**DANGEROUS GOODS TRANSPORTATION:
NEW TECHNOLOGIES AND REDUCING OF THE
ACCIDENTS**

**TRANSPORT TOWARÓW NIEBEZPIECZNYCH:
NOWE TECHNOLOGIE I ZMNIEJSZENIE LICZBY
WYPADKÓW**

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Abstract: This article examines types of modern technologies application possibilities in dangerous goods transportation. It is noted that the solution to transport technology problems is based on the improvement of technological supply, the rational usage of informational modeling methodology of the whole transportation process. The article points out the ways of reducing the risk of possible damage and probability of accident. The conditions of ensure safe transportation of dangerous goods, managing and minimising risk on carriage of such goods along the whole route are introduced. The aspects of mobile solution of transport are named in this paper too.

Keywords: dangerous goods, risk, transport.

Streszczenie: W niniejszej pracy przebadano możliwości zastosowania różnych rodzajów nowoczesnych technologii do transportu materiałów niebezpiecznych. Zauważa się, że rozwiązanie problemów technik transportowych opiera się na poprawie technologii dostaw oraz na racjonalnym wykorzystaniu informatycznych metod modelowania dla całego procesu transportowego. Artykuł wskazuje na sposoby obniżenia ryzyka możliwych uszkodzeń oraz prawdopodobieństwa wypadku. Przedstawione są warunki dla zapewnienia bezpiecznego transportu towarów niebezpiecznych, zarządzania i minimalizacji ryzyka związanego z przewożeniem takich towarów wzdłuż całej trasy transportu. W niniejszej pracy poruszone są również aspekty rozwiązań mobilnych w branży transportowej.

Słowa kluczowe: towary niebezpieczne, ryzyko, transport

1. Introduction

Dangerous freight – is a hazardous substance that is defined by the Dangerous Substances Act, to be dangerous (ADR, 2005). Dangerous goods are classified on the basis of immediate physical or chemical effects that may impact on people, property or the environment – explosive, flammable, corrosive, chemically reactive, highly combustible, acutely toxic, radioactive or infectious.

Carrying goods by road or rail involves the risk of traffic accidents. If the goods carried are dangerous, 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.

The necessity of mobile transport systems analysis is based on globalization and integration processes; interconnection of various types of transport means and their management in order to obtain more effective, safe and mobile goods motoring and the creation of the intelligent transport sector. It is necessary to improve the present European transport services and promote new services upbringing, to reveal the shortcomings.

The main possibilities to reduce accident probability and to raise transportation safety are described.

2. The main requirement of packing of dangerous goods

Dangerous goods must be properly packed into a suitable container. Container must be credibly closed. The dangerous goods should be protected from any outside influence during transportation. If the transportation circumstances are normal, the package should be protected against vibration, temperature variations, pressure variations and moisture.

Packing part, which has a direct contact with dangerous material, must be protected against chemical or any other influence of this dangerous material. If necessary, the packing surface must be covered with special materials, which prevent it from any chemical influence.

If the packing has been remade (has been installed or exchanged new facilities), this packing should be tried by following the primary requirements. Before loading such packages for transportation we make sure, that it has not been damaged by corrosion or damaged by any other way. If we detect that the resistance features have fallen down or the design has changed, we should stop using this packing and restore it until it gets primary features. However, after this repair we should check the design and attest it works properly. Liquids can be packed into packages, which can keep particular pressure of a normal transportation circumstances only. The liquid can not spread outside of packing. (Communication, 2006).

The empty packages, where dangerous goods have been packed, should be called than filled of the same dangerous goods. There are the same requirements for

empty package as for full one. The main requirement for empty and unwashed containers: they must have the same safety features than full ones and make sure there is as little ability to leak or crumble away as possible.

Experimentations for leaking of packages are made:

- Before the first transportation;
- After repair and technical changes.

Packages, which are used to heavy materials transportation, should pass the requirements of packages of liquids transportation if it can change itself physical existence from heavy to liquid material in some temperatures.

3. The regulations of balance of safety and economy

All packages must be made and tested by quality requirements of insurance program, which is made and ratified by competent government, which make sure that production and experiments would be made by recommendation rulebook. In this recommendation are claimed the main requirements for packages, because technological science is making new packages, which requires another testing conditions.

In order to warrant the maximum safety it is recommended to pack it into the packages, which are suitable for explosives or radioactive materials. By this way there would not be such term as "dangerous goods". Also there would not be "dangerous" goods, because all kind of materials should be packed good enough to be not damaged on the biggest emergency (except explosives and radioactive materials). However, the packages would cost much more than goods cost. By this way nobody would buy goods, it would cost too much. With a view to make economical efficiency, the recommendations introduce safety provisions, which let to reduce production expenditure for dangerous goods packing. For example, Sweden national testing and researching institute is researching for as cheaper as possible material, which pass requirements of recommendations. This institute (expect the scientific researches) perform packages testing (primary and permanent) for Sweden and foreign countries producers. The company is testing and trying examples, before starting the new kind of packages production. If experiments success, they start production of packages. Besides, these packages are marking by United Nations sign.

4. Methodical analysis of the accidents in transport of dangerous goods

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

It is known that the most effective way to transfer goods over large distances and long routes is 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 dangerous goods:

- Possible road accidents;
- Possible harm.

We can calculate the probability of a possible road accident in such two ways:

1. *By number of trips:*

$$\frac{\text{Number of accidents while transferring dangerous goods}}{\text{Total number of dangerous goods transfer shipments}}$$

The acquired result indicates the probability of accident for one trip.

2. *By number of goods shipped per wanted time interval*

$$\frac{\text{Quantity of goods, transferring which an accident happened}}{\text{Total quantity of goods shipped}}$$

The acquired number shows the probability of accident per 1 weight measurement. Using this we can regulate the quantity of goods transferred on one shipment, because the larger the quantity of goods, the higher the probability of the accident. Possible damage is calculated using other 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:

$$N_{at} = N_{alt} \times K_{cat} \quad (1)$$

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 in many factors, such as number and type of spilt materials, size of pollution and so on.

Both dangerous goods 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.

Both these factors are probabilities. Possibilities of reducing the first risk factor:

- 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 dangerous goods 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 dangerous goods.

Quality systems are also very important in the shipping of dangerous goods. As it was said earlier, quality systems help reduce the probability of an accident.

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

- 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 dangerous goods;
- Correctly chosen route.

After analyzing 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 dangerous goods, so the manager or forwarder of the firm must have good knowledge logistics, economics and transport politics. Every slightest misstep can bring large losses to the firm. While shipping dangerous goods all the transportation process must be thoroughly thought through, 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.

Summarizing all that was said above, it is stated that three main problems can be written in this way:

$$\begin{aligned}\min f_1 &= \sum t_{ij} x_{ij}; \\ \min f_2 &= \sum_1^n c; \\ \min f_3 &= \sum_1^n p\end{aligned}\tag{2}$$

Where:

f_1 – delivery time;

f_2 – delivery expenses;

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

5. Managing the risks from dangerous goods

Managing dangerous goods involves:

- identifying dangerous goods and site classification;
- providing information, training and supervision in evacuation and fire fighting procedures;
- controlling ignition sources such as naked lights, sparks and mobile phones where flammable atmospheres may exist;
- segregating incompatible goods;
- separating dangerous goods from ‘protected places’;
- spills management;
- selection, provision and maintenance of safety equipment and personal protective equipment;
- placarding of sites with dangerous goods in packages stored or handled above the prescribed quantities;
- displaying a clearly visible information placard on tanks holding more than 500L of LPG or 450L of other classes of stated dangerous goods and combustible liquids;
- using documented safety management systems;
- 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.
- where the goods could react violently, store them at least 5 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.
- separate enclosures or buildings may also be required for those goods with special fire suppression requirements (e.g. Class 4.3 goods react adversely with water). (OECD studies, 2006).

6. New technologies for location and control of dangerous goods and vehicles

In solving the problems associated with vehicles and transportation of dangerous goods, one should always know an exact location of transport facility and the goods transported as well as the places of goods loading, unloading and transfer. The information on the past runs on particular routes should also be studied. This could allow us to effectively control all transport facilities as well as to avoid fire explosions of dangerous goods or other accidents. The information of any deviation from the route and other related data should be recorded.

The monitoring scheme should be build around a set of guidelines:

- Method of data collection (e.g. number of measuring points);
- Evaluation of information;
- Aggregation of information.

6.1. Telematics solutions

At present telematics solutions are used in road transport. Transport telematics consists of the following aspects:

- Transmission of information to and from a vehicle (Telecommunication);
- Processing of information (Information Technology);
- Information usage for safe transport and effective usage of already existing technologies solutions.

Mobile Location is fundamentally characterised by two aspects: mobility and location information. Mobile Location Services are services that exploit the knowledge about where a mobile terminal capable of wireless data transfer is located. The end user or another person may carry the terminal, or it may be attached to an object. The wireless data connection is typically based on cellular technologies or wireless. Network-based positioning, satellite positioning or indoor positioning technologies can define the location of the terminal. The most suitable technology depends on an application, the environment and the terminal capabilities. As the mobile location services sector is still in its early phases, the terminology varies and they are also called location – based services, location – enhanced services and location – dependant services. (Baublys and Batarliene, 2007).

Typical professional applications include e.g. fleet and mobile workforce management as well as routing and navigation. Location information is very important in various fields and for various purposes.

6.2. Software application

The catalogue of telematics system has the client-server structure. All data are stored in a separate place (computer) named the server. Access to its data is

possible by a client applications installed into the user's computer. Clients are connected via, for example, a local area network (LAN) or wide area network (WAN).

The solution gives many advantages for future users. The central bank of data (server) gives certainty that all users have an access to the same updated data. Any change of the infrastructure telematics system may be input to the catalogue system directly by the service that made the change. It makes possible that the updated data will be available for all users soon after updating. Access to the server's data is restricted depending on the service needed. It is protected against free access to the data for unprivileged persons. (Jarašunienė and Jakubauskas, 2007).

The local database stores all necessary information about saved telematics systems, their items, remarks, etc. The digital map server stores a graphic representation of spatial locations where a system's item may be found. The external database module allows users to access to an external temporary database to improve the knowledge about the telematics system. The graphic user interface combines all data coming from different modules into one comprehensible view easy for user to interpret. The map scanner allows the preparation of external maps to use with the system. The last module is responsible for the analysis of loaded data from the server as an answer to user's question. Other function of the last module is the reporting. It is one of the main functions of a catalogue program.

7. A remote identification system for dangerous goods transport

The main units of the remote identification system of vehicles and goods embrace: TIP portal, TVIMP portal, content control system (SMS, GPRS), mobile phone, the unit for stating the geographical position of vehicles and goods.

TIP portal is a subsystem aimed at providing the data on vehicles. The users of the portal can obtain the required information there and use the additional portal modules and subsystems. TVIMP portal (i.e. a mobile portal for common information about transport) is a subsystem performing the function of providing open information about transport for the users of the portal.

TVIMP is designed for all users of this portal to perform the following functions:

- A mobile component allows the users to browse through a portal with a cell phone or other devices, using a WWW or WAP browser;
- Static information component collects and automatically updates static data (e. g. documents, links, etc.);
- Dynamic information component provides the dynamic information stored in the portal, i. e. news, messages/announcements from transport companies, services, etc.;
- Open statistical data component provides generalized public statistical data about flows of transport, general use of roads, etc.;

TIP is designed for registered users to perform the following functions:

- Statistical component provides statistical data on vehicle and freight traffic;

- Visualization/location component deals with enquiries, providing textual and visual information from the location server (LAS) component about the location of objects;
- User data register and its control component register the portal users, allowing them to input/present the data on the monitored company's vehicles, transported goods, etc.;
- Component for communication with external systems provides the interface for the portal communication with other systems;
- LBS (location-based services) implements and provides various services associated with user location.

Given such flexibility, services can be provided to a wide range of users, including large logistics companies as well as individual carriers. Both types of portals have access to highly developed mobile phone lines.

Dangerous cargoes require special precautions. Applying the above described system to transportation of dangerous goods, the main tasks are to ensure monitoring and control. Disposable sensors attached to packages can be used in this case, particularly, when transporting the most or highly dangerous goods (i. e. autoreactive, radioactive materials, organic peroxides), as well as goods transported:

- by vehicles with the mass exceeding 3.5 tonnes;
- by vehicles carrying dangerous cargoes in fixed or removable tanks of the capacity exceeding 1 m^3 ;
- by a battery of similar transport facilities with the total capacity exceeding 1 m^3 ;
- by containers, removable containers or ddk, with the capacity exceeding 3 m^3 per vehicle;
- by vehicles, carrying 1st grade materials or products, irrespective of the largest mass of transport facility.

In transporting dangerous goods, the route of vehicles should be known and a system for moving objects control should be provided. The latter could ensure the safety of the transported dangerous goods. A schema of purport aggregation subject to selection service is presented in Figure 1.

Fig. 1. Schema of purport aggregation subject to selection service

This system would also be useful for carrying perishables because their transportation should be controlled.

8. Conclusions

1. For supply of no emergency transportation of dangerous goods 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 dangerous goods we must take into account and estimate these 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. A system of remote identification of vehicles and goods allows the carrier to determine:
 - where the vehicle is and if it is being loaded or unloaded;
 - how the vehicle is crossing the state border;
 - when the vehicle arrives at the place of destination (terminal).
4. The portals TVIMP and TIP can provide their users with various kinds of information, including public, legal, statistical, geographical and other types of information, as well as some confidential data based on vehicle monitoring required for the effective company performance.
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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