

## APPLICATION OF FMEA METHOD FOR ASSESSMENT OF RISK IN LAND TRANSPORTATION OF HAZARDOUS MATERIALS

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### Abstract

*An increasing amount of carried transport mass, speed of transportation, intensity of traffic pose a threat to the ecosystem are presented. At risk are both the participants of the road and railroad traffic and the inhabitants of areas where those transport tasks are performed. The risk also applies to property and the natural environment – soil, water, air, and fauna. Therefore, providing the transports with high level of safety is of top priority.*

*Assessment of the risk connected with transport of hazardous materials is closely related to evaluation of road traffic rules and their violations. The risk of occurrence of undesirable events during transportation of dangerous material is connected with such events as accidents, collisions, derailments, vehicle failures. Risk assessment of hazardous materials land transportation will make it possible to indicate the factors, which determine occurrence of undesirable events.*

*An analysis of risk in land transport of hazardous materials will be made on the basis of data concerning results of road controls carried out by inspectors of Road Transport Inspection. In this research, an attempt has been made to evaluate the risk connected with land transport of hazardous materials with the use of available risk assessment methods.*

**Keywords:** road transport, rail transport, risk, safety

### 1. Introduction

Transportation is an activity that involves carrying goods or people from one place to another. In terms of economy, transportation means performance of transport tasks for a fee involving carrying people, goods and providing additional services, which are connected with this transport, including e.g. shipping. Transportation services contribute to efficient and effective functioning of all the sectors of the country economy. Transportation is a production activity, thanks to which people-in the era of limited supplies, can move the society, goods and energy from place to place in order to satisfy individual needs and desires [6].

A transportation system minimizes cooperation and growth within all the walks of life and economy, which are the cause of continuous division of work in all the countries. A transportation system performs the following economic functions [6]:

- consumption function - elimination of the transportation demand thanks to performance of transport tasks,
- production function – elimination of the demand for production services due to performance of transport tasks that is by enabling economic activities, boosting them, and affecting marketing of products and services,
- integration function- enables integration of people with their country thanks to performance of transport tasks.

An increasing number of the carried mass, shorter times of transportation, higher speeds, heavier traffic of vehicles pose a significant threat to the ecosystem.

Road and railway traffic participants as well as inhabitants of areas with transport routes are under threat. Both the property and the natural environment –soil, waters, air and flora are at risk.

Planning transportation of dangerous, materials and setting up new routes for them is a key problem [2].

As far as transportation of dangerous materials is concerned, the crucial problem is to ensure sealing of the containers carrying these harmful substances, regardless of the events, which may occur during transport. Loss of tightness can lead to fires, explosions, or contamination by toxic substances.

Carrying hazardous goods is specified by both national and international laws, which have been ratified by Poland. The purpose of the regulations is to minimize the risk of accident and the potential damage that can be caused. The basic legal act introducing consistent codification in 43 European countries is the European Agreement concerning international road transportation of hazardous materials (ADR), signed in Geneva, on 30 September 1957 [9]. It was introduced to the Polish legislation by act from 28 October 2002 on road transportation of hazardous materials. (official journal from 2002 No. 199 P.1671 amended) [7].

Regulations on the international road transportation of hazardous materials, annex no.1 to supplement B to Convention on the international railway transportation (COTIF). It was introduced into Polish legislation by act from 31 March 2004 on railway transportation of dangerous loads (official journal from 2004, No. 97 Pos. 962. amended) [7]. Assessment of dangerous materials transportation risk is inseparably connected with the related legislation and involves such phenomena as accidents, collisions, derailments and failures.

The goal of this paper is to analyze the threats connected with load transport of hazardous materials and an assessment of the accompanying level of risk. Particular goals have been formulated within the main one:

- obtainment of data on the number of controls carried out in the road transportation in the analyzed period of time,
- obtainment of data on the number of undesirable events in railway transportation in the analyzed period of time,
- analysis of risk assessment methods and choice of the optimal one.

## **2. The research object and subject**

The research objects are land transportation systems (railway road) which carry hazardous materials on the territory of Poland. The research subject is an assessment of threats resulting from violations of hazardous materials transportation laws. The research was performed on the basis of results of traffic controls performed by the Road Transportation Inspection and data obtained from the Railway Transportation Office.

## **3. Experimental tests**

The tests involved obtaining data on results of traffic controls carried out by inspectors of the Road Transportation Inspection in all the provinces in Poland, in the years 2004 -2009 as well as data collected from the Railway Transportation Office.

From the presentation of traffic controls obtained from the Road Transportation Inspection, it results that in the analyzed period of time (2004-2009):

- 92510 vehicles were controlled,
- violation were found in 10726 vehicles.

Table 1 shows the number of carried out controls and violations found in the years 2004-2009. The biggest percentage share of the discovered law violations was recorded in 2004 and accounts for 22.47% of all the controls, whereas the smallest in 2009, only 6.59%. The results presented in Tab. 8 prove that despite an increasing number of yearly controls the number of law violations is on the decrease.

Tab. 1. Presentation of road controls carried out in 2004-2009 and found violations

Name	Number of violations						Summary
	2004	2005	2006	2007	2008	2009	
Number of controlled vehicles /groups of vehicles with dangerous materials	13405	13505	15840	15729	13927	20104	92510
Number of vehicles in which violations were found	3012	2323	1765	1130	1171	1325	10726
Percentage share of discovered violations [%]	22.47	17.20	11.14	7.18	8.41	6.59	11.59

In order to unify the results of carried out controls, the discovered traffic rules violations have been classified into 6 categories:

- incomplete documentation,
- inappropriate transport conditions,
- limited serviceability of the vehicle,
- insufficient tightness of packaging, vehicle,
- improper marking,
- lack of protection equipment.

The differences in ADR and IDR control reports caused that in railway transportation there were found only three of the six discussed above traffic rules violations. Results of the controls for both branches of transport are demonstrated in Tab. 2 and 3.

Tab. 2. Presentation of abnormalities discovered during road controls according to their categories, in the years 2004-2005

Type of violation	Number of found violations					
	2005	2006	2007	2008	2009	Summary
Lack of documentation	1161	1082	910	538	769	5491
Inappropriate transport conditions	67	80	50	36	44	336
Limited serviceability of the transport unit	64	187	78	90	93	600
Lack of the packaging sealing	20	37	26	23	21	176
Improper labelling	133	369	187	167	150	1212
Lack of protective equipment	169	818	580	706	693	3432

Tab. 3. Presentation of undesirable events, which occurred during transport of dangerous materials by railway in the years 2005-2009, according to categories

Type of violation	Number of events					
	2005	2006	2007	2008	2009	Summary
Improper transport conditions	24	18	17	15	12	86
Limited serviceability of the transport unit	3	2	7	6	4	22
Lack of the packaging tightness or transport unit	6	11	6	5	4	32
Total	33	31	30	26	20	140

#### 4. Risk assessment in land transportation of hazardous materials

In effect of the carried out analysis of selected methods for risk assessment [2] for land transportation of hazardous materials, FMEA method has been chosen. This method is simple and universal and it will enable accurate projection of assessment of the risk likely to occur during transport of hazardous materials. FMEA method involves determination of probability of

occurrence of traffic rules violations and their effects in reference to the analyzed categories, presented in section 7 [1, 8].

Risk assessment by FMEA method, according to the need, is being performed more or less thoroughly. It involves determination of risk R-value [1, 8], according to formula (1).

$$R = P \cdot W \cdot Z, \tag{1}$$

where:

R – overall assessment of the risk (connected with occurrence of violation),

P – index of violation occurrence taking into consideration probability of occurrence of traffic rules violations whose value includes the assessment of violation probability,

W – index of detectability of the traffic rules violation by a driver whose value is determined on the basis of probability of detection,

Z – index of effects of the traffic rules violation (meaning of error) determines probability of loss occurring after the violation.

Values of indexes P, W are normalized in interval <1-10>. Further actions depend on the risk value level. A high value of R risk level should provide basis for taking actions minimizing occurrence of traffic rules violation [1, 8]. In Tab. 4, there is a proposal of exemplary values for indexes P, W, Z used for risk determination.

Tab. 4. Exemplary values of indexes P, W, Z. [1, 2, 8]

Probability of the violation occurrence		Rate of detectability		Index of the violation effects	
P		W		Z	
Improbable	1	High probability	1	Hardly noticeable	1
Very little probable	2-3	Medium probability	2-5	Insignificant	2-3
Little probable	4-6	Slight probability	6-8	Medium	4-6
Moderately probable	7-8	A very small probability	9	Hard	7-8
High probability	9-10	Improbable	10	Extremely hard	9-10

Assessment of probability of occurrence of a traffic rules violation is a subjective assessment. The number of points depends on the researcher knowledge and skills. Tab. 1 contains the number of points assigned on the basis of literature and tests, depending on the probability of occurrence of violations [1, 2, 8].

Tab. 5. Relationship between the numbers of points awarded on the probability of occurrence of an event

Number of points	Likelihood of the violation occurrence	Probability
1	Very unlikely	0.001-0.0099
2-3	Unlikely	0.01-0.099
4-5	Medium	0.1-0.199
6-7	Quite high	0.2-0.29
8-9	High	0.3-0.35
10	Very high	> 0.35

Tab. 6. Exemplary results of an assessment of the risk connected with traffic rules violation in road transportation

Type of violation	P	Likelihood of violation occurrence	Values of indexes			Risk level
			P	W	Z	
Insufficient documentation	0.72	Very high	10	2	1	20
Inappropriate transport conditions	0.04	Poor	2	3	8	48
Limited serviceability of the transport means	0.04	Poor	2	5	6	60
Inappropriate securing of the hazardous goods	0.01	Poor	2	7	8	112
Inappropriate labelling	0.08	Poor	3	4	3	36
Lack of protective equipment	0.1	Medium	4	1	7	28

The results of the assessment of risk connected with road transportation of hazardous materials have been presented in Fig. 1. As it can be seen, the highest level of risk including health and life loss threat is connected with insufficient sealing of the containers in which dangerous materials are transported. The second group of high-risk violations includes those related to the technical state of the vehicle transporting these materials. As it can be seen in Fig. 1, the level of risk involved in particular violations in transportation remains at the same level throughout the whole period of time, although the number of controlled vehicles increases from year to year (Tab. 1).

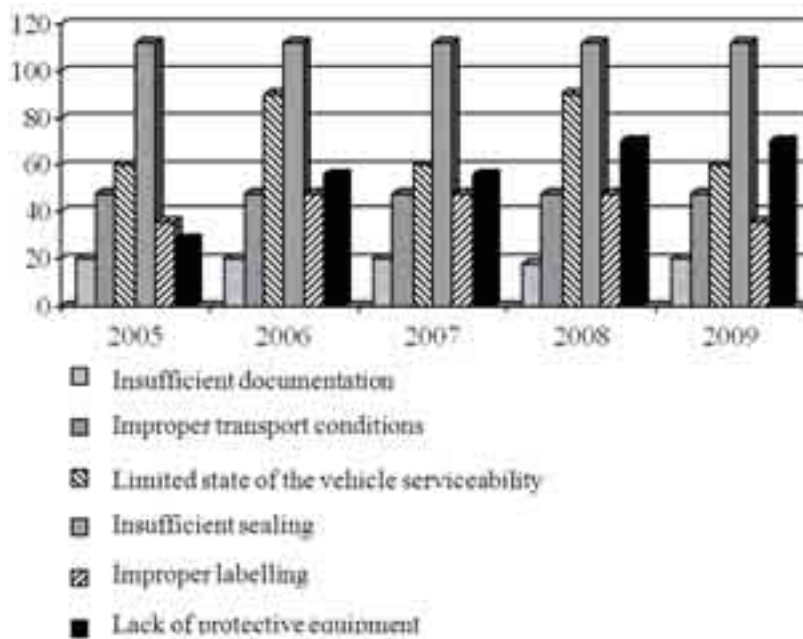


Fig. 1. Results of risk assessment connected with found violations of traffic rules in the years 2005-2009

Figure 2 shows the results of the assessment of risk connected with railway transportation of hazardous materials. In this case, like in road transport, the risk-involving occurrence of undesirable events remains at the same level in the analyzed period of time. Therefore, it is necessary to take actions to reduce the risk level of undesirable impact of hazardous substances due to their inappropriate transportation.

In Fig. 3, there is an assessment of risk connected with occurrence of violations and undesirable events in railway transportation. The highest level of risk was reported in railway transportation in the category of poor sealing of packaging and the transport unit. The risk level for railway transportation, according to the considered categories, is even five times higher than in road transport.

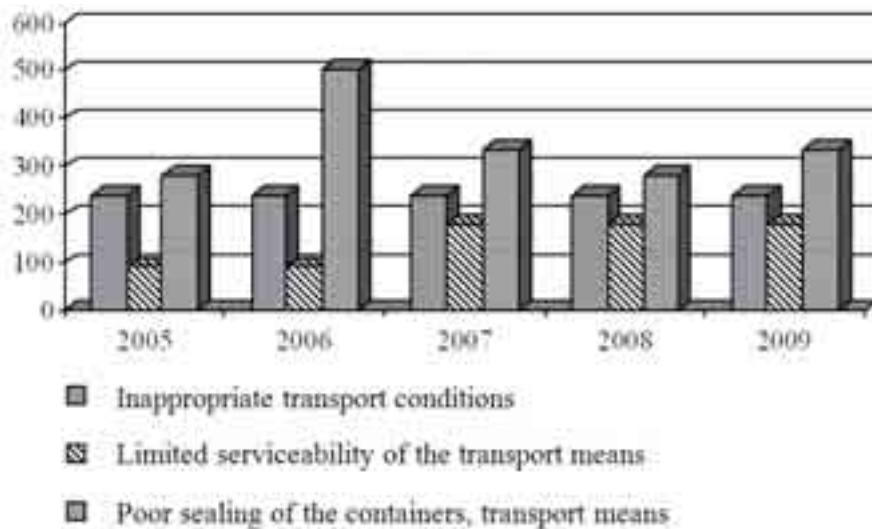


Fig. 2. Results of assessment of risk connected with occurrence of undesirable events in road transportation

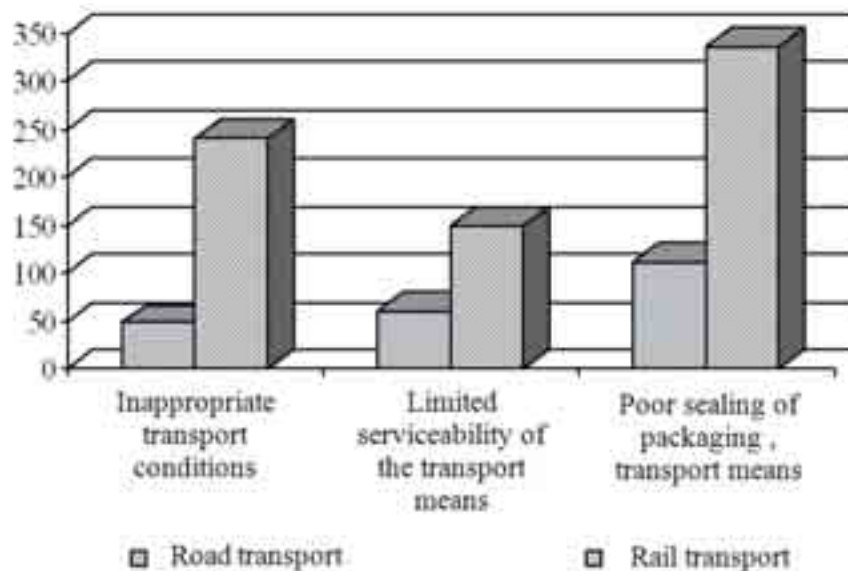


Fig. 3. Assessment of risk involved in the traffic rules violation and undesirable events occurrence

## Conclusions

As the carried out studies show the railway transportation of hazardous materials is characterized by a higher level of health and life loss risk due to likelihood of occurrence of an undesirable event within this system. The higher level of risk is posed by an event referred to as lack of tightness of the transportation unit.

The second violation posing a high risk, thus, threat for people involved in the system and its environment, are improper transport conditions (including: inappropriate securing of the load, transport of loose material, transport of goods not allowed to be carried, carrying in one vehicle articles which are forbidden to be together).

The third group of threats includes limited serviceability of the vehicles used for transportation of hazardous materials. As it can be seen all these groups of threats result from negligence of the people involved in organization of hazardous materials transportation. Therefore, top priority must be given to prevention actions, which are supposed to raise the awareness of people on the subject of threats and risks, connected with transportation of hazardous materials.

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