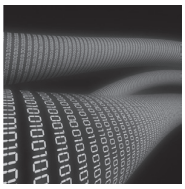

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Modern Technology Application for the Road Transport of Dangerous Goods

G. NOWACKI, R. KOPCZEWSKI
MILITARY UNIVERSITY OF TECHNOLOGY, Gen. Witolda Urbanowicza 2, 00-908 Warsaw, Poland
EMAIL: gabriel.nowacki@wat.edu.pl

ABSTRACT
The article presents modern technology application for the road transport of dangerous goods. Dangerous goods mean materials and objects which, because of the risks they pose to people and the environment, can only be transported under certain conditions. The lack of monitoring this type of carriage is a serious real threat to humans and the environment. Due to the number and complexity of decision problems encountered during its implementation becomes necessary to provide effective Information Technology. The use of Intelligent Transport Systems solutions (called - ITS) is designed to help manage the transport system, particularly transport infrastructure. The main problem of paper was formulated as follows: How modern technology can resolve problems of road transport of dangerous goods, taking into account national and international legal regulations and existing threats? In the solving of mentioned problem, the following research methods were applied: analogy, definition, analysis, synthesis, induction, deduction, modeling and diagnostic survey with expert research sample. The research included: Road Transport Inspection, State Fire Brigade, National Atomic Energy Agency, Transport Technical Supervision, Transport Companies, Department of Transport and Military Movement, Military University of Technology. The article presents the threats problems on dangerous goods in road transport and alarming statistics data of mentioned issues. The functional structure of the road transport safety management system for dangerous goods has been proposed, which can significantly contribute to limiting the number of threats and breakdowns, and in the case of their occurrence to better cooperation of emergency services in case of removing their effects.

KEYWORDS: technology, telematics, rod transport, dangerous goods

1. Introduction

Nowadays, rapid technological progress in all areas of industry and its further development causes an increase in the demand for various types of semi-finished products and raw materials to ensure the continuity of production of goods. The variety of forms and the amount of dangerous goods transported determines the formation of specialized terminals in seaports, equipment handling goods, a network of access roads.

The importance of the problem of transporting hazardous materials is evidenced by statistics that make it very clear that the risks that may occur in transport are a very important element of regional, national and international policy. This is because 90% of dangerous goods are transported by road, and only 10% by rail. Over 170 million tons per year (in 2017), more than 430 thousand tonnes per day - to transport this load on standard semi-trailers with a capacity of 18 tonnes, 24 thousand are needed trucks a day [2].

Accordingly, Europe needs a well-developed transport network to support trade and economic growth, create jobs and conditions conducive to prosperity. Transport networks are an important part of the supply chain and form the basis of the economy in all countries, enabling effective distribution of goods. Road, rail or air connections connect and bring people together, improve the quality of life and make even distant places available. Transport is the basis of the European integration process and is closely related to the creation of the internal market, which promotes employment and economic growth. It was one of the first areas covered by the common policy of the European Union. Therefore, EU transport

policy has always focused on overcoming obstacles to transport between Member States.

The smooth operation of all infrastructure components [5] does not, however, guarantee full internal security. Effective and effective methods of management, monitoring and control of work are still needed, so as to ultimately ensure safety for people, means of transport and other means of transport at the moment in its area.

In order to increase transport does not mean deterioration of road safety, it is necessary to have good law in this area and to enforce it in everyday transport practice, as well as proper training of participants in the transport chain.

2. The need of monitoring dangerous goods

Road transport, which is the most frequently used form of transport, has become one of the greatest civilization threats. Air pollution, noise emission, traffic accidents, congestion, water contamination, occupying an ever-larger area of land are associated with high costs that all residents of the Earth have to bear, not just transport users. The consequences of transport development and its negative effects are already perceptible and future effects will be felt in the future. All manifestations related to the transport of dangerous goods, having a negative impact on road safety, and not only contribute to the fact that these problems are perceived in the academic-scientific environment.

The development of transport companies is the fact that not only is their vehicle fleet increased, but also that more and more modern management systems are being introduced. To manage effectively - both effectively and economically - modern logistic systems are needed, providing quick and comprehensive information on the managed means of transport.

The current development of telecommunications and radio communication as well as IT methods enables the introduction of integrated services consisting in continuous determining the location of vehicles and automatic monitoring of transport in national and international transport, not only on road, but also on rail, etc.

Mobile communication is becoming more and more crucial during transport and search and rescue campaigns. Continuous development of roads requires the use of effective cargo management systems, enabling their location, reporting of cargo status and vehicle data.

The positioning system and given means of transport enable automatic transmission of relevant reports to the management center, which enables dispatchers to search for vehicles, observe their routes in real time and change the strategy or route. The ability to track vehicles and goods transported in them helps in finding them immediately.

Very often, the recipients of such monitoring services are transport companies. Ignorance of the position of vehicles and their technical condition, as well as the inability to quickly decide about the routes of vehicles, are reflected measurably on the revenues of the transport company.

The vehicle tracking system can meet the expectations of different user classes. Appropriate management of dangerous goods transport can help the relevant state services to fulfill their main obligations in the area of reducing the likelihood of disasters and preventing their consequences.

Therefore, it is natural to be interested in such systems from the industrial manufacturers of hazardous materials and their recipients. Efficient organization of transport, the possibility of preparing unloading on time, flexible response to unforeseen irregularities or threats in planned transports is important not only for security reasons, but also due to the optimal use of infrastructure and human resources.

3. Statistics data of dangerous goods transport

Dangerous goods (DG) have known in more commonly as hazardous materials, (abbreviated as HazMat). Dangerous goods include materials that are flammable, explosive, radioactive, corrosive, oxidizing, asphyxiating, toxic, pathogenic, or allergic [12].

The carriage of dangerous goods by road is a complex process, which is why many sectors are responsible for its implementation: minister competent for transport, Minister of National Defense, minister competent for economy, minister competent for health.

If, in connection with the transport of dangerous goods, a serious accident or breakdown within the meaning of ADR took place, the participant, within 14 days of the occurrence of the event, shall submit the report:

- Provincial Road Transport Inspector - in the case of transporting dangerous goods by road,
- Head of the Armed Forces Support Inspectorate - in the case of transport of dangerous goods by means of transport belonging to the armed forces.

Information about a serious accident or breakdown in the transport of dangerous goods is forwarded to the minister responsible for transport issues by the above authorities, immediately after receiving by them the post-accident report.

Dangerous Goods in the European Union are transported in three manners as follows: by Inland Waterways – 17%, by Rail – 25%, by Road – 58 % [8].

In Poland, however, 88-90% of dangerous goods are transported by road, and only 10-12% by rail transport [2].

The largest group of products transported in the EU in 2017 were flammable liquids - 54.3%. Two other groups, gases (compressed, liquefied or dissolved under pressure) - 13.1% and corrosives - 11.3% [8]. These statistics are similar in comparison to previous years.

In Poland there are the most products of transport are flammable liquids – 66.19% and gasses – 25.17% - Table 1.

Table 1. Percentage share of transported dangerous goods [3, 8, 9]

Class	Participation
1. Explosives and materials	0.95%
2. Gases	25.17%
3. Flammable liquids	66.19%
4.1. Flammable solids, self-reactive substances and solid desensitised desensitized materials	1.50%
4.2. Self-igniting materials	0.13%

4.3. Flame-resistant gases in contact with water	0.79%
5.1. Oxidizing materials	0.03%
5.2. Organic peroxides	0.16%
6.1. Poisonous substances	0.30%
6.2 Infectious materials	0.23%
7. Radioactive materials	Omitted
8. Corrosions	1.62%
9. Various hazardous materials and items	2.93%

Another important statistic is the percentage share of the use of means of transport of dangerous goods: cisterns up to 79%; 20% containers; canned goods 1% - Table 2.

Table 2. Percentage by carriage method [2, 8, 9]

Percentage by transport method	
Cisterns	79%
Packages	20%
Bulk	1%

Road freight transport in the EU, including Poland, is constantly increasing, as evidenced by the data presented in Table 3. In Poland, there is also a growing tendency in the transport of dangerous goods by road.

The carriage of cargo by road transport expressed in tonne-kilometers of previous years accounted for a 12% share in the total transport of the European Union, which means that Poland among the EU countries was in second position behind Germany, and before Spain and France. In international transport, Poland had a 21% share of the 28 EU countries and was in the first position ahead of Spain and Germany.

Table 3. Road transport - transport of dangerous goods [2]

Year	Weight of goods
2010	149.13 million tons
2015	150.57 million tons
2016	154.66 million tons
2017	174.72 million tons

4. Threats of dangerous goods transport

The safety of road transport of dangerous goods applies directly to the entire EU area and all its citizens. There are 495 million road users in the 28 Member States of the European Union. of which 300 million have a driving license. They use nearly 300 million vehicles on a road network with a total length of around 5 million kilometers. Every day, explosives and materials, inflammable, poisonous, infectious, corrosive and radioactive substances are transported over hundreds of thousands of kilometers. The transportation of these goods requires specialist knowledge and sometimes specialized vehicles.

Among factors causing the increase of hazard [3], which is associated with the transport of toxic substances, the most important are: number of transports (especially in road transport), technical condition of vehicles and tanks used for transport, residual or complete lack of monitoring of transports, non-compliance with international transport regulations dangerous substances (ADR), no separate safe transport routes (a small number of bypasses in large agglomerations) and finally a difficult to specify place of possible failure.

Potentially the biggest threats [7] can also cause chemical accidents and disasters. In particular, hazards resulting from the storage and transport of hazardous chemicals are predominant here. As a result of failures, often connected with the negative influence of natural forces, to the environment in an uncontrolled manner, every year a large number of chemical substances that may cause a potential danger get through.

n the analysis of road accidents, not only those connected with the transport of dangerous goods, the issue of causality comes to the fore. Identifying the main reasons [7] and conditions co-occurring in unexpected events is necessary in determining and attributing fault to the offender and the scope of his liability. In general, the following causes of accidents are indicated:

- excessive speed and non-adaptation to weather conditions on the road,
- incorrect passing, overtaking or "maneuvering" while driving,
- enforcement of the right of way and failure to comply with regulations in this respect, - failure to adjust a safe distance from the vehicle in front,
- failure to use appropriate signaling when changing the lane or turning direction, non-observance of road signs and traffic service signals,
- failure to comply with the regulations regulating traffic lights on the road,
- driving at night on traffic lights and dazzling other road users,
- lack of care for vehicle safety devices (brakes, lighting, maintenance).

In Poland, there are on average up to 70 road accidents in the transport of dangerous goods a year, in 2010-2017 there were more than 500 accidents in total. Accidents involving tanks are on average around 75% of all accidents per year. This trend remains stable, and may even increase as the forecasts for the coming years show that truck traffic will increase.

In the last period of time, the threat of using transport with hazardous materials to terrorist attacks has also increased.

5. New technology in dangerous goods transport system

5.1 General requirements

The development of transport companies is the fact that not only is their vehicle fleet increased, but also that more and more modern management systems are being introduced. To manage effectively - both effectively and economically - modern logistic systems are needed, providing quick and comprehensive information on the managed means of transport.

The current development of telecommunications and radio communication as well as IT methods enables [1] the introduction of integrated services consisting in continuous determining the

location of vehicles and automatic monitoring of transport in national and international transport, not only by road but also by rail.

As you can see, congestion on roads increases significantly in Poland as well as throughout the EU. Weather conditions are changing, appearing suddenly, and events on the roads have a significant impact on the quality and safety of transport tasks.

Mobile communication is becoming more and more crucial during transport and search and rescue operations [4]. Continuous development of roads requires the use of effective cargo management systems, enabling their location, reporting of cargo status and vehicle data.

The positioning system and given means of transport enable automatic transmission of relevant reports to the management center, which enables dispatchers to search for vehicles, observe their routes in real time and change the strategy or route. The ability to track vehicles and goods transported in them helps in finding them immediately. It is very useful in the case of theft.

Very often, the recipients of such monitoring services are transport companies. Ignorance of the position of vehicles and their technical condition, as well as the inability to quickly decide about the routes of vehicles, are reflected measurably on the revenues of the transport company.

The vehicle tracking system can meet the expectations of different user classes. Appropriate management of dangerous goods transport [1] can help the relevant state services to meet their main obligations in the area of reducing the likelihood of disasters and preventing their consequences.

Therefore, it is natural to be interested in such systems from the industrial manufacturers of hazardous materials and their recipients. Efficient organization of transport, the possibility of preparing unloading on time, flexible response to unforeseen irregularities or threats in planned transports is important not only for security reasons, but also due to the optimal use of infrastructure and human resources.

In our country, unfortunately, there is no nationwide system that would support the activities of any interested party - state institutions involved in security and the companies themselves providing specific products. Analyzing the problem of the risk of negative manifestations in enterprises, on roads, in tunnels, parking lots, etc., it can be stated that it is clearly unresolved due to the lack of a road transport safety system of dangerous goods. Although this problem has been formulated, no system has been developed so far that would focus all aspects related to security in its entirety.

5.2 Functional requirements

The figure 3 presents the functional structure design of the road transport safety system for dangerous goods.

It is necessary [5] to carry out several tasks:

- identification of vehicle tracking and tracking systems that carry dangerous goods across the EU and beyond,
- development of general, functional and technical requirements to make the system work efficiently.
- The functional structure may contain elements such as:
- on-board devices that will be installed in vehicles will enable remote data reading,
- communication servers and their control panel,
- terminals that will include key institutions and enterprises: emergency services, emergency notification center, control services, Government Security Center, Government Emergency Management Center, transport company.

Such a system may be of great importance in the case of not only the transport of dangerous goods, but also valuable cargo or requiring special supervision for other reasons (eg strategic ones). Due to this kind of use in the user's class, they can find not only the above-mentioned institutions, but also the Customs Service, the Police, the Border Guard and security companies that specialize, for example, in the transport of money, special cargoes (eg radioactive materials).

In terms of functionality, the system [5] includes:

- locating means of transport,
- configuration of devices installed in the car,
- communication with the head office and not only,
- collecting information from the on-board device of the means of transport, sensors, meters, etc.

In connection with the above, it is important to create special monitoring systems (location, radio communication and data transmission), [11] enabling data transmission over large areas, and at the same time being a reliable source of information about the location of vehicles that are of interest to companies and institutions using system services.

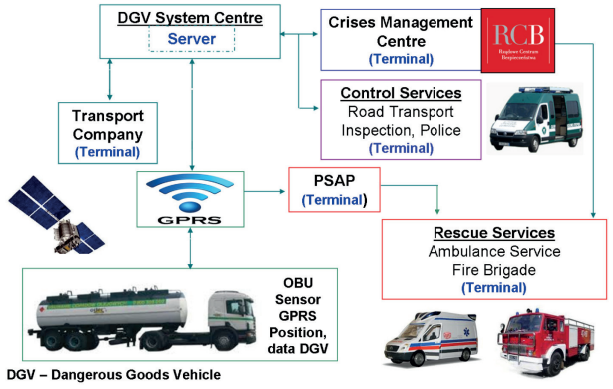

Fig. 1. Functional structure of system [own study]

To ensure effective and efficient operation, a nationwide transport base created, supporting the relevant security system operations, it is necessary to create conditions for fast data collection and exchange. Because the constantly growing transport base in Poland requires a review of existing systems and their subsequent integration.

The use of a satellite system of locations and terrestrial systems [1] is an optimal and effective way to route and ensure transport safety. It enables optimization of transport costs by reducing fuel consumption and reducing travel time. It provides access to high quality services and efficient and reliable data transmission. It contributes to maintaining the company's position as well as its development.

Carrying dangerous goods in the country, as well as outside its area and in large agglomerations, is associated with a threat to the safety of the driver and cargo. Most of the theft with cargo is carried out in the cities when delivering the product to the recipient.

The development of a functional structure that allows the continuous monitoring process throughout the country, by institutions and enterprises in real time, can facilitate not only route delineation, control of the driver, vehicle, loading and unloading.

In the created functional structure, each vehicle should be equipped with a modular location and transmission driver, thanks to which information about its location and data exchange between users will be possible at any time during transport.

The developed system and a comprehensive approach to risk will allow for the development and updating of modern standards to ensure the implementation of legal regulations concerning dangerous goods, procedures for responding to negative events. It will also enable the creation of databases on threats that occur during transport, in places that can be bypassed earlier.

There are many advantages to creating such a system. Thanks to cooperation with radio and television broadcasters and the Internet, such a system can create a wide area of information exchange, both with active and with potential road users, including pedestrians and passengers of public transport.

5.3 Technical requirements

The operation of satellite vehicle tracking systems using GPS is possible thanks to the combination of advanced satellite, telecommunications and IT technologies.

The location subsystem uses US NAVSTAR military satellite satellites [1, 4]. As of today, the accuracy of the system is about 25 m (90% of measurements), and after using the reference station the average error is about 5 m.

The data collection and processing subsystem is installed in the mobile object. His tasks include receiving satellite signals. These signals, after their processing by the microprocessor, are data in the form of geographic coordinates and the speed parameter. This information together with reports on the state of the object are sent to the monitoring station.

The data transmission subsystem uses conventional radio networks (eg PMR - Private Mobile Radio, PAMR - Public Access Mobile Radio), mobile telephony (GSM, UMTS), including packet data transmission, as well as satellite communications. This subsystem is responsible for ensuring two-way communication between the monitored facility and the monitoring center [4].

The monitoring subsystem is responsible for the continuous monitoring and management of the facility, both during its movement and when it is parked.

The monitoring station operating 24 hours a day, monitors the route of the vehicle on an ongoing basis. In the absence of current information about the location of the vehicle, it notifies the indicated and appropriate persons. If there are grounds for believing that a theft of a vehicle or load took place, e.g. after reaching an alarm monitoring station, a motion sensor installed indicating the vehicle moving without a running engine, or a driver's safety threat (panic alarm) occurred, police or other services.

Both within the country and abroad, the last known position of the vehicle is reported to the police. If the vehicle is stolen and information about the location of the vehicle continues to reach the monitoring station (which means that the vehicle equipment has not been found and destroyed by the criminal), this information is transmitted to the police on a regular basis significantly reduces the time of intervention and accelerates the vehicle and load [5, 9].

Even during a road accident or breakdown involving a truck (not only), which carries very dangerous goods, the monitoring service of carriers will significantly accelerate the crisis management process, informing the relevant emergency services, which can undoubtedly contribute to a significant reduction of catastrophic consequences.

However, it should be realized that there are communication problems, for example when the moving means of transport is in the tunnel (no GPS signals then), in urban areas with dense buildings, in bad weather conditions (hail, fog, heavy rain). In such cases, the monitoring shall take over ground communication means.

6. Results of own empirical researches

The method of a questionnaire-expert was chosen which enabled relatively fast rate of population research and ensures anonymity, thanks to which the reliability of received answers can be obtained. In the article was presented a partial result of the research that was carried out for the purposes of the doctoral dissertation. In the research, an auditorium survey was used, before which the author met directly with the respondents during a conference related to the research topic, transport companies and the mentioned state institutions. There are answers for some questions.

Question: Which elements of your opinion should be improved in road infrastructure to increase the safety of dangerous goods transport (DGT)? Please indicate up to 3 elements – Table 4.

Table 4. Elements in road infrastructure to improve the safety of DGT [own study]

The possible answers	Number of respondents	%
1. Length of motorways and expressways	53	48,6
2. Number of bypasses	69	63,3
3. Number of guarded car parks	33	30,3
4. Technical condition of roads	72	66,1
5. Road marking	26	23,9
6. ITS	24	22,0

For the above question, the most important elements that need to be improved, to be safer 66% exchanged the technical condition of roads, 63% pay attention to the number of bypasses, and 49% for the length of motorways and expressways.

In response, other respondents also mentioned several other elements that were not included in the survey: driver training, driver driving culture, secure parking lots for ADR.

The next question was to obtain information on the elements that affect the level of hazards of dangerous goods. It appears that for the lack of threat the most respondents indicated rescue (10%). Almost every third respondent stated that rescue is a low risk for the transport of dangerous goods. The respondents most frequently indicated such factors as: threat detection (39%), length of roads and motorways (40%), number of guarded car parks (44%), vehicle monitoring (45%), ITS systems (47%). The answer to the high threat is the most marked: technical condition of roads (62%).

Another question reflecting the state of road safety of dangerous goods is obtaining opinions on the largest organizational problem in the transport of dangerous goods. The respondents had only one answer to mark – Table 5.

Table 5. Elements in road infrastructure to improve the safety of DGT [own study]

The possible answers	Number of respondents	%
1. Lack of proper means of transport	11	10,2
2. Protection of loads	26	24,1
3. Regulations	8	7,4
4. Employees' incompetence	39	36,1
5. Bad work organization	15	13,9
6. Monitoring of loads	9	8,3
7. Other problems (what?)	3	2,8

In the opinion of the respondents, the most important problem in organizing the transport of dangerous goods is the incompetence of employees - 36%. Another important problem identified in the second place - 24% is the securing of loads, which in the case of transport of dangerous goods is very important for safety reasons. The incompetence of employees can be read more widely in the recent reports of the Supreme Audit Office, which in a rather negative way indicate this problem.

In response, other opinions were given, such as: no one controls drivers, road infrastructure, beltways, auto equipment with additional lights and sounds.

Other factors that affect the level of security are state services and their activities. Do you think that cooperation between institutions dealing with the safety of transporting dangerous goods is correct? Please choose one answer– Table 6.

Table 6. Cooperation between institutions dealing with the safety [own study]

The possible answers	Number of respondents	%
1. It is very good	1	0,9
2. It is rather good	62	56,9
3. It is rather bad	19	17,4
4. It is bad	3	2,8
5. I do not know, it's hard to say	24	22,0

As a result of the next question, it turned out that nearly 57% of the 110 respondents claim that the cooperation between the institutions is rather good. In spite of this, the anxiety should be aroused by the fact that only 1% of respondents say that cooperation between the servants is very good. On the other hand, over 20% of the respondents had no opinion, which may be the result of uncertainty in choosing the right answer.

Table 7 presents results regarding the operation of emergency services in Poland. How do you think the emergency services in Poland react during a dangerous incident involving the transport of dangerous goods? Please choose one answer.

Table 7. Results regarding the operation of emergency services in Poland [own study]

The possible answers	Number of respondents	%
1. very good (professionally)	22	20,2
2. rather good	63	57,8
3. rather bad	10	9,2
4. very bad (unprofessional)	1	0,9
5. I do not know, it's hard to say	13	11,9

Respondents gave a very positive opinion on the quality of emergency services in Poland. Nearly 80% of respondents believe that the response of services to incidents related to hazardous materials is good or very good. Over 10% of people did not have an opinion on this topic.

To find out what could be improved to increase the level of safety in the transport of dangerous goods was asked about the actions to be taken to minimize the risk of occurrence of hazards.

The next question: What actions would improve the safety of transporting dangerous goods? Please choose one answer - Table 8.

Table 8. Results regarding the operation of emergency services in Poland [own study]

The possible answers	Number of respondents	%
1. New procedures	7	6,4
2. Continuous improvement of employees' competences	79	72,5
3. Monitoring dangerous goods	15	13,8
4. Technological innovations	8	7,3
5. Other, what? *	-	-

In the question (Table 8), the dominated answer was the improvement of employees' competences, which was answered by as much as 72.5%. As you can see (also taking into account previous questions, to which the respondents also pointed to problems with staff) the study has a very big problem with employees' competences, which should come as a surprise, because people employed in this area should be properly trained and have a conscious knowledge about it .

The last question: What effects can be brought by the road transport system for dangerous goods that enables real-time monitoring. Please select any number of answers - Table 9.

In the question (table 9), the dominated answer was the improving transport safety, which was answered by as much as 64.25%, the second – traceability (50,5%), the third - the right route selection / route updating (47.1%).

Table 9. The effects refers to real-time monitoring [own study]

The possible answers	Number of respondents	%
Improving transport safety	70	64,2
Traceability	55	50,5
The right route selection / route updating	52	47,1
Detection of threats	46	42,2
Improvement of cooperation between carriers and emergency services	45	41,3
The quality of transport tasks	29	26,6
Effective and fast communication between the company and the driver	27	24,8
Selection of parking spaces	27	24,8
Other, what? *	1	0,9

7. Conclusion

The carriage of dangerous goods by road is a complex process, which is why many sectors are responsible for its implementation: minister competent for transport, Minister of National Defense, minister competent for economy, minister competent for health.

Carriage of dangerous goods by road creates a high risk of breakdowns or accidents that cause fire, chemical, ecological or radioactive hazards. Consequently, it can cause terrible consequences for society as well as for the economic development of the country.

EU Member States should set out priority actions to eliminate threats, involving means of transport of goods threatening the public.

In addition, it should be noted that there is no monitoring system in Poland to control the movement of dangerous goods by road in real time.

The use of GPS and GSM technology, supported by a specialized software package, gives the possibility of locating vehicles in Poland and throughout Europe.

The development of monitoring system of dangerous goods can improve people's safety and environment, the development of appropriate logistic methods can minimize the losses and costs of enterprises improving the exchange of information between the centres of production, transport, collection and rescue, that can be used in the area of transport safety.

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