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Issues of Hazardous Materials Transport and Possibilities of Safety Measures in the Concept of Smart Cities

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Abstract

The transportation of goods and supplies is an essential part of maintaining a functioning urban infrastructure. It also involves the transport of dangerous goods. This type of transportation may especially in the urban areas signify a high risk that may significantly damage the critical infrastructure of the city if there is an accident and leakage of dangerous chemical substances. The aim is, therefore, to minimize the risk and its consequences. The effective instruments are through the identification, analysis and assessment of these risks, searching for critical areas in cities and ensuring the application of prevention and safety measures. Application of risk analysis methods helps to identify the expected and probable risks that can significantly influence the safety of the critical infrastructure. On the other hand, risk analysis methods which can also identify unknown risks with low probability of occurrence are currently being developed. The paper introduces a methodology of assessment of transport risk in cities focusing on reducing the impact of hazard in cities. The risk analysis methods and approaches are subsequently proposed as the initial stage of implementing the selected safety measures. This paper aims to introduce the issue of risks associated with transportation of hazardous substances in cities and to propose measures that are in accordance with the concept of Smart Cities, in order to contribute to the creation of a functional communication network, traffic flow in cities and increasing the security of critical infrastructure.

Keywords: road accident, hazardous substances, risk, human health, environment, impact, smart measure.

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1. Introduction

One of the aims of ensuring a functional critical infrastructure is its safety. However, it can be endangered by a range of risk factors (disruption to the traffic, to electricity supply etc.). One of the key components of infrastructure is traffic, whose disruption may have an impact on the functioning of the entire society. Therefore, it is necessary to be aware of the threats and risks, their assessment, the proposal and implementation of the preventive measures leading to the minimization of these negative phenomena. On the other hand, these measures also help to enhance the ability to respond to undesirable events in time, before the

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occurrence of serious damage. The paper introduces the issue of risks arising from traffic focusing on the transportation of hazardous objects in cities, the possibilities of their identification, and analyses including the proposal of measures in accordance with the concept of Smart Cities.

Currently, the issue of Smart Cities is the area that requires the attention of many developed countries and in particular their cities. With respect to the mission of Smart Cities the emphasis is on creating an environment that uses different flows and interactions in cities (finance, energy, materials, services, etc.). These processes are becoming smart by the strategic use of information and communication infrastructures and services in the process of the transparent land use planning and management, responsive to the social and economic needs [1].

Implementing the concept of Smart Cities should thus be based on strategic planning. One of the current areas is intelligent, ecological, safe and integrated transport. There are currently many projects that are focused on, for example, reducing transport emissions that are in particular associated with the transit traffic in cities [3]. The most serious problem of transport is the contamination of air by the emissions, mainly due to their significant risk to human health, in particular in large cities with a high density of automobile traffic [5]. In recent years, the share of transport in air pollution has been significantly increasing, which leads to the increase in health risks associated with the exposure of humans to these pollutants [6, 7]. One of the completely new groups of substances flowing in this way into the environment is the platinum group of metals (platinum, palladium, rhodium and ruthenium less commonly iridium), which are part of automotive catalysts [8]. In addition to these negative phenomena, there may also be potential risks posed by the transportation of hazardous substances, which is not an isolated case in cities. This risk is only solved marginally within the Smart Cities. Considering the possible risk it deserves more attention, especially in relation to the protection of critical infrastructure, population and the ability to respond faster and more effectively to the resulting undesirable event.

2. Transport of Hazardous Substances

Hazardous chemical substances and mixtures are substances which exhibit one or more dangerous properties in terms of possible damage to people’s health or lives, to the environment etc. Road transport of dangerous things, which also includes transport of HCS, is dealt with in the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) [17]. Transportation of hazardous substances comprises about 4 - 8% of the total goods transportation in EU countries. More than 50% of the contents transported are flammable liquids, mostly in the form of propellant fuel. The second most frequently transported substances are condensed gases under pressure. In some of the European countries the amount of the volume transported in 2013 increased by nearly 100% (Estonia, Luxemburg, Great Britain) [9]. The risk of the occurrence of a serious road accident is real in spite of the application of safety and preventive measures, which should aim to minimize this risk. One of the reasons is the increasing variety of the transported hazardous substances [10, 11].

Hazardous chemicals are not only important for their negative properties but also their other properties, which are used for various activities within the functions of cities, which makes their supply so essential. Relevant examples are fuels, gaseous and liquid substances used for disinfection or cooling.

Currently, the only available summary is the statistics of accidents with leakage of hazardous substances in each country and their regions. These statistics, however, do not contain separate data about accidents of the ADR vehicle or vehicles carrying sub-limit volumes in cities. The absence of monitoring the activity of these vehicles in cities becomes a risk which may have a significant influence and impact on urban critical infrastructure and its functionality if it occurs.

The importance of the need to reduce the risk of this type of transportation is demonstrated by the experience of the past years (see Tab. 1), where there have been accidents of vehicles carrying dangerous substances in cities or urban track, which caused serious damage. In this context it should be noted that these failures have had more serious consequences in urban areas than in rural areas. The evacuation of people can significantly impair the function of the affected cities and disrupt the infrastructure.

The accidents may occur particularly in the mobile phase or during loading tasks. In both cases, the level of risk increases with regard to the venue and nature of the event (a dangerous substance was initiated - an explosion, fire, toxicity) [10].

Table 1 Overview of significant hazardous chemical substances accidents [11, 12, 13, 14, 15]

Event	Scenario	Damages
11. 7. 1978, Los Alfaques, Spain	The explosion of a truck with propylene near the camp Los Alfaques in the village of San Carlos de la Rápita	216 dead, 200 injuries
10. 11. 1979, Mississauga, Canada	The train explosion and leakage of chlorine in populated areas	Evacuation of 200 000 inhabitants
4. 8. 1981, Montanas, Mexico	The chlorine leak after truck accident	28 dead, 1000 intoxicated, 5000 evacuated
2. 5. 2011, Pilsen, Czech Republic	The fire and explosion pressure cylinders after the accident of 2086 kg of acetylene gas, 50 kg of CO_2, 240 kg of R-404A, 132 kg of R-407C, 144 kg of R-437A 66 kg R - 417A 66 kg of R-422D 72 kg R - 134A	No injuries. Serious property damage.

Event	Scenario	Damages
7. 5. 2013, Mexico City a City of Pachua, Mexico	The explosion of a tank with methane	22 dead, 36 injured, property damage: 30 houses, 20 vehicles
6. 7. 2013, Lac-Mégantic, Canada	The explosion of a freight train with crude oil	42 dead, property damage

Hazardous chemicals have become part of our lives to the extent that it is impossible to imagine a modern society where they are not used. Increasing their number as well as the amount of the chemicals transported and used combined with stricter safety requirements leads to the study of the risks arising from the use of these substances, and to the emergence of a series of measures to increase security. This is then reflected for example in legislation or the requirements for emergency preparedness. Most of the legislative instruments are focused on static sources, which are for example the production and storage of fuel. The emergency plans for the stationary installations are prepared as part of an integrated emergency system, they are under regular review and the situation is constantly monitored. But there is an absence of such measures in connection with the transportation of dangerous goods.

3. Risk of Dangerous Goods Transport in Cities

Risk identification, analysis and assessment are significant stages in the attempt to eliminate it. In general, risk is defined as the probability of an undesirable event occurrence together with often negative consequences [47]. In more detail, risk is described using three main components, which is the probability of an undesirable event occurrence, the vulnerability of the environment in relation to the impact of the undesirable event and finally also the hazard impact itself, whose extent is variable [29]. Urban housing estates not only differ in terms of architecture but also in terms of population density, buildings using hazardous chemical substances etc. That is why the level of risk is also variable in this respect and it stresses the significance of risk analysis application, on which preventive, repressive and corrective measures are based.

3.1 Critical Areas in Cities

Especially vulnerable are the urban areas where there are high numbers of people, whether permanently (city centres, businesses, transfer station hubs, hospitals, schools, etc.) or temporarily (e.g. traffic congestion on the centre circuits and in the city centres). Critical places of transport networks can be based on criteria such as: the importance of the road section and the possibility to replace it, the demand for returning the section back into operation, the importance of the section linking a significant portion of urban agglomerations or strategic places, traffic intensity, capacity segment, other risks which threaten the segment [16].

The following are the most frequent causes of road accidents of vehicles transporting goods in the ADR mode according to [1,2]:

- not keeping safe distance,
- not giving way and breaking the traffic rules,
- an obstacle on the road,
- not respecting safety barriers,
- an accident caused by another vehicle,
- not adapting the driving style to the situation (traffic density, meteorological conditions etc.).

The above mentioned causes of ADR road accidents are also the most frequent causes of accidents of common personal vehicles and lorries. This increases the risk of accident occurrence which may involve a vehicle transporting HCS.

Currently, the movement of dangerous goods by road is coordinated in Czech Republic only through safety signs (B18, B19) according to the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) [17]. Each country implements the ADR Agreement into its national legislation. An example is the Regulation on the national and international transport of dangerous goods by road, railroad and inland waters (GGVSEB) in Germany [43]. This regulation especially concerns motorway transport. Outside built-up areas, roads with more lanes and the shortest routes must be used. In a built-up area, a bypass should always be used. In Germany and Austria, there are also legal measures ensuring the restriction of hazardous chemical substances transport through road tunnels [44]. In the Czech Republic the movement of these vehicles is limited by prohibition traffic signs especially before some road tunnels where the risk is especially high if an accident occurs. Critical points are particularly important transportation constructions, such as bridges, tunnels, intersections. By early identification of these critical points the level of risk can be reduced by using prevention and safety measures. Such measures could be, for example, CCTV monitoring sites, prohibiting signs for vehicles carrying dangerous substances or providing short arrival times of rescue. One of the effective tools is the application of risk analysis methods and support software tools that can identify, analyse and evaluate the risk, including the modelling of dangerous scenarios development of the situation [10].

3.2 Approaches to Assessing the Risks of Dangerous Goods Transportation

The identification and assessment of the risks of damage requires a comprehensive system approach, both in terms of acute and chronic risk. While the acute risk effects show immediately, especially at the accident location, identification of the chronic risk effects is a complex and time-consuming process [10]. These risks can manifest themselves, for example in the form of chronic disease on the affected population in the form of respiratory diseases, for example, or the deterioration of environmental quality [5].

First it is necessary to define the area to be evaluated as well as the problem situation and the phase during which the leak occurred:

- mobile phase (transportation by road, compulsory safety breaks, checks by state authorities),
- loading tasks (loading, unloading, cleaning the shipping containers etc.).

In road accidents involving vehicles transporting HCS, there is not only a risk of leakage of a large amount of the transported substance but also a risk of fuel leakage. The volume of fuel in fuel tanks ranges from 200 to 1.200 litres depending on the size and the current condition of the vehicle. Although this is an under limit amount of HCS, which is not included in transport according to the ADR international agreement, it may also have a significant impact [2].

Besides the hazardous substances, the extent of an accident is also significantly influenced by external and internal factors [38] whose character varies with each transport phase (climatic conditions, technical condition of the vehicle, the vulnerability of the environment, health and mental condition of the driver etc.) as shown in Figure 1. The example shows the basic factors which can cause an accident either separately or together. With regard to the individual scenario of each road accident or an accident involving leakage of hazardous chemical substances, the probability data are not given for each factor. It is necessary to mention the fact that, with regard to the causes of road accidents mentioned above, it is the human factor which has a significant impact and it is not only the driver of the vehicle transporting hazardous chemical substances but also other road users. It must also be noted that the selection of logic gates may vary regarding the specific hazard scenario. The fault tree (FTA) shown below in Fig. 1 is therefore illustrative and demonstrates one of the possible scenarios. It is, therefore, necessary to define all the aspects of the transport of dangerous chemicals that may be significant risks for the examined process.

A significant part is also the definition of the critical infrastructure vulnerability, which plays a very important role in risk analysis and damage prediction. Vulnerability is an important element in the issue of critical infrastructure and its protection, which is also related to transport of HCS. Vulnerability expresses the extent to which a system is able to resist adverse effects and, on the contrary, when the ongoing processes and their full functionality are disrupted.

According to [29, 30, 31], it is important to distinguish between risk and vulnerability, which is related to loss potential in connection with an accident, destroying, damaging or disrupting a system and its processes. On the contrary, risk is expressed by the degree of probability of an undesirable event occurrence and by the consequences which may be expected within this event.

The risk of an accident occurrence involving leakage of HCS significantly lowers the limit to which the whole system (town or village) is able to resist adverse effects. The reason is a high number of residents found in one place at the same time, also the absence of identifying and monitoring the activity of dangerous mobile units in cities, numerous built-up areas, one way streets, heavy traffic without the possibility of providing proper detours when a dangerous event occurs etc. This is also related to the common problem of the time interval of rescue units, which operate in difficult conditions especially in traffic congestions in the morning and afternoon hours.

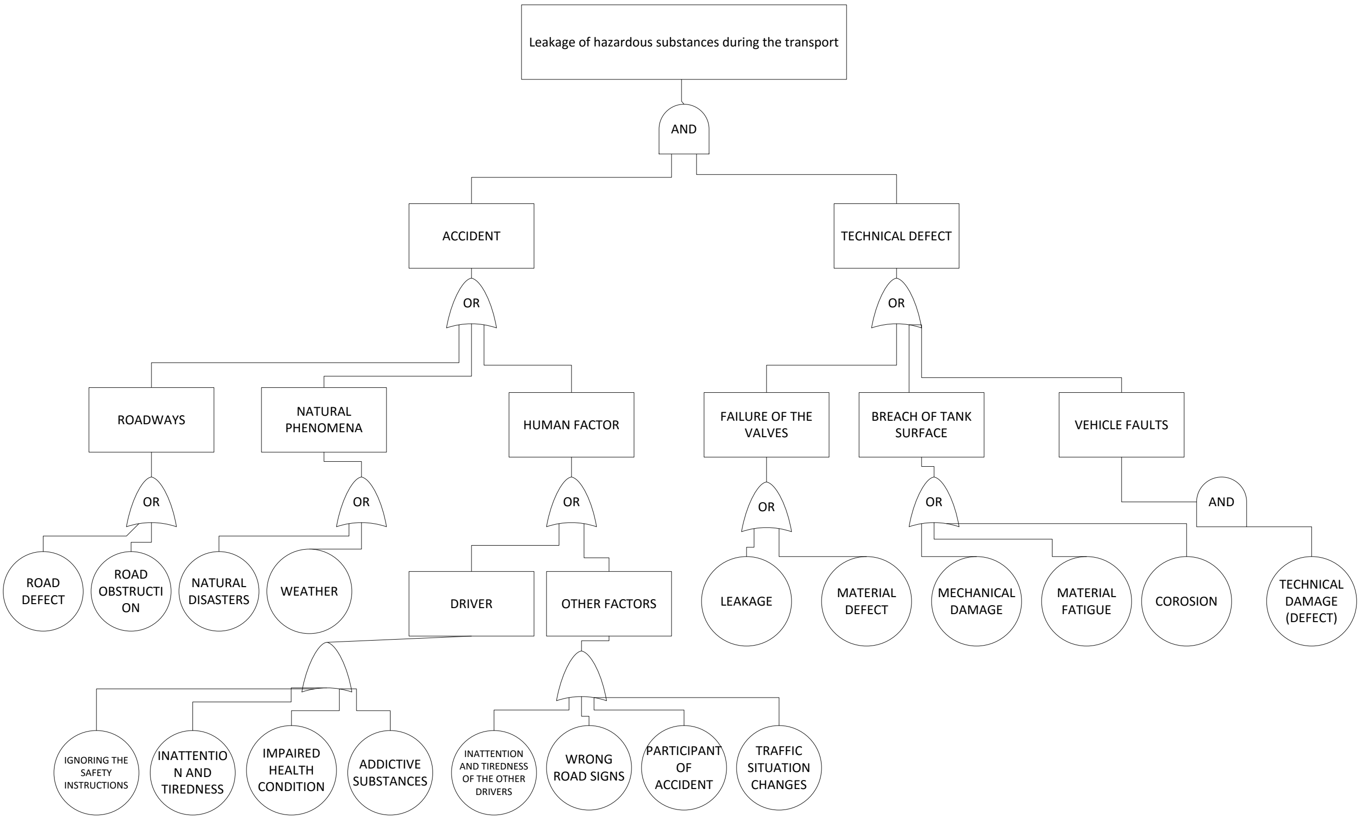

Figure 1 FTA diagram of hazardous materials release during road transport [10]

3.3 Application of Risk Analysis Methods to Identify Risks in Urban Areas

In risk analysis, decisions are made based on the probability estimation (P) of an undesirable event occurrence and its consequences (C) [18, 47]. Deciding about the risk means estimating the probability of its occurrence and the probability of the hazard scenario happening [19]. Risk analysis of transportation of hazardous substances by road, not only in cities, is a very complex problem as for the selection of a suitable methodology. The aim of the analysis is to obtain relevant information describing the identified risks and their importance for the given area. Therefore, it is important to use a combination of methods based on a qualitative, semi-quantitative and quantitative approach. In the first phase of a qualitative approach the process assessed is defined including its components which are related and influence each other. Applying this approach can even detect so-called hidden processes, which may occur in connection with the transport of dangerous substances [9]. The application of methods which are based on a semi-quantitative approach using a numerical scale helps to determine the level of risk. It becomes an intermediate stage of risk assessment and their categorization and the assessment of events related to each other [19].

The quantitative approach allows modelling of the consequences of hazardous substance leakage in specified areas using precise numerical data. In the case of hazardous substance transportation, the scenarios may include fluid leak followed by evaporation, gas leak with immediate dispersion into the atmosphere, flammable liquids with immediate or subsequent initiation. In general, quantitative approaches numerically evaluate the frequency of undesirable manifestation of the risk sources and their consequences. Since the risk analysis methods cannot be used individually for all the transportation phases, the particularly suitable methods are those that are based on a multi-criteria approach using map data and information on where the incident occurred or may occur. Some analytical instruments may have a software form and can be connected to an electronic database of chemicals [18, 19].

Risk identification should never be underestimated and the occurrence of phenomena which lie beyond the boundary of common expectations (so called black swans) should also be considered. These events are often considered highly improbable as such events have not occurred before, for example in connection with a particular subject and it is therefore not possible to deduce that this situation will occur. It is the current situation, in which the activity of dangerous substances in a city is not monitored, which means a hidden threat with very serious consequences. These threats do not include only accidents of vehicles transporting HCS. It is also necessary to realize the risk of a possible abuse by terrorist or other radical groups. In transport of HCS, it might be about a deliberate disregard of risk considering the low frequency of these accidents. It could also be a kind of a black swan, the so called unknown known, when the risk significance and its possible fatal impact are realized especially by a group intending to abuse these ADR vehicles.

Although it is not easy to predict precisely the occurrence and extent of the impact of events (e.g. black swan), it is important to ensure that sufficient functional background work is undertaken, which is based on the creation of a communication network and on the preparedness to respond immediately with primary and secondary measures with regard to the safety of the human society. It should also include an adequate analysis and assessment of undesirable events with the objective approach, which includes external experiences and the assessment [20, 21].

Within risk analysis and identification, a solution area has been proposed in accordance with the above mentioned procedure. In this case, it is the cities or particularly the urban roads which can be used by vehicles transporting HCS. Regarding the high number of various municipality features, the general character of a city with vulnerable elements of critical infrastructure such as bridges, tunnels, roads and the related places like public transport hubs, built-up areas etc. has been considered.

4. Proposal for the Introduction of Smart risk Minimization Measures

Currently, there are camera systems monitoring the traffic in most towns. Some of them are able to identify a vehicle based on its licence plate. It is especially carriers who use other smart systems – locators – which are linked to an electronic logbook. These locators are equipped with a device based on the Global Position System (GPS) and they can provide information about the current location of a vehicle including a real time display in a map with the update interval of approx. 30 seconds. Daily ride overviews allowing for displaying routs in 3D maps are recorded in logbooks. However, these locators are mainly used by private companies and organizations and therefore it is not possible to obtain this data easily and use it for processing statistical data and for marking dangerous routes.

With regard to the possible use of safety measures in cities, it is necessary to introduce smart systems that identify the moving city traffic unit, warn drivers of ADR vehicles about the route for transportation, communicate with the emergency services and warn other drivers and residents in time in the event of an accident. Monitoring of vehicles transporting hazardous chemical substances has been implemented for example in Germany, where it is a voluntary measure though especially for private carriers. What is widely used here is for example the RFID system from 2011 [39] or the Tracking and Tracing application for private transportation companies, whose data are not publicly available. In 2011, the SaveNav project was also launched, which works with smart warning signs called OrangeBox. These signs automatically detect a road accident of a vehicle carrying dangerous material and they automatically report the location and some other important information to an emergency center [40, 4]. Other projects focusing on monitoring the movement of dangerous material include the BlueBox project with the display in map data. The situation in Austria is very similar to that in other EU countries. Even here there is no legal obligation to monitor the movement of vehicles carrying dangerous material. What is working here, however, is the monitoring of vehicles in the ADR mode in tunnels, which uses telematic systems. In the Alpine regions, it is also Germany and Italy who cooperate in the monitoring [44]. The Czech Republic is also considering the monitoring of vehicles in the ADR mode. However, the carriers are afraid of losing sensitive data [45]. Some projects concerning the monitoring and identification of vehicles carrying dangerous material were created for the purposes of emergency services which can prevent some other serious consequences of accidents by an early intervention. One of these in Europe is the MITRA project [46]. In the Czech Republic there are also companies in the chemical industry cooperating with the integrated rescue system and the carriers using the TRINS system [47]. The above mentioned examples of project results focus on an overall monitoring of vehicles in the ADR mode following their routes, which also means outside cities, and using the GPS signals. Unfortunately, these measures are not legally obligatory and that is why we cannot rely on the carriers to use them also due to their mistrust in the safety of sensitive data mentioned. However, for the purposes of increasing the safety of critical infrastructure in cities, it is also possible to use the existing systems which have been implemented to monitor regular traffic.

One of the measures proposed is the identification and monitoring of the ADR vehicles that are arriving in the city or moving around the city. What can be used is the existing CCTV system, which is already widely used in most cities. Given that these types of vehicles in cities are moving mostly in order to supply, the carrier or the recipient could report the planned entry of vehicles into the city and their predicted route. The Integrated Rescue System should be able to monitor vehicle movement and communicate with it in order to prevent undesirable events (e.g. the information about the closures, traffic congestion). Another option is automatic vehicle identification by the ADR marking, which is already used for license plates of vehicles [22]. The necessary need for the monitoring of the movement of vehicles transporting hazardous substances has been proved by research projects carried out in Europe and worldwide [23, 24, 25]. Applying these measures may be important not only in the area of prevention.

In cases where there is a leakage of dangerous substances, it is necessary to avoid movement in the so-called danger zone in which the substance is spread. In this case, it is necessary to transfer early information to drivers through dynamic information panels informing about the incident in the danger zone and allow other drivers to choose alternative routes. These measures are already often used for example in road tunnels, where the drivers must be informed immediately about the situation if a dangerous event occurs and a safe evacuation of persons present in the tunnel must be ensured. [27]. The timely information through visual communication mediated by these panels can prevent the traffic collapse and enables the rescue services to get to the crash site and to the injured persons. Dynamic information panels would be appropriate to supplement a warning light signalling for the cases of an undesirable situation. As study [26] shows, implementing these signs is important for increasing safety not only in the case of an accident but also for prevention and in informing the driver about a possible risk. When these measures are implemented, it is possible to monitor the average activity of HCS in cities, their intensity and possibly also the kind of substance. Based on this data it is possible to produce statistics and their evaluation allowing for identification of areas in cities where there is the highest incidence of these mobile sources of risk. As a consequence, safety measures can be adjusted in accordance with the requirements.

4.1 SWOT Analysis of the Proposed Measures

Considering the complexity of some operations needed for the possible implementation of these measures into the Smart Cities system, a SWOT analysis was carried out (see Table 2, 3). The aim of the SWAT analysis was to identify the individual aspects of the measure from the point of view of internal and external aspects, which may have a significant influence on the decision concerning their integration. Within the method, classification and evaluation were divided into 4 basic groups where the mutual interactions of strong factors (S) and weak factors (W) with opportunities (O) and threats (T) were compared. The qualitative information obtained helped to define and evaluate the level of their mutual clash.

Defining the individual factors in the groups was preceded by an analysis of the current state, which was briefly introduced in the chapters above. It was necessary to define the areas which these measures would apply to. The first part dealt with the legislative and legal form so that the monitoring could be implemented in cities as the measures are currently not enforced on the national, regional or local level. In this case, it is important to formulate a proposal for the measure implementation so that it is in accordance with the current legislation on all levels. Therefore, it is not only about cooperation between the state, the regional offices and the municipalities but also cooperation with carriers. These legislative measures should consider the ability to ensure prevention and safety from the point of view of mobile sources, which is currently not dealt with properly except for the ADR regulation. It is a complicated step, which may, nevertheless, significantly contribute to the protection of critical infrastructure from the perspective of legal tools.

Another discussed area is the assessment of technical equipment using the technical elements that have already been implemented or the need for new equipment. The assessment has been based on the obtained data on the technical possibilities of passing on dynamic information and early warning of drivers. The financial demands have also been considered in the case of implementing a completely new system in towns. The ability of the proposed measures to increase effective communication in the case of an accident has been assessed. The measures have also been assessed from the perspective of the integrated rescue system. The first measure assessed by the SWAT analysis is shown in Table 2, which focuses on monitoring vehicles transporting HCS and thus also its ability to identify and analyse a potential source of danger. Table 3 specifies the key factors for the provision of dynamic information panels and signs in cities aiming to make communication easier not only with the drivers.

Table 2 SWOT Analysis of the ADR Vehicles Monitoring in Cities

STRENGHTS	WEAKNESSES
• automatic ADR vehicles identification • awareness of ADR vehicles movement • ability to respond rapidly to adverse situation • use of existing camera systems (CCTV) location and communication with the drivers of the ADR vehicles • exact location of potentially dangerous goods	• obsolete camera systems (CCTV) • small CCTV coverage • CCTV coverage without automatic identification of the ADR signs • the new system price • absence of the equipment for communication with the driver of the ADR vehicle • absence of solutions in the current legislation
OPPORTUNITIES	**THREATS**
• increase of safety and security • improvement of the drivers (ADR vehicles) and the integrated rescue system communication • providing better traffic flow • improvement of prevention measures • the annual statistical	• ADR vehicles without signs • deliberately poorly labelled ADR vehicles • illegible signs for vehicles • unreported transport in the city • poor communication by the carrier and recipient • disagreement with the

reports for the evaluation of the critical points • introductions of these measures into legislation	Czech and European Union legislation

Then, five or six key points of the internal and external factors were selected based on the SWOT analysis. Monitoring ADR vehicles in cities is one of the measures for which the existing CCTV systems, implemented mainly in big cities, can be used. The strong point in this case is the possibility of automatic identification, which warns about the activity of moving mobile sources of risk in towns. What is also an advantage is the possibility of communication with the driver of an ADR vehicle and allowing him to change the rout if there is an obstacle such as an accident etc. The main advantage could be the possibility of a quick response to the occurrence of an undesirable event. What could become the weak point in this case is an obsolete camera system which is not capable of automatic identification. Another weak point of these measures could be a considerable financial burden on towns when implementing these new camera systems. On the other hand, it is an important safety measure allowing for a significant reduction in losses in accidents or other unfavourable events. What is a threat are vehicles that are not marked because of transport of a very small amount or an intentional substitution of the marking, which happens mainly due to the conditions of transport requirements. If there is an accident involving unmarked or badly marked HCS, the risk considerably increases. An especially important opportunity in this case is to improve communication among carriers in ADR and rescue services in order to increase safety and security, and to prevent accidents with spills of hazardous substances and ensuring traffic flow.

Table 3 SWOT Analysis of the Dynamic Information Panels in Cities

STRENGHTS	**W**EAKNESSES
• rapid transfer of the information • ability of the rescue services and drivers to respond rapidly to the undesirable situation • communication with drivers and persons around • using and supplementation of the current dynamic information panels • ensuring the traffic continuity in the case of an accident and information about alternative routes	• the new system price • the choice of a uniform style of information for drivers and other persons • obsolete system that does not allow connections to GSM emergency services • selection of specific locations for the placement • depending upon a source of energy
OPPORTUNITIES	**T**HREATS
• increase of safety and security and accident prevention • improvement of the drivers (ADR vehicles) and the rescue services communication • ensuring a better traffic flow not only in the case of an accident • utilization of the information panels not only after the accident cases • the renewable energy use (alternative or additional source of energy for information panels)	• accident in location without information panels • unreadable information • failure of energy resources • broken communication system • delay of the information transmission

Another analysed measure is the use of the dynamic information panels, which are now commonly used for highways or city circuits. That is why this system has also been chosen as a suitable device for communication with drivers. A strong point of this measure is the possibility of a rapid transfer of information on an undesirable situation. This is especially true if the dynamic traffic panels are placed where the vulnerable elements are and they can therefore become an effective information and communication device. These measures can also serve as suitable measures for ensuring the traffic fluency if there is a major accident involving a leakage of HCS and for preventing the movement of persons in a dangerous zone. The weak point is the difficulty in selecting suitable locations for the placement of these information panels. That is why it is important to identify the high-risk areas first and to assess the necessary amount and layout along roads. To ensure fast communication with drivers, a suitable marking of an alternative route is necessary as well as its comprehensible presentation, the choice of language etc. That is why an inappropriate choice of information and its formulation may become a weak point. Although these types of panels are equipped with light signs with a relatively long lifetime period, it is necessary to appoint a person who will be responsible and to set the dates of regular checks on the functionality of the dynamic panels to prevent non-functionality of the information or its part. The threat is therefore in this context particularly an accident in an area without the information panels and movement of people in the danger zone. Like the previous measure, this one also provides an increase in safety and prevention ensuring the traffic flow and a reduction or complete averting of the undesirable impact in the case of an accident. The possibility of ensuring substitute or additional power sources to prevent any malfunction of the system due to power failure is also important. Currently, the variable information panels and traffic signs are equipped with LED diodes as they do not require a lot of power supply. This measure could become effective in this case, especially if there is a loss of energy resources. The variable information panels could support the weakening of the power supply or possibly become an alternative energy source for a certain period of time

Discussion

The risk related to hazardous chemical substances depends on the type and the dangerous properties of these substances such as toxicity, explosiveness, flammability etc. There are also other factors that have a significant influence such as the amount of the leaked substance, the presence of initiation sources, the character of the surroundings where the leakage occurred, the number of persons present in the vicinity of the accident etc. [10]. While the toxicity of the leaking hazardous substances has a significant impact on the residents and on the environment, both acute and chronic, it is especially the explosive and flammable substances that are significant for the overall functionality of the critical infrastructure in cities [13]. These may have, after their initiation, destructive effects not only on a human being but also on property and public urban facilities [12]. Therefore, there is an important question of whether vehicles in the ADR mode can pass through cities without limitation and whether there is a need for special safety measures for some vehicles with regard to the level of risk and the environment vulnerability.

Currently, there are more options of monitoring vehicles including the projects mentioned above [39 – 42, 46], which deal with the monitoring of vehicles using the GPS signal. However, these are often devices intended for private carriers and in some cases the information is not provided to the emergency services, which may influence the development and seriousness of an accident. What can be used are the monitoring systems that are a common part of the technical equipment in cities and towns such as the CCTV. This is a vehicle monitoring system based on identification of signs such as the licence plate or the ADR vehicles marking (the UN code and the Kemler code) [32, 33] and it works on the principle of converting digital images into electronic text [34, 35]. The reasons of an insufficient identification of a vehicle marking are bad lighting conditions, illegible marking due to staining or because there is another object or vehicle covering it [36 - 38]. Identification by the licence plate is suitable for vehicles transporting a sub-limit amount of hazardous substances. Considering the number of vehicles in the ADR mode and the number of haulage and similar companies, it seems more suitable to identify vehicles by their special marking, which some software is already able to identify [34, 35]. As there are camera systems widely used in cities and towns, the costs are not expected to be as high as for a completely new monitoring system. What remains a problem is the absence of a legal obligation to monitor vehicles transporting hazardous material not only in cities but in all of the EU territory and other places in the world [41, 42]. Making this a legal obligation is a matter of a long-term process and it is necessary to notify the state and governing bodies not only in individual countries of the threats posed by insufficient monitoring of hazardous material.

The need for legal securing of the other measure (dynamic information panels) is not such a significant problem. Applying these measures is a common safety and preventive element in road traffic. Its adjustment to accidents involving ADR vehicles does not require complicated modification to be functional and implementable. The important thing here is their placement in pre-selected critical locations in cities, where the level of risk is particularly high and an accident may have serious negative consequences. That is why it is important to apply a detailed risk analysis including assessment and determination of the seriousness of various hazard scenarios and the risks arising from them as the paper explains.

Applying risk analysis and using the proposed measures based on its results should lead to a reduction in hazard thus eliminating the risk. They are especially preventive measures offering alternative uses of the existing safety features to ensure a correct functionality of the infrastructure required by the Smart Cities standards.

Conclusion

The possibilities of implementing the Smart Cities concept are very wide and it is a long process. The paper points out the issue of the hazardous substances transport in cities which is currently not dealt with enough. It is an essential part of maintaining their functional infrastructure. Despite the low probability of a traffic accident and leakage of hazardous substances the significance of their impact is very high. To ensure prevention and improvement of safety the important part of communication is not only with carriers in ADR, but also with other drivers and people who are moving at the place of an accident. Therefore, a good knowledge of the transport infrastructure in cities including critical locations is necessary. This paper, therefore, introduces the basic methodology approach to risk identification and analysis. It proposes measures that can be incorporated into the already functional systems in cities and can be used not only for the purpose of transporting hazardous substances in cities which have been assessed by the elementary SWOT analysis. In the analysis 5 - 6 key factors were selected that can positively or negatively affect the whole process. The important opportunity is not only to improve the communication network between drivers and emergency services but also the possibilities of using so-called green energy, which can be used in both of the proposed measures. The aim of this paper was mainly to highlight the current situation and the need to ensure the activities in this area. Detailed procedures for removing the weaknesses and threats will be the subject of further solutions and research.

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