the environment. If the accident happens in an inhabited area, it can have unpredictable consequences for the population.

Fig. 1. 27.12.2015 Julia Creek, Australia [7] [8]

1.3. Examples of accidents in Hungary

On 02.04.2015, during the setting up of a train set at the marshalling yard of Miskolc, and during the switching the points of railroad switch a tank car filled with liquefied isobutene (UN 1969) was derailed and turned over to its side on the rail brake while hump shunting. The derailed car collided with two empty cars while shunting, and the rolling cars also derailed. The tank car was not damaged to such extent that could have caused the release of dangerous substances into the environment. [9]

On.03.12.2013, at the marshalling yard of Eperjeske and Fényeslitke-Déli, dangerous substance leaked into the environment from the tank cars filled with liquefied hydrocarbon gas mixture (UN 1965). [9]

Fig. 2. The overturned tank car filled with liquefied isobutene at the marshalling yard of Miskolc [9]

On 03.12.2013 and 04.12.2013, at the station of Kelebia, dangerous substance escaped from the internationally used tank cars filled with hydrocarbon gas mixture (UN 1965) as a result of untight sealing. The vehicle was returned from the station of the Serbian town Szabadka for repair. [9]

On 16.10.2013, at the station of Almásfüzitő-felső, dangerous substance leaked from a Slovakian tank car filled with hydrocarbon gas mixture (UN 1965), and the main railway line no. 1 was closed from traffic for one hour. As the leakage (dripping of the liquefied substance) could not be stopped at the station, the tank car was forwarded for offloading and service at a restricted speed with interrupted power supply. [9]

On 12.05.2012, between Máriabesnyő and Bag, six tank cars of a freight train derailed and overturned. The railway track, the overhead contact line system and the vehicles suffered serious material damage (approx. 200 million HUF). The accident was caused by the fault of the track and the inattention of the driver failing to observe the speed restrictions and exceeding the speed limit. Other irregularities also played a part in the accident. Besides the six tank cars, a tank car filled with sulphuric acid was also added to the train, but luckily, it did not derail. [9]

Fig. 3. The tank cars at Mariabesnyő [9] [10]

Besides high-capacity heavy train sets, high running speed and the technical condition of the vehicles and the tracks can also affect the safety of freight transport. In many cases, however, it is the cumulative effect of many factors, the fault of a number of responsible persons, as well as long-existing technical problems, which can lead to an accident causing significant damage. Such a case has been presented through a foreign example, where a large amount of dangerous substance escaped into the environment. Considering the circumstances in Hungary, sadly, it can be said that only luck has prevented the happening of accidents with more tragic consequences.

Other examples of accidents in Hungary which are not related to freight transport, but which resulted in the release of dangerous substances into the environment:

On 20.11.2014, between the stations of Révfülöp and Badacsonytomaj, a Bz multiple-unit train hit a wild boar, and 700 litres of gas oil (UN 1202) escaped from the fuel tank of the multiple-unit cars into the environment. [9]

On 30.08.2014, between the stations of Millér and Szajol, in the middle of construction work, a misplaced railway construction material (long rail) caused significant material damage and environmental pollution. It ripped the fuel tank of the locomotive without the driver noticing it. He only noticed it after travelling three kilometres, by which time 1600 litres of gas oil (UN 1202) had escaped. [9]

Fig. 4. The gas oil tank of the locomotive which was ripped on open line, and the long rail causing the accident [9]

On 09.12.2012, between the stations of Baja and Bácsalmás, a passenger train hit a snowdrift, and its fuel tank was damaged, which caused the leakage of 500 litres of gas oil into the environment. [9]

In many cases, these non-freight accidents are due to the circumstances caused by negligent or inappropriate working practice. Technical failures only rarely lead to the release of dangerous substances, as, for example, a passenger train does not carry a significant amount of dangerous material, apart from the gas oil in the fuel tank of diesel locomotives, and the material collected in the closed-system toilet of modern passenger trains or multiple-unit trains, which could pollute the environment.

1.4. Impact on the Environment, Public Safety, Transport Infrastructure and Business Costs

The accidents and incidents happening during the transportation of dangerous goods have a wide range of negative effects. For example, they can significantly affect the population (death, injuries), cause long-term damage to the environment, may require the evacuation of the population, or harm the infrastructure, the buildings or vehicles. Explosive materials pose further risks, as terrorists can use them to attack civilians or critical infrastructure. [11] [12] [13]

An average tank car has the capacity of 60 m3 (60 000 litre). In 1995 in Hungary (Kaba – Straw factory) a disaster-like event of environmental pollution took place at the industrial site. 200-400 m3 of gas oil leaked onto the ground, which leached into the soil and groundwater. After 10 years, during the remediation process, nearly 14 000 m3 of polluted groundwater has been extracted and cleaned. Also 135 litres of hydrocarbon products have been extracted. [14]

1 litre of gas oil can pollute 1 million litres of water. [15] Therefore, in case of the release of 60 000 litres of gas oil, 60 billion litres of water could become unfit to drink. This, besides causing significant harm to the environment, would have serious effect on public and personal safety, and the remediation process would impose an immense financial burden on society, as it could last for decades. As the above examples show, in the event of such accidents, the transportation infrastructure can also be seriously damaged. The damages caused in railway infrastructure can mount to hundreds of millions forints, as, in case of a single rail car, the damages often reach the amount of tens of millions forints.

2. Administrative background - Transportation of Dangerous Goods Regulations and Laws

Goods, materials or objects are considered dangerous if their extraction, production, storage and/or transport can have a harmful effect on the environment (e.g. pollution, fire or explosion) and on people's health (e.g. poisoning or radioactivity).The transportation of such goods are strictly regulated in road, rail, water and air traffic. According to these regulations, all dangerous substances have their own UN numbers. The list of dangerous substances are rather limited compared to the number of known chemicals, however, the substances on this list have been given their UN numbers. At the transport of dangerous goods, an orange plate, the sign of danger, indicates the UN number and the Kemler number, which identify the transported material. The Kemler number shows the main and secondary hazards of the substance identified by the UN number.

"The transport of dangerous goods by rail is regulated by the Regulations Concerning the International Carriage of Dangerous Goods by Rail (RID) specified in Annex C of the Convention Concerning International Carriage by Rail (COTIF). The version of its text harmonized with ADR, the RID 2011 was issued with Act LXXX of 2011."[16]

The act of 2011 has been amended several times, as in 2013 and last year as well. Therefore, the second annex of the Act LXXXIII of 2015, which has been in effect since 02.07.2015, is Annex C of the Convention Concerning International Carriage by Rail (COTIF) which consists of 1337 pages including the Regulations Concerning the International Carriage of Dangerous Goods by Rail (RID). The above regulations do not apply to all countries, only to the RID Contracting States, or more specifically, to the members successfully concluding the ratification process.

Besides the above-mentioned international regulations, the European Union issued Directive 2008/68/EC on the transportation of dangerous goods on land. This was necessary to provide uniform regulations for dangerous goods at the level of the member states. International agreements do not always ensure that all member states observe its regulations, and the differences between member states must also be regulated. [17]

In order to apply the regulations in effect, an interpretative decree was issued by the Ministry of National Development: Decree No. 62/2013 (X.17.) entitled "The Domestic Application of the Regulations Concerning the International Carriage of Dangerous Goods by Rail (RID), which is still effective.

The above-mentioned laws and regulations mostly referred to the agreements between the countries of Western Europe. Therefore, international freight transport between the states of the former Soviet Union or China, Vietnam, etc. (eastern "socialist" countries) and Hungary (23 member states) is regulated by the SMGS Convention. It is entitled "Act XXXVII of 2011 on the publication of the consolidated text of the Convention concerning International Freight Traffic by Rail (SMGS) and its Annexes with modifications and complements". This law was amended as "Act LXVII of 2014 on the announcement of the modification of the Convention Concerning International Freight Traffic by Rail (SMGS) and it Annexes of 2014".

2.1. Hazard Identification

The classification of dangerous substances, according to the Convention Concerning International Freight Traffic by Rail (COTIF) Annex C, is based on the Regulations Concerning the International Carriage of Dangerous Goods by Rail (RID) in effect since 1st January 2015, which divides the substances into classes from 1 to 9. Class 1 includes explosive materials and objects. Class 2 covers gases, while Class 3 flammable liquid substances. Class 4.1 includes flammable solid substances, self-reactive substances and desensitised solid explosives. Class 4.2 is for substances liable for spontaneous combustion, while Class 4.3 covers those materials which, in contact with water, can emit flammable gases. Class 5.1 includes oxidising substances, while Class 5.2 is for organic peroxides. Similarly, in case of Class 6, Class 6.1 includes toxic, while Class 6.2 infectious substances. Class 7 is for radioactive, Class 8 for corrosive and Class 9 for miscellaneous dangerous materials and objects. [18]

The above-mentioned UN and Kemler numbers indicate the type and hazardousness of dangerous goods. Example for the UN number: UN 1202 – gas oil or diesel fuel or heating oil light (flash-point not more than 60 °C). Kemler numbers (2-4 numbers) indicate main hazard and secondary hazards as the following:

2. gas released due to pressure or chemical reaction

3. flammability of liquids, gases and vapours
4. flammability of solid materials
5. oxidising (fire-intensifying) effect
6. toxic effect
8. corrosive effect
9. risk of spontaneous violent reaction [18]

If the number of secondary hazard is zero, the secondary hazard is negligible. However, if the letter x appears before the series of numbers (max. 3 numbers) the substance can have dangerous reaction with water.

Apparently, the identification of the transported dangerous goods is not an easy task for humans, especially in extraordinary situations. The recognition and identification of dangerous goods must be achieved by using machines. The modern ID system allows the storage and, if necessary, the display of much more information than manual solutions.

3. Security and Monitoring System prototype system architecture

In Europe, the vehicles carrying dangerous goods are identified by the visual inspection of the RID plate on site. The inappropriate transportation of goods causes significant hazards (see Fig. 5). Vehicles transporting dangerous goods cannot be identified in a standard, automatic way. In case of an accident, every minute counts in the identification process, as human lives may depend on it. Any delay in the recognition of hazards can cause more extensive and more serious damage.

Fig. 5. Inappropriate transport of dangerous goods [19]

Therefore, a uniform monitoring, tracking and identification system is needed throughout Europe for the transportation of dangerous goods (see Fig. 6). In the situation of an accident such a system could provide information for the disaster management staff. It could also help to identify the causes of the accident. It could send alert (via e.g. GSM-R) to the competent persons if a loss of pressure occurs in the tank, or the temperature of the transported substance exceeds the pre-set level of temperature. Each of the railway vehicles has own ID tag (RFID tag). [20]

A further advantage of such a system is that it does not only make the transport of dangerous goods safer but it also improves the safety of the entire system of traffic. Through the collection and analysis of data, it is possible to predict certain events. This way all traffic participants can be informed about any current and expected events.

This system is based on communication and intelligence programmed into various system elements. This intelligence means that the different system elements are able to communicate with each other, and based on their states, perceived information and calculations they are able to influence and inform the participants of the system.

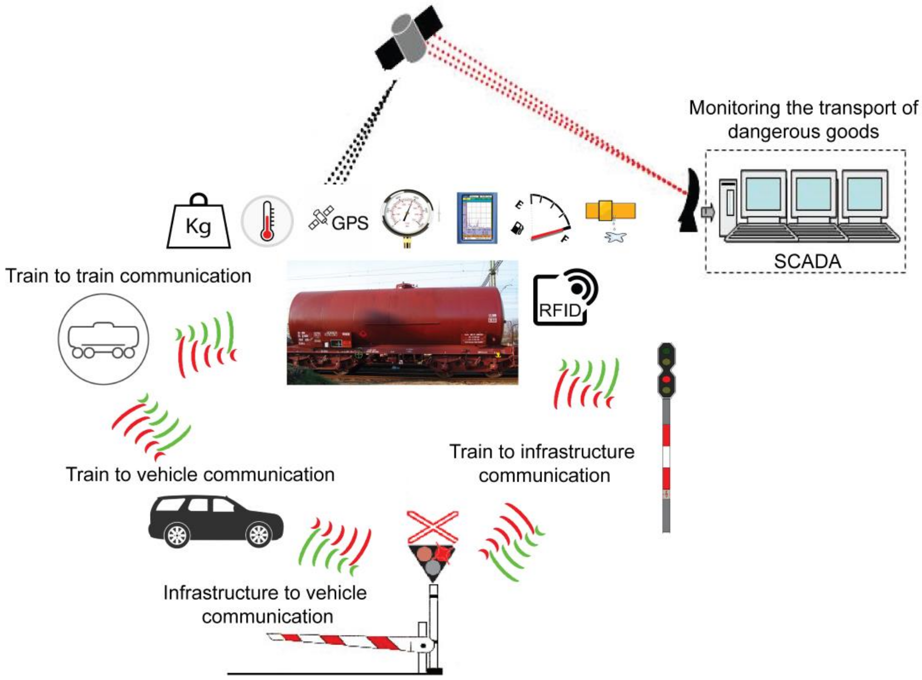

Fig. 6. Monitoring system of the transport of dangerous goods and communication systems for safer railway transport

4. Summary

Dangerous substances, due to their material properties, can carry potential risks in themselves even during their warehouse storage. What can happen then, if such substances are taken into rail transport, a system which is known for having its risks? The average speed of international railway transport in Europe is 18 km/h [21], while, according to certain references, the average speed of freight trains in Hungary could reach 20-40 km/h, but in reality, the average speed is only the fraction of the European level. Elsewhere in the world, for example in India, freight trains move at an average speed of 14-25km/h. [22] The reason for such a low average speed is of course the amount of time spent waiting during the route. The real momentary speed of a freight train can be higher. In case of the accident of a high-speed vehicle, the physical harm, and, therefore, the material damage is more extensive, and the transported dangerous goods could be scattered or spilt in a larger area. Consequently, this could affect a greater number of people. Slow international traffic could also cause problems, as the train sets transporting dangerous goods spend more time in the territory of our country, carrying further risks. Potential risks, therefore, could arise from the transport of dangerous substances, their storage in railway territories, or their trafficking by the areas used by railway staff or passengers. The factors causing accidents include the technical conditions of the railway lines and vehicles, the negligence of the participants of the transportation process, or their inappropriate working practice. However, certain unexpected events could also happen, such as the accidents caused by the failure of noticing different signs (e.g. at road and rail crossings, passing the stop sign) or the error of the participants of railway traffic (e.g. engine driver, switchman or train dispatcher).

Considering the examples of the above-mentioned railway accidents, it can be stated that the release of dangerous substances into the environment is often caused by human inattentiveness, and it is followed by a long and expensive remediation process. The safety of the transport of dangerous goods by rail primarily depends on the observance of transport regulations, but it is not possible without ensuring the adequate level of safety in railway traffic. Therefore, the issue of safety needs to be addressed in a complex way in this case, too. It can only be achieved by collecting and analysing a wide range of information about the system with the help of the presented monitoring system.

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