

RISK FACTORS FOR HAZARDOUS MATERIALS TRANSPORTATION IN THE CZECH REPUBLIC

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Summary: The paper is focused on hazardous materials transportation by road and investigates risk factors influencing risk associated with such transportation. Statistical data on this special type of transportation are used in order to detect most important factors, increasing accident probability. Paramount attention is devoted to the drivers and factors causing the accidents. Measures reducing risk of hazardous material transportation are proposed in this paper

Key words: hazmat; accident; driver

INTRODUCTION

Hazardous materials (hazmat) are defined as any substance or material capable of causing harm to people, property and the environment (1).

Among most frequently transported hazmat are petroleum products and other flammable liquids, toxic substances, corrosive liquids, gases and other dangerous substances (2). Such materials are used for numerous purposes as semi-products or by-products in various industry operations, and also by general public on a daily basis.

Hazmat are transported mainly by specialised companies using certain equipment: tank vehicles, tank wagons or chemical bulk carrier ships. Hazmat are also transported as piece goods by all transport modes. Such piece goods consignments are often shipped as part of general freight. Although the relative volume of piece goods is small, the actual consignment number and the number of involved operators are large. In addition, piece goods are often transported through densely populated areas, creating specific challenges to the carriers, senders, receivers and responsible authorities (3).

Hazmat transportation and its potential consequences typically raise public interest after a large accident with hazmat release. Since hazmat accidents are usually regarded as low probability and high consequence events, do attract public attention when fatalities or other losses are high (4).

The main focus of the investigation has been on human aspects and its role in the safety of hazmat transportation. Therefore a thorough analysis has been devoted to the statistical data describing the driver, his experience and behaviour as well as accident causation.

1. METHODOLOGY

Hazmat accident data were provided by the Police Presidium of the Czech Republic (5). This authority is in charge of accident investigation and maintains detailed statistics. There were investigated accidents with the hazmat vehicle/driver as an offender, as well as the

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accidents with just an involvement of hazmat driver. There occurred 322 accidents caused by the hazmat vehicles, generating 578 accidents with hazmat transportation involvement in the Czech Republic from 2011 to 2015. The database contains over 60 specifications recorded for every accident, ranging from their localization, infrastructure, vehicle and driver details and, of course, consequences.

For a comparison whole transport accident database consists of total 419,864 accidents occurred in the Czech Republic in 2011 – 2015. Input data for the computation were retrieved from Transport year books released during this period (6).

Vast majority of the hazmat accidents were associated with heavy goods vehicles (HGV). The database contains data on a HGV split into subsequent categories: a single heavy goods vehicle, HGV with a semitrailer and HGV with a trailer. Nevertheless according to the Czech legislation, HGV are considered even small lorries up to 3.5 tons. Since small lorries up to 3.5 tons are, similarly to passenger vehicles, carrying hazmat rarely, only HGV with semi-trailers or trailers were put into computation in order to investigate the ratio of hazmat accidents on HGV accidents.

2. CONSEQUENCES OF HAZMAT ACCIDENTS

Various consequences of hazmat accident will be investigated from the vehicle perspective, fatalities and injuries as well as accident distribution throughout regions of the Czech Republic.

2.1 Vehicles involved in accidents

Table 1 illustrates accidents split by a number of vehicles involved. Hazmat accidents are mostly associated with two vehicles and only less than one third of hazmat accidents are single vehicle accidents. On the other hand, there is a distinctive shift in accident distribution when all accidents in the database (including mostly passenger vehicles driven by non-professional drivers) are taken into account. Much higher share of single vehicle accidents is among all accidents in the database. **Since a single vehicle accidents are usually crashes with solid obstacles such as trees, pointing at lower driver's skills of non-professional drivers. This fact leads to the first preliminary assumption that the hazmat drivers are of a higher quality than the reference group of drivers consisting of all drivers in the Czech Republic. On the other side, multiple vehicle accidents (participation of 3 and more vehicles) are more frequently connected with hazmat accidents which may indicate that hazardous nature of transported goods can have influence on severity of accidents.**

Tab. 1 - Number of vehicles involved in accidents

No. of vehicles	No. of hazmat accidents [-]	Share of hazmat accidents [%]	No. of all accidents [-]	Share of all accidents [%]
1 vehicle	158	27.34	172,606	41.11
2 vehicles	368	63.67	224,793	53.54
3 vehicles	45	7.79	18,454	4.40
4+ vehicles	7	1.21	4,011	0.96

Source: (5), (6), author

2.2 Fatalities and injuries

Statistical database contains data on fatalities and injuries split into two segments by severity of injuries. Table 2 indicates accident consequences within the hazmat vehicle. Accidents with the hazmat driver as an offender were computed separately. Only one hazmat accident (0.31 %) led to the fatality of a driver, injuries were rather low too. However, data in Table 3 illustrating total accident consequences in 24 hour horizon show different tendency. These data contain also information on other participants involved in the accidents (drivers of other vehicles, pedestrians, cyclist etc.). All monitored indicators (fatalities, severe injuries, minor injuries) indicate an increase throughout the monitored period.

Comparison of data in Table 2 and Table 3 implies that the hazmat accidents are more dangerous for surroundings than for the hazmat drivers. Reason for this fact can be, apart from envisaged larger impact of hazmat substances on surrounding, the size and weight of hazmat vehicles (98.8 % of hazmat vehicles are HGV).

Tab. 2 - Consequences of hazmat accidents in a vehicle

Consequence	No. of all hazmat accidents (with hazmat vehicle involvement)	No. of accidents caused by a hazmat vehicle	Share of accidents caused by hazmat vehicle [%]
Fatality	1	1	0.31
Severe injury	3	2	0.62
Minor injury	25	15	4.66
No injury	549	304	94.41

Source: (5), author

Further investigation of data in Table 3 indicates that **only minority of accidents with consequences to humans (22.2 % to 30.1 %) were caused by the hazmat vehicles**, while the rest by the other vehicles. Moreover, **the ratio of the accidents caused by the hazmat vehicles is lowest in the accidents with most severe consequences (4 out of 14 fatalities – 22.2 %), whereas highest in accidents with least consequences (56 out of 130 minor injuries – 30.1 %)**. Another clue that the hazmat accidents caused by hazmat vehicles usually cause less severe impact provides overall characteristics of the accidents.

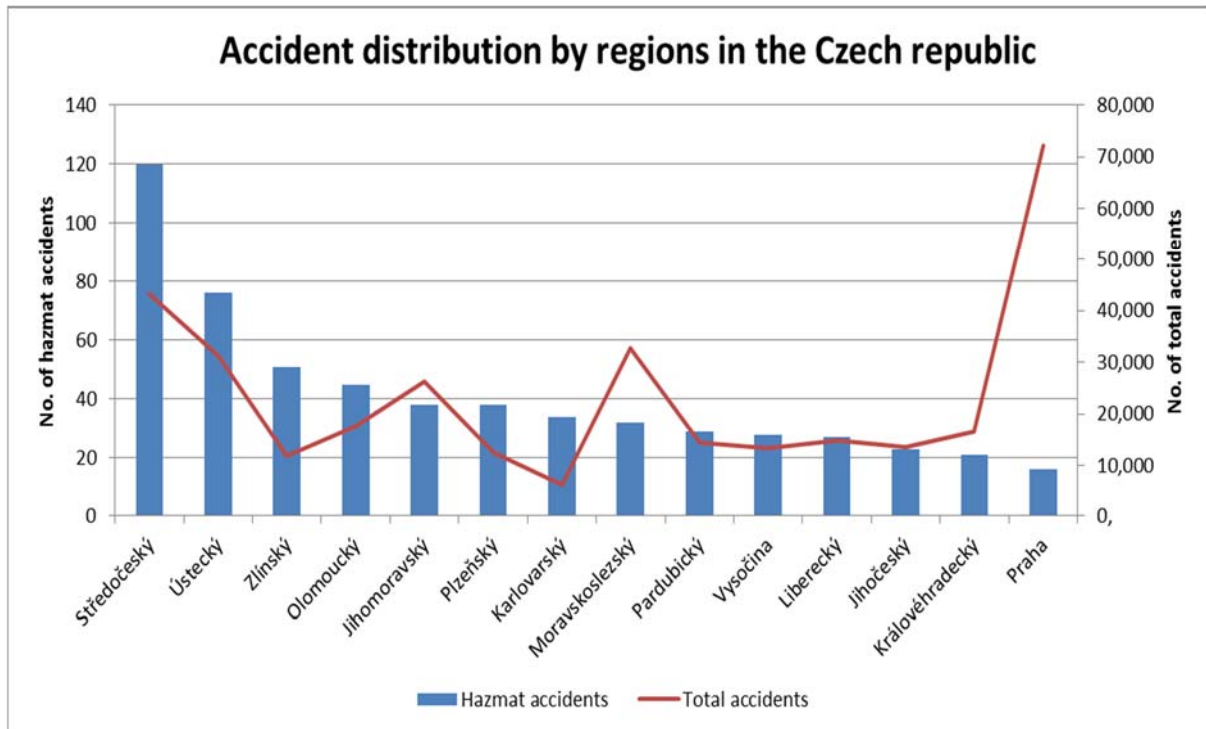
Tab. 3 - Total hazmat accident consequences in 24 hours

	Fatalities		Severe injuries		Minor injuries	
	No. of accidents	Share of accidents [%]	No. of accidents	Share of accidents [%]	No. of accidents	Share of accidents [%]
Accidents caused by a hazmat vehicle	4	22.2	14	25.9	56	30.1
All hazmat accidents	14	77.8	40	74.1	130	69.9

Source: (5), author

2.3 Accidents by regions

Picture 1 provides information on hazmat accidents (columns) as well as all accidents (line) split by geographical regions of the Czech Republic. There is a distinctive imbalance between two distribution patterns. Differences are given by the nature of each particular region. Typical urban region is Prague, which is a country capital. Other regions are more or less rural with various number of settlements, different level of industrialization and quality of road infrastructure. Urban regions, primarily Prague, but to some level also Moravskoslezsky, Jihomoravsky and Stredocesky region are suffering from higher level of general accidents.



Source: (5), (6), author

Picture 1: Hazmat accidents split by regions – total numbers

3. CAUSES OF HAZMAT ACCIDENTS

Core purpose of this work is investigation of hazmat accidents causes. Data in Table 4 show that majority of accidents caused by the hazmat vehicles are crashes with other driving motor vehicles (39.1 %), followed by crashes with a solid obstacle (25.2 %) and breakdowns (15.5 %). **Most important finding is regarding hazmat vehicle crashes with other driving vehicles. The ratio of the accidents caused by the hazmat vehicle is only 0.363. It means that majority vehicle collisions were caused by the non-hazmat vehicles.** However, it has to be stressed out that the share is influenced by about 9 % of hazmat accidents with an involvement of three or more vehicles, statistically decreasing the probability of hazmat vehicles to be an offender.

Tab. 4 - Types of accidents

Type of accident	No. of all hazmat accidents	No. of accidents caused by hazmat vehicle	Ratio of accidents caused by hazmat vehicle [-]	Share of accidents caused by hazmat vehicle [%]
Collision with a driving motor vehicle	347	126	0.363	39.1
Collision with a parked vehicle	42	23	0.548	7.1
Collision with a solid obstacle	90	81	0.900	25.2
Collision with a pedestrian	8	8	1.000	2.5
Collision with a forest animal	21	21	1.000	6.5
Collision with a domestic animal	2	1	0.500	0.3
Collision with a train	3	3	1.000	0.9
Collision with a tram	0	0	0.000	0.0
Breakdown	50	50	1.000	15.5
Other type of accident	15	9	0.600	2.8

Source: (5), author

Table 5 shows data on offenders of accidents. Naturally majority of accidents caused by the hazmat vehicles were caused by the driver at the same time (89.75 %). In comparison with causes of all accidents in the database (last column of Table 11), the dominance of a driver as main risk factor is even strengthened. It is mostly due to the fact that the drivers of non-motoric vehicles (e.g. cyclists) are not involved in the hazmat accidents at all and pedestrians have also lower interaction with hazmat accidents than with general accidents. **These data indicate that most hazmat traffic might be conducted on a prominent road network, such as highways with limited non-motorized transportation. Additionally, share of hazmat transportation in cities may be lower.**

Data on accidents caused by technical failure show an interesting tendency too. Even though this factor represents relatively small hazmat accident share (1.55 %), it is still three times more than in general accidents. It seems that technical complexity of vehicles carrying hazmat substances (especially tanks) creates higher risk of accident than technical condition of passenger vehicles, which are dominating the database of all accidents.

Tab. 5 - Offenders of accidents

Offender of accident	No. of all hazmat accidents	No. of accidents caused by hazmat vehicle	Share of accidents caused by hazmat vehicle [%]	No. of all accidents in the database	Share of all accidents [%]
Driver of a motor vehicle	542	289	89.7	281,758	86.2
Driver of a non-motor vehicle	0	0	0.0	10,088	3.0
Pedestrian	3	3	0.9	4,847	1.4
Forest or domestic animal	23	22	6.8	24,607	7.5
Other participant	0	0	0.0	533	0.1
Infrastructure flaw	1	1	0.3	1,478	0.4
Vehicle flaw	7	5	1.5	1,852	0.5
Other offence	2	2	0.6	1,635	0.5

Source: (5), (6), author

Table 6 illustrates causes of the hazmat accidents. By far main accident cause embodies inaccurate driving (64.9 %). The ratio of hazmat accidents caused by the hazmat driver on all hazmat accidents leads to following assumptions. **Only minority of accidents caused by inappropriate overpassing (ratio 0.17) were caused by the hazmat vehicles. This finding is in line with the premise that HGV are lower speed vehicles, overpassing infrequently. However, it can be influenced by better hazmat drivers' skills too. Additionally, significant driving infringement – not giving a way has a lower ratio (0.38) among professional hazmat drivers. By contrast technical flaws, even though rarely occurred, were mostly associated with hazmat vehicles (0.71). Most frequent cause of accidents – inappropriate driving behaviour has also higher occurrence (0.60) among drivers of hazmat vehicles.**

Tab. 6 - Causes of accidents

Cause of accidents	No. of all hazmat accidents	No. of accidents caused by hazmat vehicle	No. of accidents caused by hazmat vehicle (only trailer and semitrailer)	Ratio of accidents caused by hazmat vehicle [-]	Share of accidents caused by hazmat vehicle [%]
Not caused by the driver	29	28	25	0.97	8.7
Unadjusted speed	94	48	32	0.51	14.9
Inappropriate overpassing	30	5	4	0.17	1.5
Not giving a way	71	27	20	0.38	8.3
Inaccurate driving	347	209	155	0.60	64.9
Technical flaw of vehicle	7	5	3	0.71	1.5

Source: (5), author

Most frequent cause of hazmat accidents – inaccurate driving is rather general and therefore was investigated into greater detail in Table 7.

Tab. 7 - Accident cause: inaccurate driving in detail

Types of inaccurate driving	No. of all hazmat accidents	No. of accidents caused by hazmat vehicle	Share of accidents caused by hazmat vehicle [%]
Driving on the wrong side, entering wrong way of one-way communication.	34	8	3.8
Overpassing without sufficient lateral clearance.	32	21	10.0
Not keeping a safe distance behind the vehicle.	69	33	15.8
Improper turning or reversing.	25	14	6.7
Lapses in giving direction.	0	0	0.0
Reckless, aggressive driving.	1	1	0.4
Sudden unreasonable speed reduction.	0	0	0.0
Not paying full attention to driving.	96	63	30.1
Unsecured self-movement of the vehicle.	0	0	0.0
Entering the unconsolidated verge.	33	33	15.8
Uncontrolled driving.	26	18	8.7
Driving the opposite side of a one-way street.	0	0	0.0
Usage of Police stops devices.	0	0	0.0
Usage of Police gun.	0	0	0.0
Implementation of Police action.	0	0	0.0
Other type of inaccurate driving.	31	18	8.7
Total	347	209	100.0

Source: (5), author

CONCLUSION

Hazmat accidents lead us to the conclusion that understanding the potential risk and threats associated with hazmat transportation is crucial for maintaining safety of the public. Comparison of hazmat accidents with HGV + semi-trailers or HGV + trailers involved with all HGV accidents leads to the ratio of 1.886 % hazmat accidents. However, these accidents were causing 4.00 % of fatalities and 2.563 % injuries associated with HGV transportation. Accidents will become more common and disastrous if we become complacent.

Investigation shows that professional hazmat drivers are of better quality than “average”, usually non-professional drivers of passenger vehicles. Hazmat vehicles have lower share on accidents as offenders in all monitored categories, especially regarding most important parameters such as fatalities and severe injuries. Hazmat accidents are frequently more dangerous to surroundings than to hazmat drivers themselves.

Most frequent cause of hazmat accident (30.1 %) was not paying full attention to driving. There can be various reasons for such behaviour ranging from attention loss as a result of tiredness, or underestimating driving conditions to technologically oriented distractions e.g. navigation, telephone or maybe even a notebook. This cause as most

important shall be investigated in further research to be able find all reasons and circumstances for attention loss and implement adequate measurements in order to mitigate risk of hazmat transportation. Interaction with electronic devices shall be monitored and enforced by drivers' management and Police.

Second most important cause of hazmat accidents is not adhering to safe distance behind a vehicle and also equally entering unconsolidated verge (15.79 %). Maintaining a safe distance is a problematic issue for all types of drivers according to statistics. However, HGV drivers are supposed to keep such a distance that the overtaking vehicle could safely finish the movement before him apart from certain circumstances by Czech Act no. 361/2000 Coll., On Traffic on the Road Network. Appropriate driving behaviour shall be emphasized not only in driving school, but also on vocational training.

Unconsolidated verges are typically dangerous for HGV especially on lower class communications. For this reason, hazmat transportation shall be diverted to higher class communications and highways whenever possible.

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