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ACCIDENT PROBABILITY RISK FACTORS OF HAZARDOUS FREIGHT TRANSPORTATION

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Transport accidents of hazardous substances are increasingly frequent and can cause serious injuries in densely inhabited areas of the environment. For quantitative risk assessment and mitigation planning, consequence modelling is necessary.

The article points out the ways of reducing the risk of possible damage and probability of accident. The conditions of ensure safe transportation of hazardous freight, managing and minimising risk on carriage of such goods along the whole route are introduced.

This article presents the probabilities in transport of hazardous freight, probability of a possible damage and that of a possible accident, when transporting hazardous freight and a method of calculating costs of damage to environment and that of calculating accident probability. The main possibilities to reduce accident probability and to raise transportation safety are described.

Keywords: hazardous freight, risk, control, transportation, accident

1. Introduction

The transportation of hazardous freight is one of the most complicated spheres of transport and one that requires the most safety measures because if there is an accident, a hazardous freight can get into the environment and cause grave consequences.

There are many dangerous goods in Lithuania transported as transit goods and also inside of the country: by road transport – 25 %, by railroad transport – 55 %, by pipe transport – 100 %, by air about 1% of all goods transported with corresponding mean of transport. Particular statistic data according to groups or goods, transported by road transport are given in the Table 1:

Table 1. Inside transportation of freight by means of road transport according to groups of freight in Lithuania

Groups of hazardous freight	**2008**	**2009**	**2010**
	thousand t.	**thousand t.**	**thousand t**
Total	*2 229,3*	*1 692,1*	*1 565,2*
Explosives substances and articles	1,3	0,8	6,2
Gases	308,9	353,4	228,2
Flammable gases	1 793,6	1 222,7	1 099,9
Corrosive substances	30,3	43,3	45,5
Miscellaneous dangerous substances and articles	95,1	72,0	131,2

Accidents during the transportation of hazardous freight often have serious consequences: the socio-economic cost of a tanker accident may be twice as high as that of a "normal" goods-transport accident due to the hazardous freight escaping and the environmental damage caused by this. However, compared with the accident occurrence in the transportation of general goods, accidents involving hazardous freight are rare: around eight out of 1,000 personal injury accidents involving goods vehicle are classified as accidents involving hazardous freight.

One problematic aspect of these accidents is that the cargo is often inadequately secured. This can be seen through analysis of "serious" accidents involving hazardous freight vehicles in which people are injured due to the hazardous freight or in which more than 100 kg or litres of the hazardous freight are released. As approximately 29 % of hazardous freight transported are "poisonous", it is particularly important that the cargo is correctly secured and the vehicles are correctly labelled.

2. The Main Risk Factors while Transferring Hazardous Freight

Carrying goods by road or rail involves the risk of traffic accidents. If the goods carried are hazardous, there is also the risk of an incident, such as spillage of the goods, leading to hazards such as fire, explosion, chemical burn or environmental damage. Most goods are not considered sufficiently hazardous to require special precautions during carriage. Some goods, however, have properties which mean they are potentially hazardous if carried.

The shipper first faces an important issue of hazardous freight transfer when determining the type of transport to be used.

The three most important criteria are in order of importance:

1. Reliability / punctuality – the chance of delivery at destination being on time.
2. Flexibility – ability to adapt to the customer's changing requirements or to fluctuating factors outside.
3. Journey time – time needed for goods transport from door to door.

It is known that the most effective way to transfer goods over large distances and long routes is the railway transport. But the high risk probability of possible harm to nature and people arises immediately. Accordingly, the costs of special insurance and other related cost increase. The shipper is faced with a dilemma, what is better, large quantity per one run using railway transport, or the same quantity in smaller shipments, suffering road expenses while using road transportation. If the second choice is taken, a second risk factor arises – the possibility of road accidents. So there are two main risk factors while transferring hazardous freight:

- Possible road accidents;
- Possible harm [1].

Both hazardous freight shipment risk factors are related, because when you have an accident, harm will incurred, but harm is not always a straightforward reason of an accident, thus the first factor is more important and plays a bigger part in the reasoning of the transportation choice problem; but the second factor should not be forgotten, as it also plays a important role. The harm possibility factor directly intertwines with monetary loss because much attention is now paid to the protection of environment and the money's worth harm to the surroundings is large, directly influencing the cost of the transportation.

3. Analysis of the Accidents in Transport of Hazardous Freight

Possible damage is calculated using methods when oil is spilt into water or soil and so on. As an example we can calculate monetary damage to polluted water reservoirs. It can be calculated using this formula:

$$N_{at} = N_{alt} \times K_{cat} ,$$

where N_{at} – the monetary loss of spilling pollutants in a prohibited area, territorial waters or economic zones, evaluating the category of the reservoir;

N_{alt} – the monetary loss, which is taken from tables after assessment of the type and quantity of the pollutant;

K_{cat} – coefficient evaluating the category of the reservoir.

As we can see, the harm and losses depend on many factors, such as number and type of spilt materials, size of pollution and so on.

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Both these factors are probabilities. The possibilities of reducing the first risk factor are as follows:

- Increase the quantity of goods per one shipment, because increase in the quantity transferred reduces the number of shipments, and less shipments means smaller number of road accidents;
- Reduce the number of shipments thus reducing the probability of accident;
- Ensure the quality of hazardous freight packaging, loading, reloading and goods fastening, as this reduces the harm and influence to people and environment, also can help avoid negative consequences;
- Correctly choose a route, which has less inhabited areas and no reservations, where driving conditions are good, which reduces the probability of an unforeseen accident, where no traffic-jams or other accident stimulating conditions occur;
- Notice the climate conditions and season; materials, which are entailed with the danger of inflaming at a specific temperature should not be transferred at very hot temperatures. Also transportation of dangerous materials should be avoided in winter on slippery roads, when the chance of accident is twice as high;
- The driver's and transportation workers preparation, experience and knowledge play a vital role in their work with hazardous freight.

Quality systems are also very important in the shipping of hazardous freight. As it was said earlier, quality systems help reduce the probability of an accident [4].

Risk factor opportunities of possible harm are closely related in many fields, so the risk can be diminished by as follows:

- Reduction of goods quantity in one shipment, – this is the opposite action from the reduction of an accident possibility, but a smaller amount of dangerous material directly results in reduced level of harm, influence on people and surroundings;
- Increasing the number of shipments in order to maintain the same amounts of goods transfers; decreasing the goods quantity for one shipment, the total number of those shipments should increase, but it is not an economic solution, and the effect of this risk possibility reduction is fairly equal to the decrease in the probability of accident;
- Ensure the quality of the packaging, loading, reloading and fastening of hazardous freight;
- Correctly chosen route.

After analysing the conditions of risk factor possibility diminishment, they can be classified as qualitative and quantitative – according to transferred goods amount and shipment frequency. The risk factor of accidents is included into the quantitative factors, since it directly depends on the number of shipments. The risk factor of harm is a qualitative factor, because the harm directly depends on the material, that is on the quality of the transferred material (in this context quality is understood as the hazard level of the material).

It is noticeable that the first two methods of accident and harm risk reduction are contradicting each other, so here the leading role of choosing the means of transportation will be delegated to other criteria. One of them is price. There are dangerous materials, which do not cost much, like wastes, but are very large in quantity. It is possible that the price of transportation will exceed the price of the material, and in this case the shipper will most likely choose the cheaper transport. It is not easy to choose the right transport vehicle for hazardous freight, so the manager or forwarder of the firm must have good knowledge logistics, economics and transport politics. Each the slightest misstep can bring large losses to the firm.

While shipping hazardous freight all the transportation process must be thoroughly thought-out, taking into consideration the warehousing, resting time and place, reducing to a minimum the standstill and warehousing time. In the case of multimodal transport much attention is granted to planning the route with minimum number of reloads or warehousing and stoppage time, using up-to-date packaging methods and ways, such as containers. It is convenient not only for multimodal but also for intermodal transport.

It is stated that three main problems can be written in the following way:

$$\min \ f_1 = \sum t_{ij} x_{ij};$$

$$\min \ f_2 = \sum_{1}^{n} c;$$

$$\min \ f_3 = \sum_{1}^{n} p$$

where

f_1 – delivery time;

f_2 – delivery expences;

f_3 – accident probability.

Each of these problems should be solved separately and the best results with the minimal value should be detected. Then a comparative analysis should be performed and optimal results selected.

In order to ship hazardous freight we must take into account and estimate:

- The technical base of type of transport (for example, the base in road transport is better than in railway transport).
- Safety guaranties.
- Length of the road.
- The cost of the shipment in comparison to the cost the goods.
- Chemical properties of the material and its quantity.
- The preparedness and knowledge base of the staff.
- Route.
- Climate conditions.
- Probability of accident.
- The level of probable damage, and if needed change it into monetary expression [5].

Shippers, forwarders and other transportation participants (loaders, warehouse workers an so on) must comprehend that only full understanding and wide knowledge will allow to safely and economically ship hazardous freight, which according to previously stated aspects will have higher risk, but will not cause danger.

4. Improving Safety of Transportation of Hazardous Freight

It is necessary to regulate, control and check transportation of hazardous goods because of their peculiarities, percentage and real danger. Strict requirements are estimated for transportation, packing and marking of hazardous goods, requirements for vehicles, transporters, storage and other logistic functions.

It is necessary to solve the problem of safety of traffic while transporting hazardous freight complementary – to analyse reliability of the whole system "Participant of traffic – vehicle of road transport (car) – road (street) – environment". Besides, the safety while transporting the hazardous goods is affected not only by these main four parts of the system, but also by different kinds of vehicles and society.

Analysis of transportation of hazardous goods capacity according to different kinds of transport characterises demands, while transporting hazardous freight, development degree of the process and describes organizational-technical means, for the purpose of scientifically motivated process of transportation of hazardous freight.

In to the process of organizing transportation, goes technical supply transportation mean's (vehicle's, container's and package's, means of mechanization of loading – unloading work) selection, safe transport according to estimated course, training of drivers and operating personnel. Estimation of course, selection of vehicle and transportation control depends to the administration functions. To realize these tasks informational system, which allows storing with information every link of transportation organizing, is needed.

To insure safety of transportation and to select means, primary it is necessary to investigate factors, which has influence to danger of transportation. By organizing transportation of hazardous goods, it is necessary to consider such factors:

- Technology of transportation process.
- Interaction with other ways of transportation.
- Estimation of routes.
- System of permissions to hazardous freight transportation.
- Transportation control.
- Elimination of accident results.

All these factors depend on informational supply.

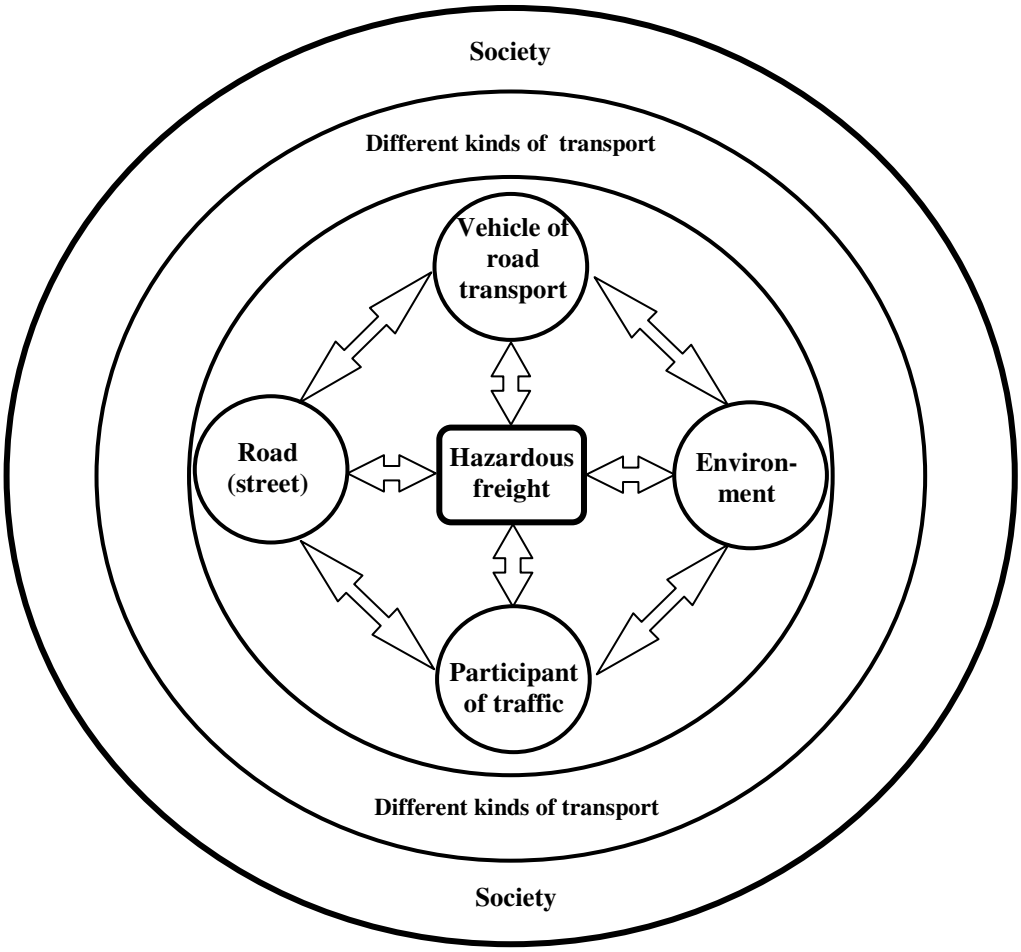

Figure 1. System's „Participant of traffic – vehicle of road transport (car) – road (street) – environment“ general structure

The danger of transportation is determined by three main elements of hazardous goods transportation:

- Capacity of transportation.
- Course of transportation.
- Technology of transportation.

Each of these elements has influence on danger of transportation, there parameters and various qualitative and quantitative compatibility features shows their level and degree. It is advisable to arrange transportation danger according to degree of danger, which is determined choosing and estimating technological transportation processes. In this way we estimate danger degree of transportation, as mathematical expected loss magnitude, which can increase, while transporting hazardous goods.

Making the technology of transportation better, a big role is played of solution of theoretical problems and usage of practical means, while improving the process of safe hazardous good's transportation.

Managing hazardous freight involves:

- Identifying hazardous freight and site classification;
- Controlling ignition sources such as naked lights, sparks and mobile phones where flammable atmospheres may exist;
- Segregating incompatible freight;
- Separating hazardous freight from 'protected places';
- Providing information, training and supervision in evacuation and fire fighting procedures;
- Spills management;
- Selection, provision and maintenance of safety equipment and personal protective equipment;
- Using documented safety management systems;

- Placarding of sites with dangerous goods in packages stored or handled above the prescribed quantities;
- Keeping unused storage or handling systems clean and safe.

To avoid the possibility of an explosion or the emission of toxic flammable or corrosive gases:

- Store two incompatible goods at least 3 m apart.
- Consider storing some goods (especially highly pyrophoric or unstable goods e.g. Class 4.2 or 5.2) in separate fire rated enclosures or separate buildings with appropriate fire suppression equipment.
- Store goods at least 5 m apart in case they could react violently.
- Separate enclosures or buildings may also be required for those goods with special fire suppression requirements (e.g. Class 4.3 freight react adversely with water) [6].

5. Conclusions

1. For supply of no emergency transportation of hazardous freight an effective developed examination transportation process and methodology of management is needed. For this purpose it is necessary to go from partial, though gross problems, to complex solutions of problems.
2. In order to ship hazardous freight we must take into account and estimate the following main aspects:
   - the technical base of type of transport;
   - length of the road;
   - the cost of the shipment;
   - the preparedness and knowledge base of the staff;
   - route;
   - climate conditions;
   - the level of probable damage.
3. The transportation of hazardous freight can be mathematically expressed using probability theory and express and calculate costs based on this information. These methodological assignment solutions are important, since they allow lowering the risk factors to a minimum in different situations and shipment stages.
4. The solution of the risk assessment assignments enables to find the minimal risk by using the same technical and technological means.
5. The risk assessment gives an opportunity for carriers to choose the main transportation criteria, flexibility, to use alternative using the risk assessment it is possible to reduce accident probability and to raise transportation safety.

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