Number 2, Volume XII, July 2017

DETERMINATION OF TIME RISK ASSOCIATED WITH TRANSPORTATION OF DANGEROUS GOODS 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 dangerous goods transportation in the Czech Republic are used in order to compute transportation patterns and identify time distribution of accidents. Numerical approach to determine a risk of time in hazmat transportation is presented. Measures reducing risk of hazardous material transportation are proposed in this paper.

Key words: dangerous goods; hazmat; accident;

INTRODUCTION

U. S. Department of Transportation defines dangerous substances as any substances or materials which may cause harm to persons, property or to the environment (1). Similar definition is in the Czech legislation. Dangerous substances are defined as substances, which may by their nature, quality or condition, cause risks to persons, animals, objects, or may cause some environmental risks in connection with the transportation (2). We are often encountering two basic terminologies in this research area. Hazardous materials, frequently shortened as hazmat is widely used in American literature and dangerous goods, which are used mostly in Europe. Both terms are relevant for this study and will be considered as equal.

Hazmat transportation is connected with some degree of risk as well as any other transportation. Risk is usually defined as probability of unwanted event and its consequences (3). Transportation leads to traffic accident, providing the level of risk in the transport process is exceeded.

Traffic accidents involving vehicles transporting dangerous goods are considered very unlikely, but large consequences events (4). Hazmat accidents as well as other severe accidents usually raise public interest after a large accident associated with release of transported material, when fatalities or other losses are high (5). Therefore some countries or even individual cities initiated research activities in order to assess risk associated with hazmat transportation. One of the most comprehensive studies worldwide was Hazmat transport routes assessment in Boston area, USA (6). Research team evaluated transport routes in a metropolitan area characterised by numerous tunnels. Various travelling patterns and population distribution throughout a day and a week were taken into account. Finally recommendation for increasing safety in the area and enforced transport routes were presented. Similar extensive study has not been carried out in circumstances of the Czech

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Republic. Nevertheless various investigations regarding risk identification, assessment or reduction in the process of dangerous goods transportation were published. Predecessor of this work was the study identifying some risk factors in dangerous goods transportation, especially those focused on drivers (7). Human aspects in the safety of dangerous goods transportation in the Czech Republic were presented as a leading determinant of the safety.

1. METHODOLOGY

Statistical data on accidents during dangerous goods transportation by road were provided by the Police Presidium of the Czech Republic (8). Statistical database of the Police Presidium contains over 60 specifications recorded for every accident, ranging from their localization, infrastructure, vehicle and driver details to the consequences. Accident data representing five year period 2011 to 2015 have been used. Database contains 578 hazmat accidents which occurred in the Czech Republic during the aforementioned period.

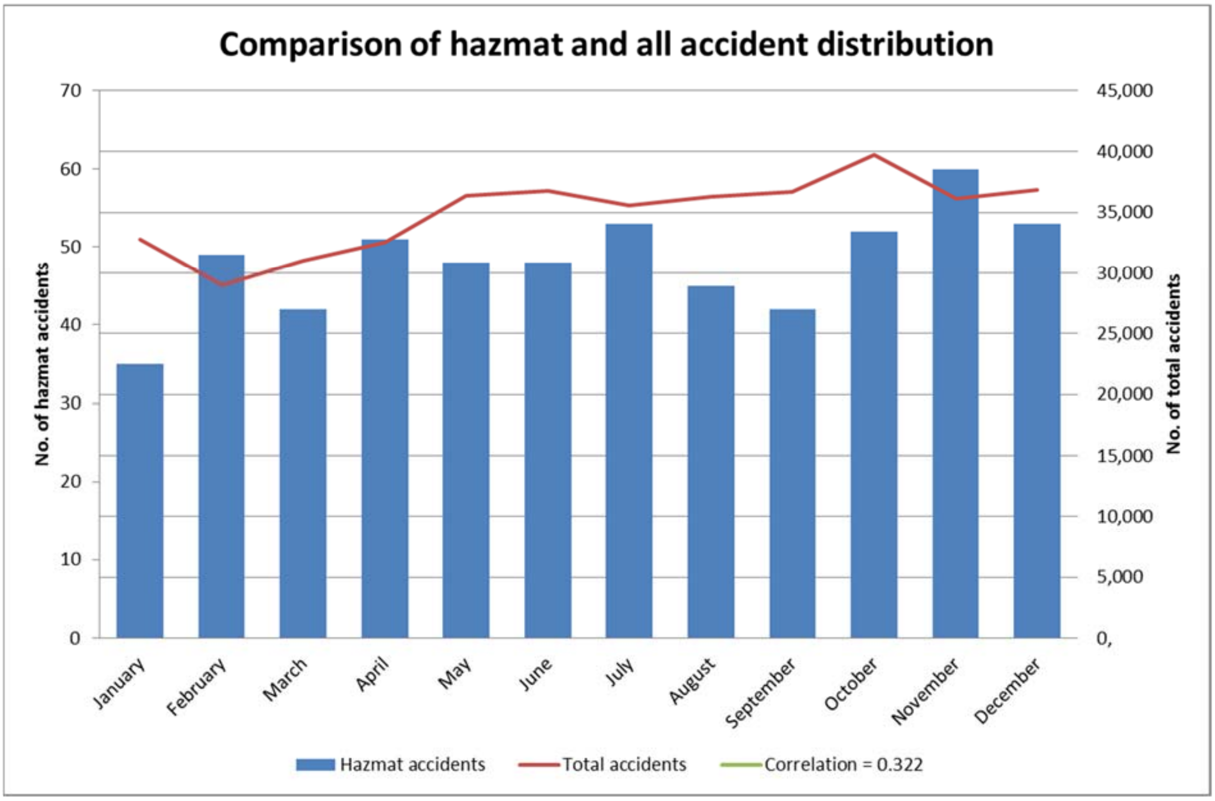
In addition, database of all accidents was used for comparison of hazmat data with a reference statistical data. This database consists of 419,864 accidents, which occurred in in the Czech Republic in 2011 – 2015. These data were retrieved from Transport year books released during this period (9).

Investigation of a time distribution of hazmat accidents in the Czech Republic will be carried out. Accidents will be investigated from the longest time horizon of one year to the shortest one throughout a day. Longer time periods enable to get preliminary information of the highest accident exposure months, while distribution throughout a day enable better understanding of hazmat driver’s habits.

Numerical approach to determine a risk of time in hazmat transportation will be based on statistical regression of available data. Certainly the factor of time is not sole determinant of risk associated with whole transport process. However, approach suggested in this paper can be further developed and extended on other risk factors such as route choice, type of transported hazmat or human related factors.

2. TIME DISTRIBUTION OF ACCIDENTS

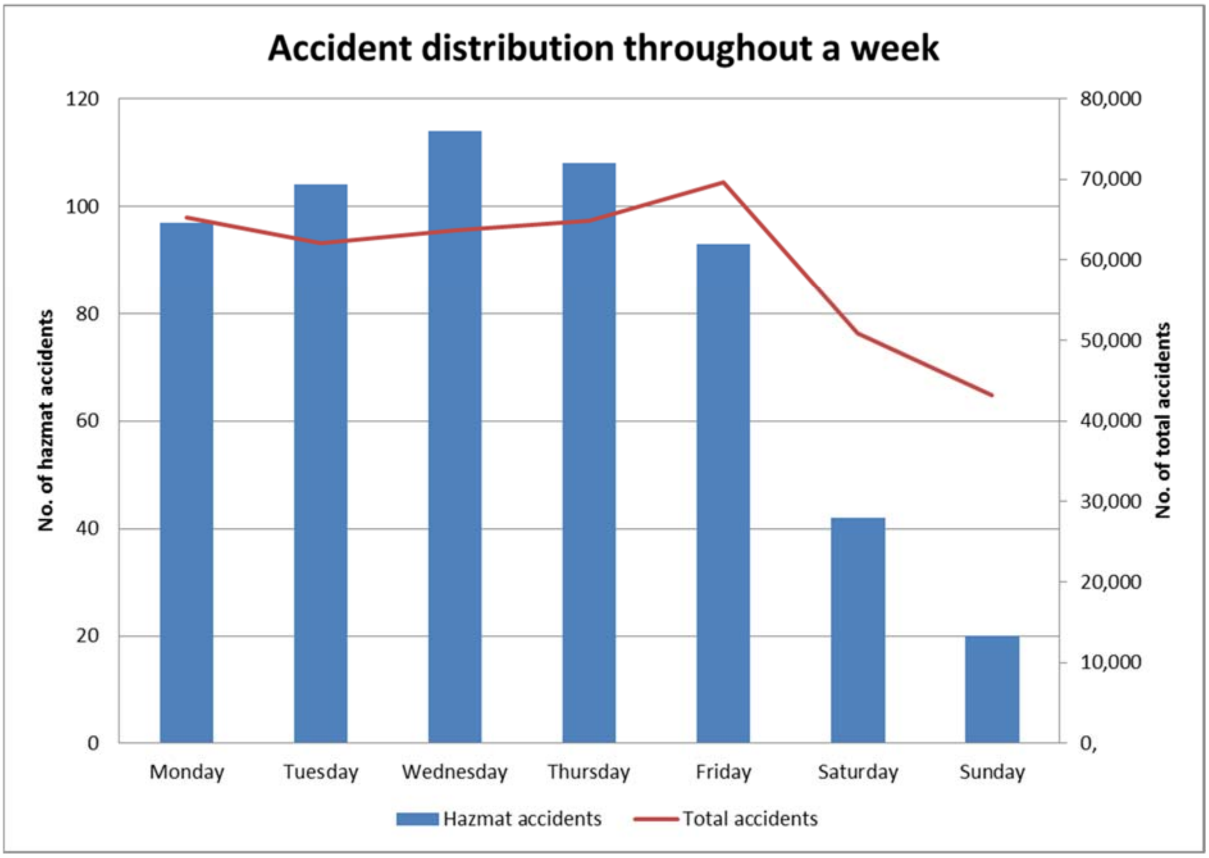
Picture 1 illustrates hazmat accident distribution as well as all accident distribution throughout a year. **Winter months are known for worst driving conditions, which shall have a negative impact on probability of accidents. On the other hand there is usually lowest traffic intensity during this time of year. In a simplified interpretation it may have two different implications on safety of hazmat transportation. Firstly, less traffic decrease probability of vehicle collisions, especially if less experienced “summer” drivers are not driving at all. Secondly, less traffic reduces demand for petrol and diesel, two by far most frequently transported hazmat substances, which shall induce lower hazmat transportation. Nevertheless Picture 1 at the same time illustrates that maximum number of hazmat accidents occurred in November, which would support the hypothesis of worst driving conditions (bad weather, fog, early darkness etc.) increasing risk of hazmat transportation.**



Source: (8), (9), author

Fig. 1 - Accident distribution throughout a year (hazmat and all vehicle accidents)

Picture 2 illustrates accident distribution throughout a week, involving hazmat accidents distribution, as well as all accident distribution. Booth distributions show that accidents are less frequent during a weekend. Nevertheless decline in hazmat accidents is greater on a weekend due to professional nature of transport business and legislative restrictions of road freight transport in the Czech Republic on Sundays. Hazmat accidents have highest exposure in the middle of a working week (Wednesday), while most critical for all vehicles is end of a working week (Friday). **This pattern may be caused by a different nature of hazmat transportation, operated mostly by professional drivers, and whole traffic volume dominated mostly by non-professional drivers. According to the number of accidents, hazmat transportation shall be safer on the start of a week and towards its end. However, it would be very helpful to investigate the influence of hazmat transportation intensity on each day of a week and the level of tiredness of professional drivers, which is anticipated lowest right after Sunday. Statistics indicates a divergence between the hazmat accidents and total number of accidents on Fridays. Nevertheless these data is influenced by a legislation ban on road freight transportation at some routes on Friday afternoon and Saturday morning during summer.**

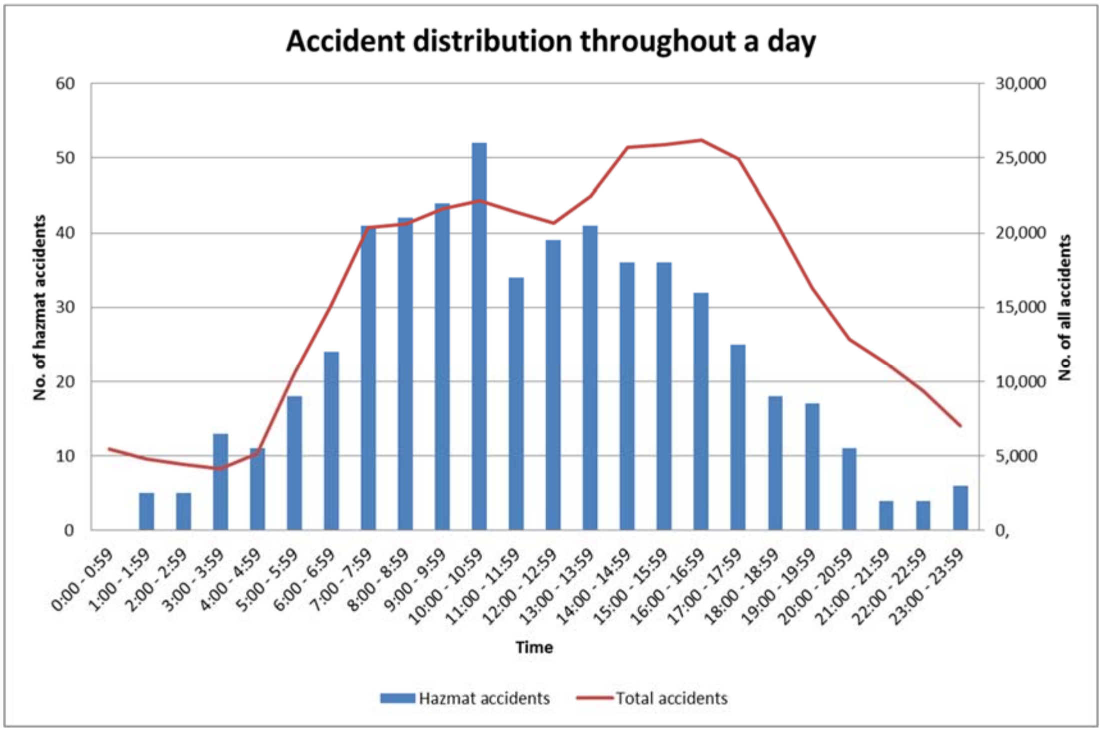


Source: (8), (9), author

Fig. 2 - Accident distribution throughout a week (hazmat and all vehicle accidents)

Accident distribution throughout a day is depicted in Picture 3. Out of 578 hazmat accidents in the database for monitored period 558 accidents have recorded time. There is a distinctive difference in two accident patterns. Hazmat accidents involving mostly professional drivers are distributed rather evenly throughout a working day with slow decrease after 2 pm. On the other hand, all accident distribution has a peak after 4 pm, reflecting heavy traffic intensity and congestions caused by commuting workers using individual means of transportation.

Focusing on the hazmat accident distribution, there is a significant peak in the amount of accidents between 10 and 11 o'clock, followed by a harsh decline next hour. **Explanation of this phenomenon may be connected with accumulation of tiredness just before most drives take a lunch break. Further investigation on driving time of professional drivers and influence of work load on their ability of safe driving shall be initiated.**

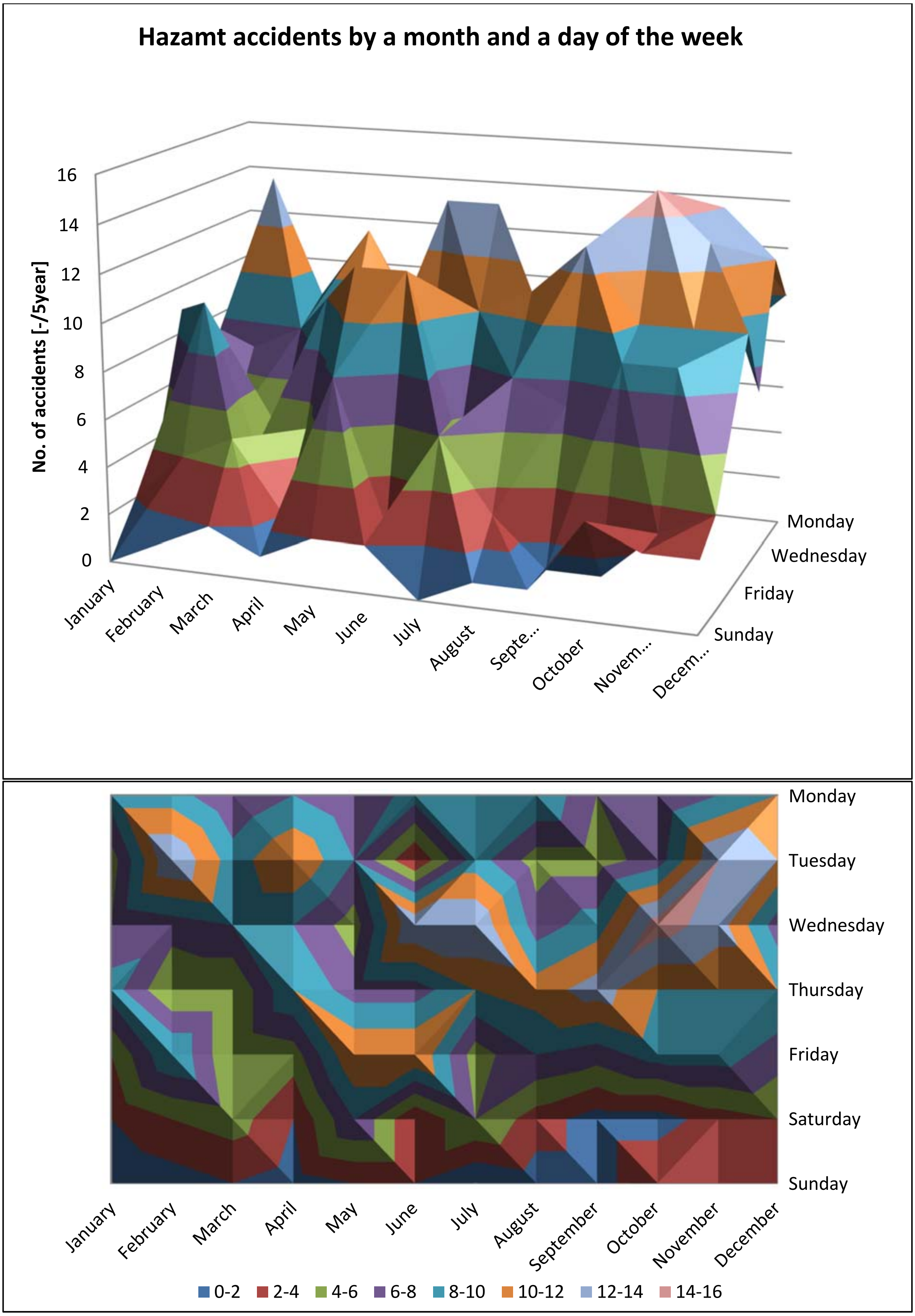


Source: (8), (9), author

Fig. 3 - Accident distribution throughout a day (hazmat and all vehicle accidents)

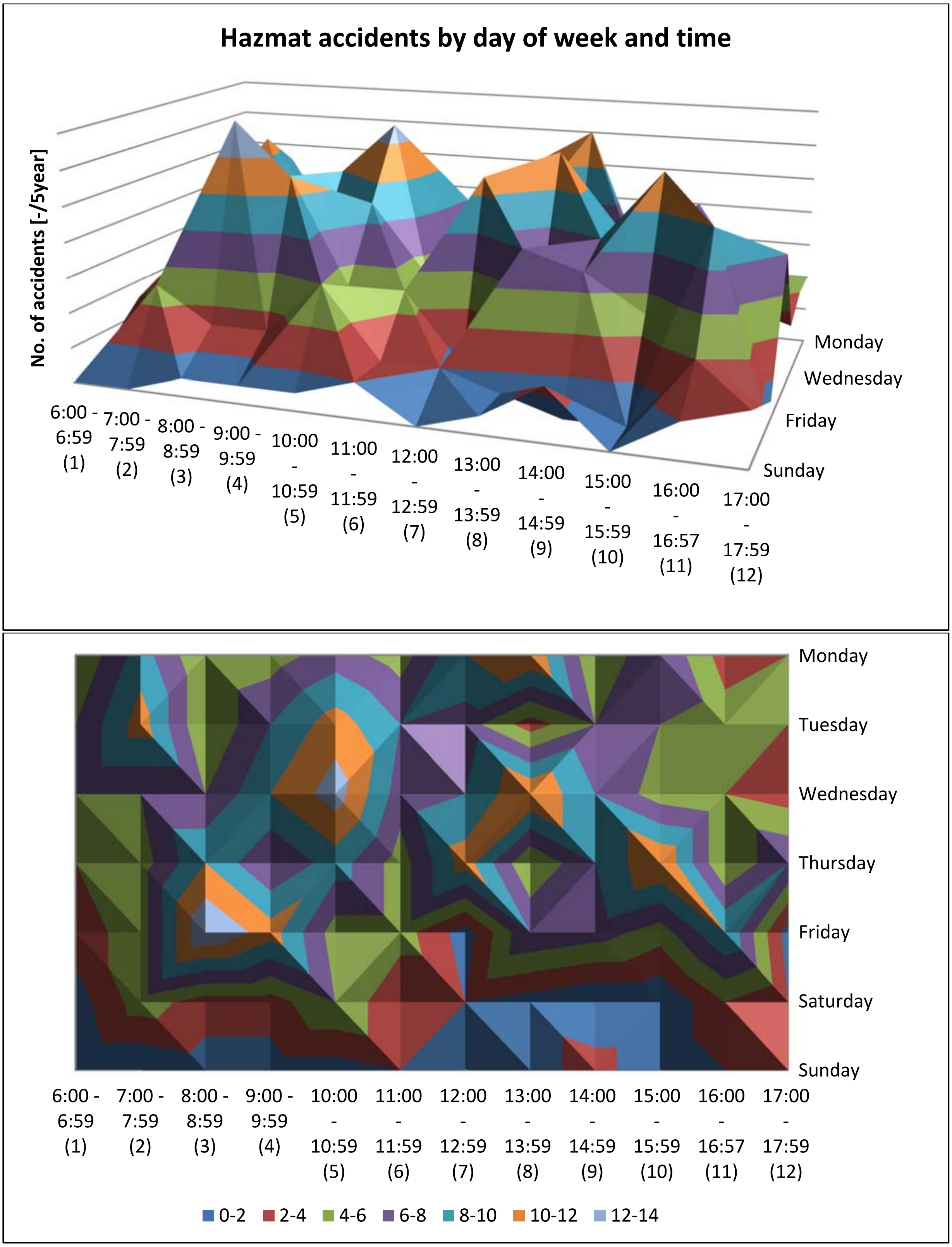
3. HAZMAT ACCIDENT DISTRIBUTION IN A WEEK AND A DAY

Following Pictures 4 and 5 are showing hazmat accident time distribution in the Czech Republic during monitored period 2011 – 2015. Picture 4 visualises occurrence of hazmat accidents in the matrix of weekdays and months. At the same time Picture 5 shows matrix of an intraday distribution of hazmat accidents on days of week. Picture 3 proved that exactly 80 % of hazmat accident occurred from 6:00 to 17:59. Therefore Picture 5 compares only this daily period when majority accidents occurred.



Source: (8), author

Fig. 4 - Hazmat accidents by a month and a day of the week

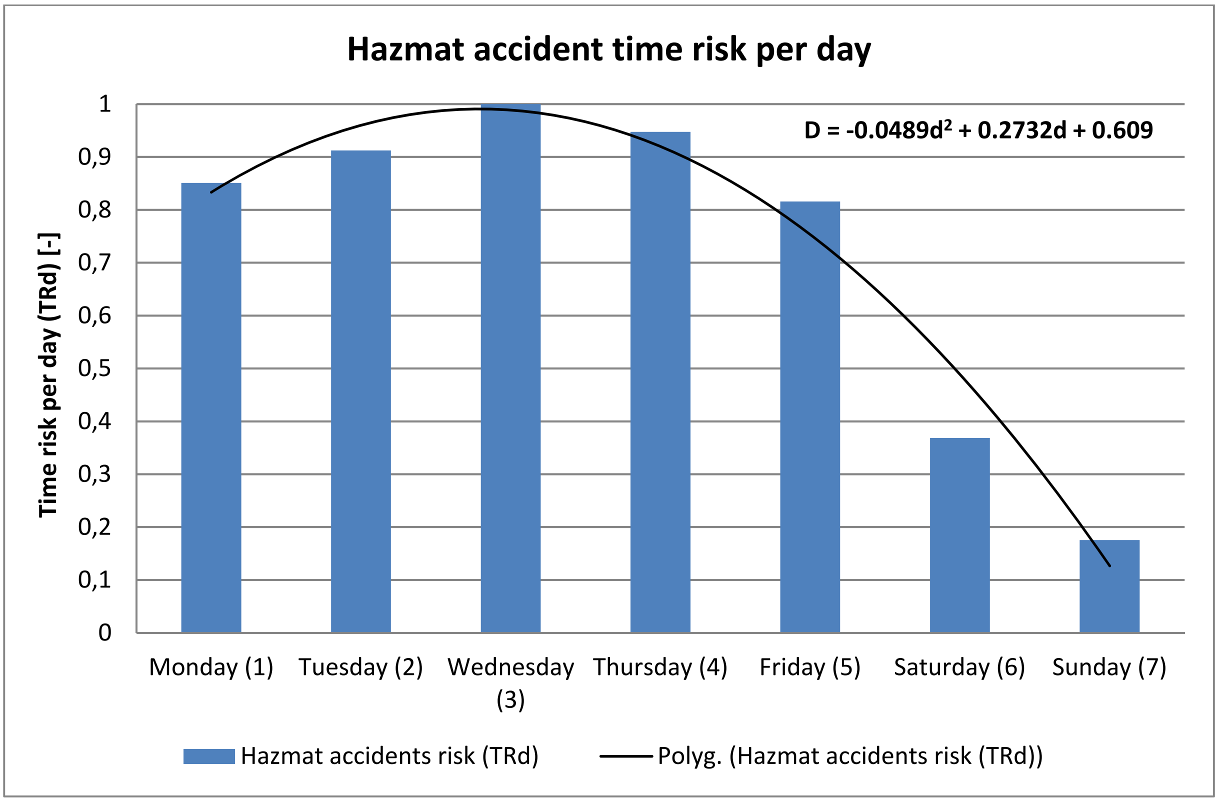


Source: (8), author

Fig. 5 - Accidents by a day of the week and time

4. NUMERICAL APPROACH

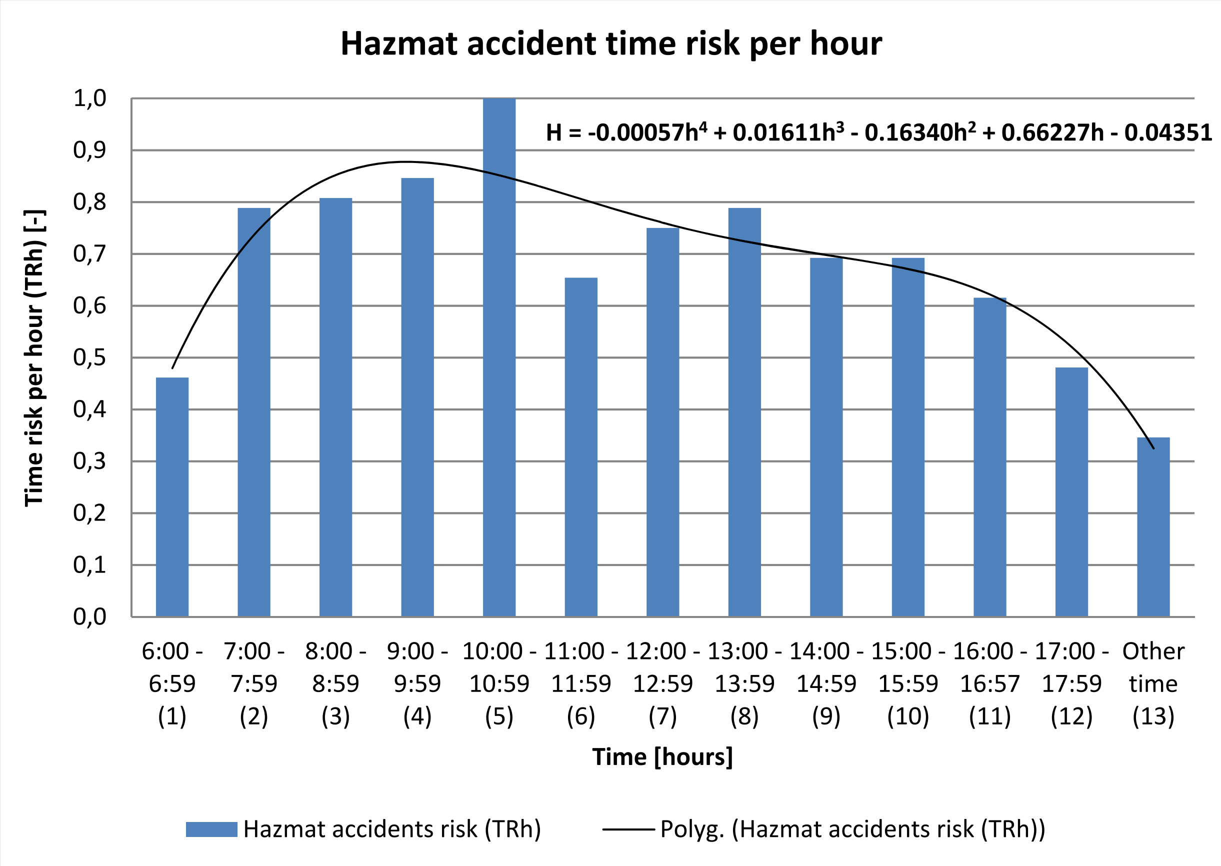
Numerical methods to quantify time risk associated with hazmat accidents will be presented in this section. Picture 6 identifies Wednesday most adverse day for hazmat transportation. Polynomial regression has been employed to describe time risk of hazmat transportation. For hazmat accident time risk based on a day of week a parabolic curve (second order (d=2) polynomial form) was identified as satisfactory.



Source: (8), author

Fig. 6 - Hazmat accident time risk per a weekday

On the other hand distribution of an intraday hazmat accident risk is not as symmetric and centralised as risk based on a day of week (Picture 7). Therefore a fourth order (h=4) polynomial form had to be used for description of dependence. The same time interval 6:00 – 17:59 covering 80 % hazmat accidents as in Picture 4 was used.



Source: (8), author

Fig. 7 - Hazmat accident time risk per an hour

Time risk of hazmat transportation in a given day and time is computed in Equation 1. Premise is knowledge of time risk in most adverse day and hour. Then the risk for a particular day and time is a function of time risk through a week and day. Equation (2) was prepared to compute total hazmat accident time risk. Aggregation of risk in any day of week, as well as time of day has been implemented. Nevertheless intraday risk is computed directly only for twelve most likely hours (6:00 – 17:59 constituting sequence 1 – 12) and any other time is automatically considered as sequence 13.

$$TR_{d,h} = TR_{max(d,h)}.fR_d.fR_h \quad (1)$$

$TR_{d,h}$ Time risk in particular day and hour [accident/vehicle-km]

$TR_{max(d,h)}$ Time risk in most adverse day and hour [accident/vehicle-km]

fR_d Function of time risk through week [-]

fR_h Function of time risk through day [-]

$$TTR = TR_{max(d,h)}\left(\sum_{d=1}^{7} fR_d\right)\left(\sum_{h=1}^{13} fR_h\right) \quad (2)$$

TTR Total time risk [accident/vehicle-km]

Equation 3 is an extension of Equation 1 with implemented risk functions of time. Similarly Equation 4 is an extension of Equation 2 with implemented risk functions determining total time risk of hazmat transportation.

$$TR_{d,h} = TR_{max(d,h)}(-0.0489d^2 + 0.2732d + 0.609)(-0.00057h^4 + 0.01611h^3 - 0.1634h^2 + 0.66227h - 0.04351) \quad (3)$$

$$TTR = TR_{max(d,h)} \left[\sum_{d=1}^{7} (-0.0489d^2 + 0.2732d)\right] \left[\sum_{h=1}^{13} (-0.00057h^4 + 0.01611h^3 - 0.1634h^2 + 0.66227h - 0.04351)\right] \quad (4)$$

CONCLUSION

Understanding the potential risk and threats associated with hazmat transportation is crucial for ensuring desired level of safety.

Investigation of an accident distribution throughout a year proved lowest accident exposure at the beginning of a calendar year (especially January). Accident distribution throughout a week shows anticipated decrease of hazmat accident risk on weekends. However, interesting findings were associated with accidents on business days. Contrary to all accidents distribution suggesting Friday as most dangerous day on roads in the Czech Republic, hazmat accidents are symmetrically distributed around middle of work week with top on Wednesday. Also comparison of hazmat and all accidents throughout a day proves different professional nature of hazmat transportation. Findings presented in this paper imply further investigation on driving time of professional drivers and influence of work load on their ability of safe driving.

Special emphasis shall be put on training of accident precautions, safe and defensive driving and, of course, steps towards mitigation of hazmat accidents impact. Further investigation of correlation between hazmat drivers' training and safety of transportation shall be conducted.

Approach towards time risk in hazmat transportation suggested in this paper can be further developed and extended on other risk factors such as route choice, type of transported hazmat or human related factors.

ACKNOWLEDGMET

This article was produced with the financial support of the Ministry of Education, Youth and Sports within the National Sustainability Programme I, project of Transport R&D Centre (LO1610), on the research infrastructure acquired from the Operation Programme Research and Development for Innovations (CZ.1.05/2.1.00/03.0064).

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