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EXAMINATION OF ROAD TRANSPORT ACCIDENTS INVOLVING DANGEROUS GOODS

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ABSTRACT

The prevention and management of emergencies arising from the transport of dangerous goods is one of the basic tasks of the professional disaster management authority in Hungary. The identification and documentation of the causes leading to the accident are essential elements of the development of an appropriate risk analysis methodology and the establishment of risk communication as well as the prevention of incidents involving the transport of dangerous goods. The prevention and the management of such incidents can be an extremely complex task, where the potential for reducing the time factor is highly justified. This paper presents the summary of research revealing the causes, consequences and frequency of road transport accidents involving dangerous goods in Hungary.

KEYWORDS: road safety, accidents, dangerous goods, ADR

1. Introduction

A wide range of activities involving dangerous substances are now regulated by a number of international conventions, but the risk of an accident occurring can never be reduced to zero. This is particularly true of the emergence of hazardous situations due to the changing position of goods, where it is extremely difficult to predict the location, time and consequence.

The causes, consequences and frequency of accidents involving the transport of dangerous goods by road must be investigated, and it is essential to identify ways of reducing the risks and to find and apply technical solutions to improve the effectiveness of consequence management. Maintaining the continuity and uninterrupted transport of dangerous goods is a priority in the interests of society as a whole. Short-term risks to human

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health from thermal radiation, explosions and toxic effects are discussed in detail in the international and national literature. Environmental effects are primarily understood as environmental hazards from the emitting source (Kátai-Urbán et al., 2019). Pollution of Hungary's surface waters is a recurring problem, as our country lies at the deepest point of a major river basin (Nagy, 2023).

The United Nations has set 17 Sustainable Development Goals (SDGs) for 2030, of which Goal 3 is "*Ensure healthy lives and promote well-being for all at all ages*". Within this set of goals is *"(3.9) By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination*" (United Nations, 2025).

The value of the EU's chemical imports increased from €97 billion in 2002 to €363 billion in 2022, an average annual growth rate of 6.8%. Over the same period, exports grew from €152 billion to €523 billion, an average annual increase of 6.7%. Over the period 2002-2022, EU trade in chemicals increased steadily, rising from €55 billion in 2002 to €190 billion in 2022 (Eurostat, 2025). As trade in chemicals increases, we can expect the frequency of transport accidents to rise in the future.

Hungary's geographical location exposes it to a strong flow of goods to and from the East and South, which results in a high share of transit shipments in addition to domestic shipments. Our transport infrastructure plays a key role in Hungary's economy. It is a legitimate social necessity that the increase in the volume of dangerous goods transported should be matched by an increase in the level of transport safety and that the burden on the environment should not increase. For this reason, regular and consistent checks on dangerous goods and the sites where they are transported, the investigation of accidents and the sanctioning of any irregularities detected have become the primary preventive tasks of the inspection authorities. The proper conduct of investigations into accidents during the transport of dangerous goods and the evaluation of the experience gained from accident investigations are very important issues. The identification of the causes and consequences of accidents and incidents during the transport of dangerous goods and possible ways of preventing them is of key importance. The main objective of the regulatory activity is to investigate and document the incidents by the emergency services in an appropriate manner, to draw the attention of operators and transporters to the shortcomings and, if duly justified, to initiate legislative amendments to prevent further accidents (Érces et al., 2023).

This publication is a synthesis of the results of three main research areas. The three main sub-areas are: the investigation of the causes, consequences and frequency of road transport accidents of dangerous goods in Hungary, the identification of risk reduction options and the investigation of technical solutions to increase the efficiency of consequence management.

2. Literature Review

The European Agreement concerning the International Carriage of Dangerous Goods by Road (hereinafter: ADR) was signed in Geneva on September 30, 1957 and entered into force with its Annexes on January 29, 1968. The text of the Agreement has been amended twice so far, first in 1975, in the wording, and secondly in 2020, in the title. The most important part of the Agreement's short text is Article 2, which states that substances the international transport of which is not prohibited by Annex A may be transported under the conditions set out in Annexes A and B. Annex A lays down conditions for the dangerous goods in question, in particular their packaging and labelling, while Annex B lays down conditions for the

structure, equipment and transport of the vehicle carrying the goods. The inseparable Annexes A and B of the ADR have been regularly reviewed and amended since their entry into force (UNECE, 2025).

Hungary acceded to ADR in 1979, following the accident involving a cargo of liquid ethylene in Aszód in September 1976.

Directive 2008/68/EC on the inland transport of dangerous goods by road, rail and inland waterway is now uniformly binding on the Member States of the European Union for the application of international rules on the inland transport of dangerous goods.

In Hungary, Act CXXVIII of 2011 on Disaster Management and the Amendment of Certain Related Acts entered into force on January 1, 2012, simultaneously with the new Fundamental Law. Following the new Disaster Management Act, significant changes have taken place since the integration of the state fire service and civil protection on January 1, 2000. Since January 1, 2012, the modern Hungarian disaster management has been complemented by a sector of equal importance, the system of industrial safety tasks, in order to protect the life and property of the population, to protect the national economy and to increase and guarantee the safety of Hungarian industry. One of the main tenets of the new Disaster Prevention Act is that disaster prevention is a national issue, so the role of the state must be increased and the preventive nature strengthened. The basic function of disaster prevention is to identify the threats, analyze the risks, provide information, inform, prepare, notify, alert, formulate the decision of the authorities, intervene, rehabilitate and ensure proportionality between the threat and the measures taken. The disaster management system is unidirectional and has elements that are not interchangeable in time: prevention, rescue and damage repair, recovery and reconstruction (Muhoray, 2016).

Act I of 1988 on Road Traffic establishes the authority of each authority to carry out independent checks and to impose fines. The law defines the procedure for the imposition of fines in accordance with the powers of control. The bodies entitled to carry out inspections are the traffic authority, the police, the customs authority and the disaster prevention authority.

Accidents involving road, rail, water or air transport of dangerous substances, accidents in hazardous industrial plants, hospitals, landfills and other hazardous installations can release substances into the environment that pose a risk to health, the environment or material assets, and in extreme cases can endanger the normal functioning of part of society and the economy. In our country today, the protection of the population and the intervention personnel during accidents involving hazardous substances, as well as the prevention of further acute damage to the environment, is carried out by the Hazmat Unit (Disaster Management Mobile Laboratory, DMML), which is part of the forces and equipment of the professional disaster management body. The DMML is responsible for identifying, monitoring and forecasting the release of dangerous substances, as well as the official supervision of the transport of dangerous goods. In the event of an incident, the DMML proposes the creation of safe working conditions for the first emergency services (firefighters, ambulances, police) and the introduction of the necessary measures to protect the public and the environment. The DMML has the technical and human resources necessary to collect, organize and process the initial data for the assessment of the emergency and to identify the materials, and maintains permanent contact and cooperation with the partner services and participates in the coordination of the emergency response.

3. Introduction of the Research Problem and Objectives

The international regulatory framework for the carriage of dangerous goods sets out, among other things, the technical requirements for classification, packaging or vehicles, the quantities that can be carried, the training of personnel or the requirements for transport document entries. However, it does not provide specific guidance on the methodology for risk management. The ISO 39001 standard, Road and Transport Safety Management System (RTSMS), sets out guidelines for road risk reduction. Improving road safety is a strategic issue for improving quality of life (Conca, Ridella & Sapori, 2016).

Button and Reilly (2000) investigated the predictability and recurrence of spills and fires during the transport of dangerous goods by road. An attempt was made in the study to determine how many events are expected per billion vehicle kilometres. Ohtani and Masayuki Kobayashi (2005) investigated the causes of the increasing number of dangerous goods transport accidents in Japan. No explanation was found for the increasing trend in the number of accidents, the main reason for which was attributed to the quality and reliability of the accumulated data (Nancy et al., 2000).

The foreseeable increase in the traffic of dangerous goods and the associated risk will necessitate the investigation of accidents involving the transport of dangerous goods by road, the documentation and systematisation of investigation results, and the development of related risk analysis procedures and risk mitigation measures, as well as incident management tools, which can be identified as a scientific problem in their own right.

The most common risk factor for dangerous goods is flammability, which is the main hazard for more than half of the total volume of cargo.

However, the flammability and fire risk go well beyond the main risk that characterises most of the goods transported, for example the proliferation of lithium-ion batteries, which are non-flammable materials, is a growing challenge for firefighters due to the specific fire risk (Ohtani & Kobayashi, 2005).

However, it is not sufficient to expose only the flammability property.

Accidents involving the transport of dangerous goods pose different types of risks to the life and health of the road users and the forces and first responders deployed to deal with them. Several types of hazards may occur simultaneously. When examining accidents, we can state in general that the main hazards are physical, fire, heat and toxic.

Some risk assessment methods for the transport of dangerous goods, showing that research on risk assessment models for the transport of dangerous goods by road is comprehensive, but incomplete for rail and intermodal transport (Guo & Luo, 2022).

There are many methods for assessing the risks of transporting dangerous goods by road, and thus reducing the risks, and there are several different classifications. Three main kinds of risk assessment methods: quantitative, semi-quantitative and qualitative risk assessment can be distinguished (Dziubinski et al., 2006).

With a longer time horizon (2012-2022) to reduce the frequency of accidents involving the transport of dangerous goods by road in Hungary, the causes of accidents have not yet been systematically identified, the critical road sections, periods and materials transported have not been defined, and a specific risk analysis procedure has not been developed.

The investigation of accidents involving the transport of dangerous goods and the identification of the causes is not only to identify those responsible, but also to reduce the frequency of these types of incidents and to manage future incidents more effectively (Kátai-Urbán et al., 2016).

The investigation of incidents related to the transport of dangerous goods by road, the systematisation and documentation of the investigation results, the definition of the risk analysis methodology and the drawing of conclusions in order to identify appropriate technical improvement directions and procedures, is an ongoing research task.

The following scientific problem is identified.

In Hungary, in order to determine the frequency of accidents involving the transport of dangerous goods by road, the causes have not been studied and classified over a longer time span (a decade), critical road sections, periods and goods have not been identified to determine the appropriate preventive procedural and technical measures.

Based on the above circumstances and scientific problem, the following hypotheses can be made. By analyzing and systematizing the causes, consequences and frequency of road accidents involving dangerous goods transport in Hungary between 2012 and 2022 it is possible to reduce the frequency of serious accidents. It can be assumed that the incidents of the period under consideration are well documented by the professional emergency services, in particular with regard to the causes, critical road sections, periods and dangerous goods.

The research objective can be formulated on the basis of the definition of scientific problems.

The objective of the research was to analyse and systematise the causes, consequences and frequency of major road accidents involving dangerous goods in Hungary between 2012 and 2022 to identify risk reduction measures, with particular attention to critical causes and time periods.

4. Methodology and Research Results

The research utilizes a combination of qualitative and quantitative methods, including case studies and empirical analysis. It involves examining both domestic and international literature, legal standards, and best practices from other countries. Comparative evaluations and consultations with experts at international conferences also support the study. Core scientific approaches include analysis, synthesis, deduction, and systematic investigation, with results shared through academic publications and presentations.

The research work could be based firstly on the database on dangerous goods transport accidents of the National Directorate General for Disaster Management, Ministry of the Interior (NDGDM) and secondly on open-source data exploration.

The research work was complicated by the fact that the technical supervision of the device for recording the driving time of drivers and the analysis and evaluation of driving time are the responsibility of other authorities, but could help in the analysis of human factor incidents.

During data processing, special attention was directed toward identifying and evaluating causal factors of accidents, critical road sections, critical time periods, and high-risk goods. These insights form the basis for defining an appropriate risk assessment methodology and for developing effective risk reduction strategies.

Human factors: 67% of transport incidents were attributable to human error, independent of technical failures or non-compliance with ADR regulations (Figure no. 1). However, focusing exclusively on driver readiness, mental and physical condition, or performance is insufficient. Human error must be contextualized by examining hazardous road segments and time periods in parallel. Although artificial intelligence offers potential to reduce risks by substituting for human drivers, cultural and operational factors imply that the human element will remain integral to road

transport. Technical factors: 26% of incidents were caused by technical failures, with no associated ADR violations or human errors. These failures can only be mitigated through systematic, and potentially unscheduled, on-site inspections of vehicles and cargo. Regulatory non-compliance: 7% of incidents were linked to ADR violations, exclusively related to cargo securing deficiencies. Such cases can be prevented by rigorous inspections during the preparation phase of transport.

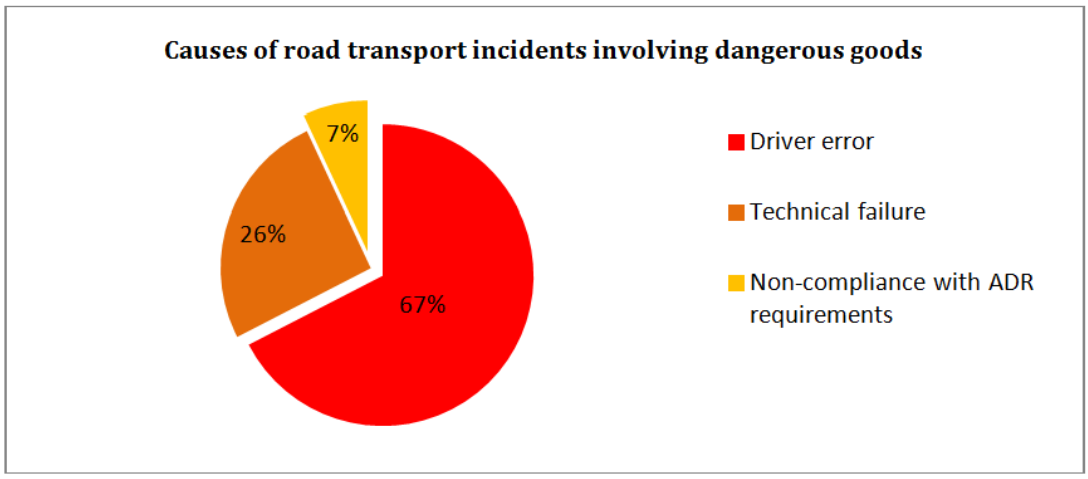

Figure no. 1: *Documented causes of adverse events in the period under review (2012-2022) in Hungary*
(Source: Authors)

From a risk perspective, it is possible to identify specific road segments prone to recurrent incidents, as well as county-level emergency management directorates more frequently involved in serious accidents. Temporal patterns were also evident: while no significant seasonal or monthly trends were identified, February and June showed slightly elevated incident frequencies.

A weekly distribution analysis revealed that 28% of incidents occurred on Mondays and 23% on Tuesdays, with risk highest at the start of the week and declining steadily thereafter (Figure no. 2).

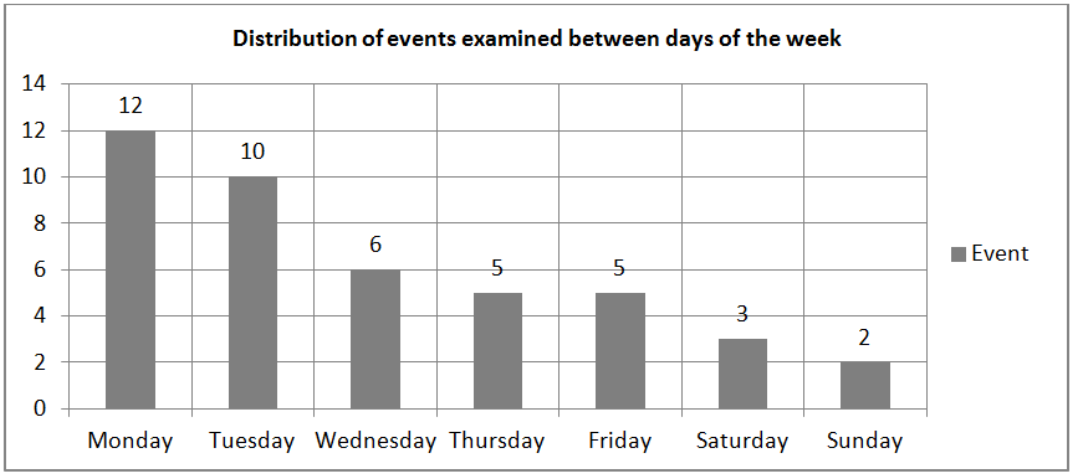

Figure no. 2: *Distribution of events by day of the week (2012-2022) in Hungary*
(Source: Authors)

Daily temporal analysis demonstrated that 65% of accidents occurred during morning and mid-morning hours (06:00-14:00), indicating this period as particularly high risk for accidents involving dangerous goods transport (Figure no. 3).

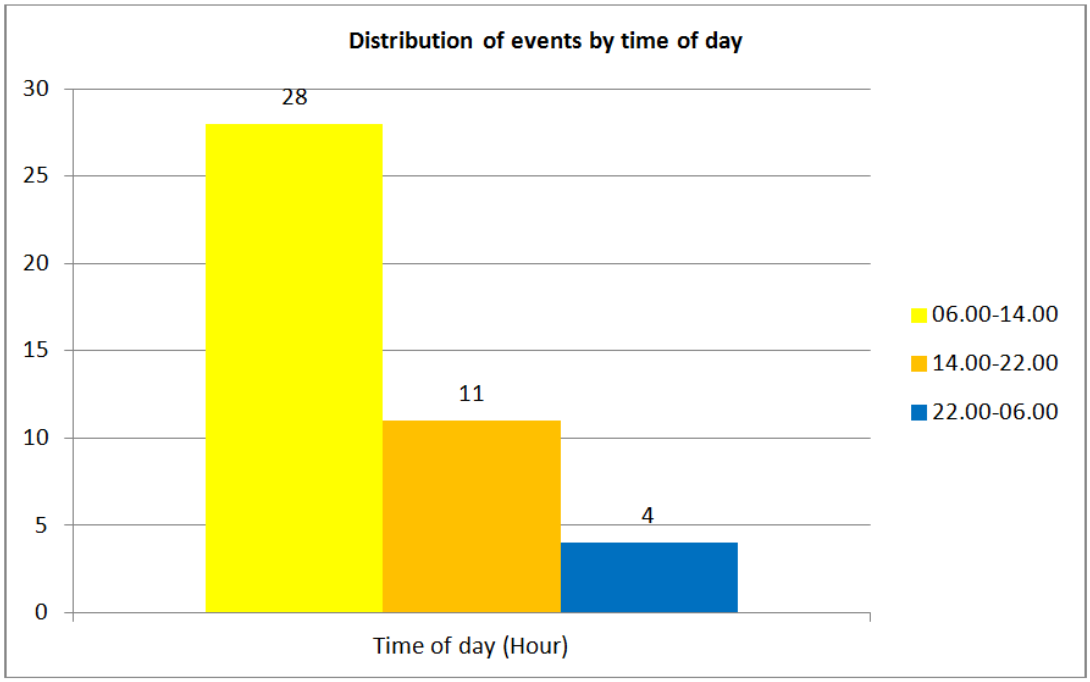

Figure no. 3: *Distribution of events by time of day (2012-2022) in Hungary*
(Source: Authors)

5. Conclusions

In order to reduce the frequency and understand the nature of dangerous goods transport accidents by road, the causes, consequences and frequency of serious road dangerous goods transport accidents in Hungary between 2012 and 2022, as well as the riskiest road sections, periods, and materials, have been systematized and determined.

The aim of this research was to provide a comprehensive overview of road transport involving dangerous goods in Hungary, with particular emphasis on accident patterns, through systematic and analytical investigation. The methodology is based on document review and the analysis of publicly available data generated during the examination of incident causes and circumstances, managed by the NDGDM.

In the field of analytical investigation of serious accidents in the transport of dangerous goods by road, the events that occurred in Hungary between 2012 and 2022 have been systematised and analysed. In the framework of the scientific work, the causes of the events that occurred in the period under study were identified, the road sections at risk of recurrence, the county disaster management directorates, the risk periods and the most affected materials were defined.

By studying the documents created during the investigation of serious accidents in the transport of dangerous goods by road, I came to the conclusion that the causes of the incidents can be clearly defined and distinguished. About two-thirds of all investigated transport incidents are the result of driver error, which can be clearly separated from technical failure and non-compliance with ADR rules. Only a quarter of the incidents were caused by a technical malfunction. Non-compliance with the rules of ADR was identified as the root cause in the

smallest proportion of the investigated incidents. By examining the locations of the accidents that have occurred, it can be established that there are sections of the road where a recurrence of a serious damage event should be expected. Based on the test results, the county-level disaster management directorates most involved in the management of repeated, serious incidents can be identified. The risky periods where serious accidents can be expected to occur again can also be easily identified. More than half of the investigated incidents took place on Monday and Tuesday, and serious accidents typically occur in the morning-afternoon period. On the basis of the analytical investigation, it can also be established that a (relatively) narrow range of transportable substances was involved in the serious incidents, but about three-quarters of the released dangerous goods were substances hazardous to the aquatic environment.

The scientific results of the research can be used in several fields.

The results of the study examining the causes, consequences and frequency of accidents in the transport of dangerous goods by road could be also used in the development of technical requirements promoting the sustainability and safety of transport in domestic and international contexts, they can be used by the professional disaster management body, the police, the environmental protection authority, the transport authority for damage prevention and during the development of emergency management strategies, and can be integrated into the curricula of all training courses that include the sustainability and safety of the approach.

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