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REVIEW ARTICLE

The impact of accidents during the transport of dangerous good, on people, the environment, and infrastructure and measures for their reduction: a review

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Abstract
Road transport is one of the most dangerous methods of goods transport. Driver errors and poor traffic conditions can cause traffic accidents, which can have a negative impact on people's health, the environment, and infrastructure. The main influence on the level of the consequences is the chemical composition and amount of the transported substance. This paper presents the causes of traffic accidents during the transport of dangerous goods. In addition, how traffic accidents during the transport of dangerous goods affect people's health, the environment, and infrastructure was shown. After that, measures for accidents avoidance and the alleviation and reduction of dangerous goods were given. From the review of studies from the subject field, it can be concluded that the dangerous goods are very harmful to people, the environment, and infrastructure when transport accidents occur. Lessons should be learned from the history of accidents involving the transport of dangerous goods to avoid repeating the same mistakes. The review conclusions indicate that a routes optimization and investment in road infrastructure are needed to reduce risk during the transport of dangerous goods.

Keywords The transport of dangerous goods · People health · Preservation of the environment · Safety

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Introduction

Road transport is a usual way for to transport dangerous goods (Holeczek 2019), such as the transport of fuels for vehicles, but also transport of many other substances used in industry. Statistical data show that more than one billion tonnes of dangerous goods are transported yearly by road transport (Liu et al. 2020), and this amount rises annually (Laarabi et al. 2014). Figure 1 shows the amount of dangerous goods transported, divided by classes for the EU-27, during 2020 (Anon 2022), and it can be noticed that the transport of liquid flammable substances occurs most often. The vehicles used for the transport of dangerous goods can be considered as a mobile source of danger. Because of this, the manufacturer, receiver, government and services for urgent interventions, and even civilians, who live near the transport routes where the dangerous substance is transported, have different interests (Bula et al. 2019), and on each one of them the transport of dangerous goods has a different impact. For people who live near such routes, it is only important to be safe, while for the sender and receiver, to have the lowest possible costs, while the government, on the

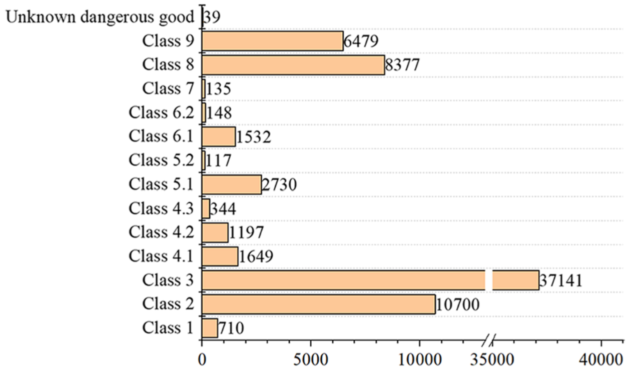


Fig. 1 The amount of transported dangerous goods for EU-27 during 2020 (million tonne-km)

other hand, has the responsibility to maintain an adequate level of safety (Vlies 2021).

The international classification of dangerous goods, according to the ADR (Anon 2021), is divided into nine classes. Each dangerous goods class has its characteristics of danger, that is, the specie and the level of danger. Based on this, the classification of dangerous goods was conducted according to their physical characteristics, chemical characteristics, and danger characteristics as follows:

- Class 1: Explosive substances and articles
- Class 2: Gases
- Class 3: Flammable liquids
- Class 4.1: Flammable solids, self-reactive substances, polymerizing substances, and solid desensitized explosives
- Class 4.2: Substances liable to spontaneous combustion
- Class 4.3: Substances which, in contact with water, emit flammable gases
- Class 5.1: Oxidizing substances
- Class 5.2: Organic peroxides
- Class 6.1: Toxic substances
- Class 6.2: Infectious substances
- Class 7: Radioactive material
- Class 8: Corrosive substances
- Class 9: Miscellaneous dangerous substances and articles.

Within each class exist a great number of different substances considered as dangerous according to their characteristics, can cause consequences for people, the environment, or infrastructure. The characteristics of the transported substance and the amount of this substance determine the so-called impact zone of the dangerous substance. Besides these two characteristics, the weather conditions and the characteristics of the terrain also influence the impact zone. Table 1 shows the impact zone of dangerous substance for each class of dangerous goods that

Table 1 The size of the impact zone of dangerous goods (Milovanovic and Jovanovic 2016)

Class	Name	Impact zone (m)
1	Explosive	800–1600
	Gases	
2	2.1 Flammable	800–1600
	2.2 Compressed	100–800
	2.3 Poisonous	800–1600
3	Flammable liquids	300–800
4	Flammable solids	100–800
5	5.1 Oxidizing substances	100,800
	5.2 Organic peroxides	250–800
6	6.1 Toxic substances	100–800
	6.2 Infectious substances	
7	7 Radioactive material	100–300
8	Corrosive substances	900–1600
9	Miscellaneous dangerous substances and articles	25–500

varies from 25 m for dangerous good class 9 to 1600 m for dangerous goods classes 1, 2, and 8. Several thousands of dangerous goods species exist (Board 2005), and Table 1 presents only the values for the impact zone of dangerous goods for each class separately. These data indicate that without knowledge about the size of the impact zone of dangerous goods, it is not possible to determine the level of consequences for each element exposed to the risk, and a possibility of great error exists, if the correct value of the impact zone of dangerous goods was not taken into consideration during the process of the risk evaluation.

Logistic systems can contribute to the accidents with dangerous goods, including production, storage, reload, transport, and use (Janković 2016; Sremac et al. 2020). Accidents with dangerous goods can be without injured people, with injured people, with fatal outcome, and can cause damage to the environment and infrastructure, which can cost several millions of dollars (Abkowitz et al. 2001). Work with dangerous substances can lead to fires, explosions, and toxic releases (Baalisampang et al. 2019), which can have a very negative impact on people's health, the environment, and infrastructure. From 1980 to 2015, worldwide 9467 accidents occurred involving 19 dangerous substances (Tanackov et al. 2018), see Fig. 2. From 2013 to 2019 in China, 2340 accidents occurred on the highway (Li et al. 2021). The greatest number of accidents in China involved dangerous goods classes 2, 3, and 8 (Shen et al. 2014). These transport problems, are why we want to conduct this kind of research. It is very important to know when, how, and where the traffic accident has occurred, in order to avoid this problem in the future, and to use the results obtained by summing the research of other authors.

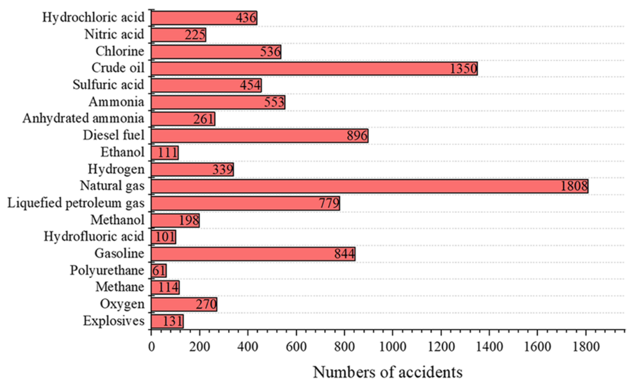


Fig. 2 The number of accidents from 1980 to 2015

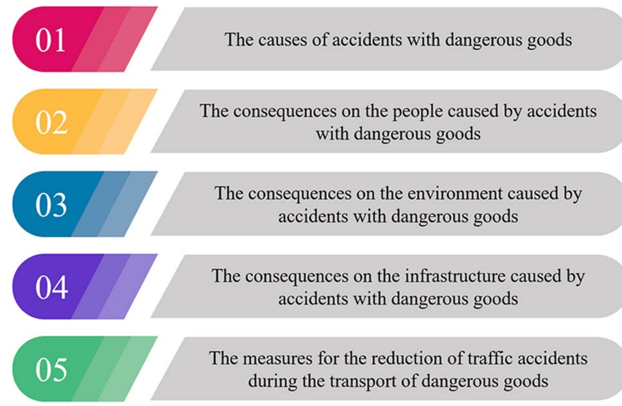


Fig. 3 The structure of the paper

The transport of dangerous goods presents valid concerns for the protection of people's health, preservation of the environment and infrastructure (Inanloo and Tansel 2016). From this comes the main questions: "How to prevent accidents during the transport, such as rollover, sliding of the cistern, or traffic accident?, What the person who organizes the transport of dangerous goods must know to minimize the risk and costs of transport?, What will happen regarding people, the environment, and infrastructure in the case of an accident?. In order to answer the first question, it is necessary to analyze what happened in the past during the transport of dangerous goods, and on the basis of the events from the past to define the route, as well as what time of the day is good to transport dangerous goods, then what are the causes which led to the traffic accident (the second part of this paper). In addition, models and algorithms of transport can be created based on past events that will provide suggestions for the transport of dangerous goods with less risk, and this is shown within the sixth part of this paper. All previous studies answer the first and second questions, while the answer to the third question is addressed in the third, fourth, and fifth part of this paper. In this study, it can be noticed that questions and answers actually represent a set of mutually related elements, which will be processed through five basic points in this paper, as shown in Fig. 3.

The causes of accidents with dangerous goods

Accidents during transport can happen due to the wrong actions of the driver, unadjusted vehicle speed, or driver tiredness (Xing et al. 2020). Ma et al. (2018), concluded unadjusted vehicle speed makes it much harder to control the vehicle, leading to accidents. In addition, vehicle failure can result from bad maintenance (Men et al. 2022; Qureshi et al. 2020), such as the malfunction of the brake system, malfunction of front and rear shields of carriers (Ghaleh et al. 2019), or corrosion on the vehicle or on the equipment (Nivolianitou et al. 2006). Niu and Ukkusuri (2020) determined four factors are most responsible for traffic accidents, from the 17 considered, and they are traffic flow, weather, average velocity, and travel time. In addition, outdated applied technics can cause traffic accidents during transport (Hermans et al. 2009). The road maintenance, that is, the road condition, as well as the road locations, can impact the occurrence of accidents during the transport of dangerous goods. Narrow roads, with steep inclination and many curves, can contribute to the occurrence of traffic accidents (Vrabel et al. 2015). Also, the season of the year influences the number of traffic accidents. When the temperatures are high a greater number of traffic accidents occur compared to when the temperatures are low. However, the greatest number of traffic accidents occur under poor visibility conditions, which is characteristic for rainy or snow days. According to Qiu and Nixon (2008), more traffic accidents happen during snow days. Also, a slippery road is characteristic for such conditions, which contributes to the greater number of traffic accidents. According to Men et al. (2022), traffic accidents happen due to the problem of packing of dangerous goods (14.6%), incorrect actions of the driver (13.7%), unsafe distance from other vehicles (13.4%), unadjusted speed (11.1%), and problems with the vehicle (8.2%). It was determined that the greatest share of the accidents were caused by a human factor, which is the consequence of insufficient training (Zhao et al. 2018) (Fig. 4), and Zhang and Zheng (2012) have come to the same conclusions. According to Batarliene (2020), the factors contributing to traffic accidents can be divided into the three groups, and each group includes ten subgroups (Fig. 5). The research conducted by Ambituuni et al. (2015) shows that from the total number of traffic accidents (2318), 79% were caused by human factors, mostly by dangerous driving.

The traffic accidents during the transport of dangerous goods are rollover (28%), crash (17.8%), rear crash (21.9%),

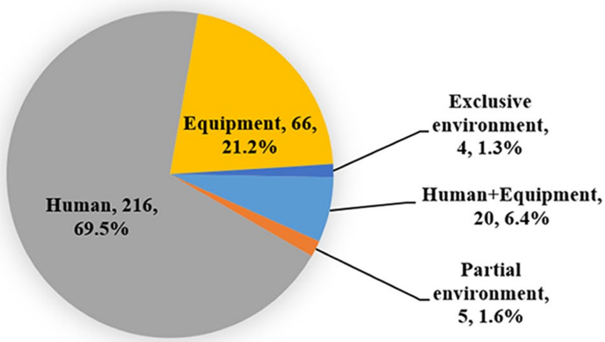


Fig. 4 Causes of traffic accidents during the transport of dangerous goods

lateral sliding (3.8%), deflagration (10.5%), leakage (16%), and scratch (16%) (Men et al. 2022). While a vehicle is driving the fluid inside the cistern moves, by splashing the walls of the cistern, or it leads only to its movement, which alters the center of the gravity of the vehicle, and in this way leads to the loss of stability. Which further causes the vehicle to rollover, especially during some sudden maneuvers with the vehicle, or while driving on a curve (Shen et al. 2014).

The consequences on people caused by accidents with dangerous goods

Accidents involving vehicles transporting dangerous substances can be divided into accidents with fatal outcome, with injured, with evacuated, and with poisoned (Yang et al. 2010). Traffic accidents involving dangerous substance spills represent not only a danger from the fire but also a toxic danger (Chakrabarti and Parikh 2013a, b).

During the year 2001, in Louisiana, 815 accidents happened, and 1164 chemicals were released into the environment, which caused the injuries of 63 persons, where most were in the shape of irritations of the respiratory system (Hu and Raymond 2004). In a traffic accident that happened on January 13, 2004, in Baltimore, Washington Highway, USA, with a vehicle transporting propane, ten people died (Abbasi and Abbasi 2007). One of the worst traffic accidents occurred in the Salang tunnel in Afghanistan, involving a cistern with fuel and a truck with ammunition (Alhazmi and Molloy 2016), and it was reported that 64 soldiers and 112 civilians died. Another of the worst traffic accidents where 219 persons died, happened on the 799 North Bound, N5 Highway near the town of Ahmedpur Sharqia, Pakistan (Qureshi et al. 2020). According to Ewbank et al. (2019), 224 fires or explosions involving oil tanker trucks occurred, and 2909 people died, while 3038 were hospitalized. Accidents involving liquefied petroleum gas, depending on the amount released into the environment, first causes poisoning (Zengin et al. 2015), and finally have fatal consequences for people (Dadashzadeh et al. 2014). In the traffic accident with a vehicle transporting liquefied petroleum gas – LPG in Wenling, Zhejiang Province, China, which happened June 13, 2020, 20 people died, while 175 were injured (Lyu et al. 2022). The traffic accident happened because the vehicle hit the concrete protective wall, and exploded, releasing 25.36 t of liquefied petroleum gas. Accidents involving vehicles transporting LPG can cause more traffic accidents and thus impact the number of injured or dead, and also can lead to suffocation, which arises due to poisoning with this gas (Bhattacharya et al. 2013).

Depending on the substance transported, and if during its transport leads to outflow/leaking, different consequences for people can be expected. In the case of a traffic accident with hydrofluoric acid skin injuries can occur, for example, on the skin on the hand which was exposed to this substance,

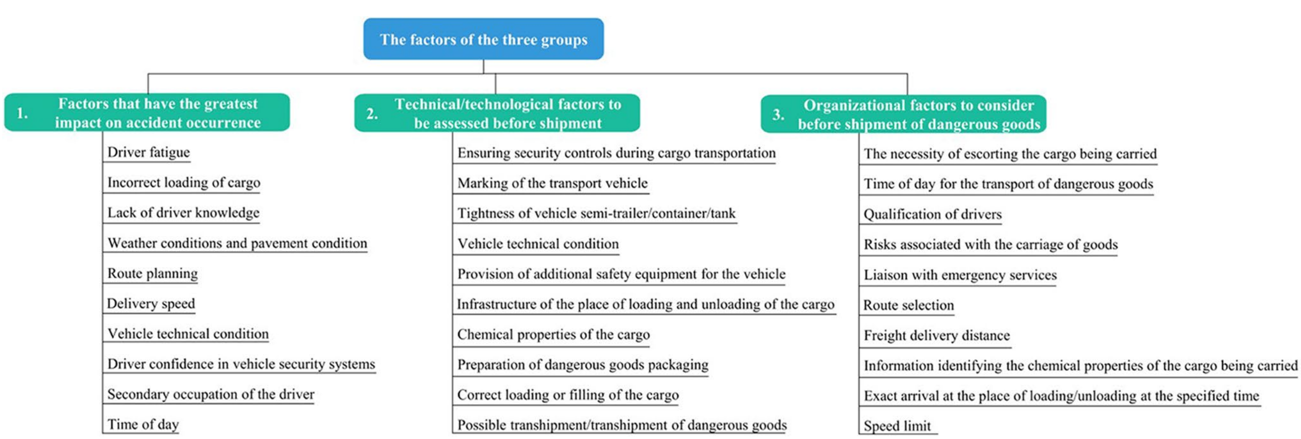


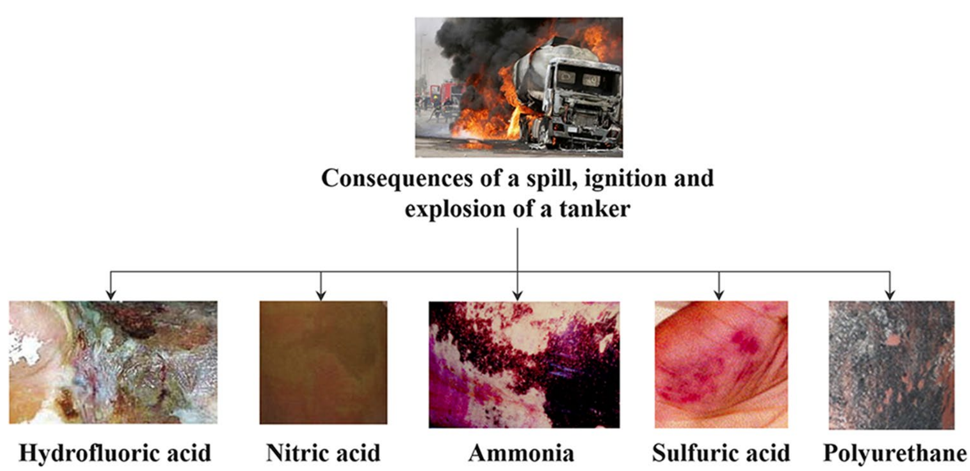
Fig. 5 Influential factors on the occurrence of traffic accidents

shown on Fig. 6, clearly are visible silvery-gray or blue-grayish necrosis. After skin exposure to hydrofluoric acid occurs and the person does not seek urgent medical help quickly, a further bad clinical outcome will result (Dinis-Oliveira et al. 2015). Burns arisen due to the exposure to hydrofluoric acid can capture a smaller surface of the skin (Tremel et al. 1991), influencing the possibility of a mortality increase. If more than 20% of the skin is burned, the possibility of mortality approaches to 100% (Dünser et al. 2004). The exposure of humans to nitric acid can lead to protein denaturation and coagulation with a specific yellow to brown color of the skin (Kolios et al. 2010), see Fig. 6. However, the tissue destruction is not as deep as in the case of skin exposure to hydrofluoric acid. Polyurethane also causes burns of the skin (Keskin et al. 2008), and can cause death if not reacted to on time. Accidents involving ammonia, nonwatery, can cause people frostbite from I to III degree (Fig. 6), and often is followed with expressed toxic effects, and sometimes with death (Amshel et al. 2000). Ammonia inhalation can cause different respiratory problems, such as tracheobronchitis, laryngitis, bronchopneumonia, bronchiolitis, and pulmonary edema (Tonelli and Pham 2009). In addition, the exposure to ammonia can cause chronic sinusitis (Brautbar 1998), while in extreme cases, it can cause blindness, lung damage, and even death (Kaye, et al. 2005). Accidents with sulfuric acid have a negative impact on people. In a great number of accidents, 14.1% involve the entire body, 86.7% the face, 66.7% the head and neck, 60% arms, and 53.3% the chest (Asaria et al. 2004). While in the case of inhalation, the sulfuric acid can cause permanent damage to respiratory organs and even can cause death (Benomran et al. 2008). In addition, the inhalation of sulfuric acid fumes, besides the permanent consequences on humans, even after 10 years after the accident, can cause death (Li et al. 2013). A high level of exposure to chlorine, which can happen due to a traffic accident involving a vehicle transporting chlorine, can lead to acute lung injury and acute respiratory distress syndrome, and 1% of exposed persons die (White and Martin 2010). In the simulation conducted by Brzozowska for the city Bielsko-Biała, the results show that in the case of chlorine release from the cistern, where there was 10 t of chlorine, depending on the direction of the wind, a surface over 2 km^2 can be captured, with 5000 people deadly threatened (Brzozowska 2016).

The consequences on the environment caused by accidents with dangerous goods

Traffic accidents involving vehicles transporting dangerous substances can lead to the outflow, and afterward to the penetration of these substances into the ground, underground water, and watercourses, which further causes water pollution (Ebrahimi et al. 2020; Leitner et al. 2021), soil degradation (Junior et al. 2014), and biological damage (Yang et al. 2010). One of the main ecological worries is the risk of water and soil pollution (Machado et al. 2018a). The seriousness of accidents with dangerous goods depends on the amount and chemical composition of the dangerous substance released into the environment (Ambituuni et al. 2015), as well as the soil sensitivity (Siqueira et al. 2017). The damage caused by the outflow of oil derivatives costs around 7 million USD (Ambituuni et al. 2015). In the case of the outflow of liquid dangerous substances (for example, diesel fuel), this substance will enter by roots into the plant, which further can impact the plant health (van der Meijde et al. 2009). While in the case of gas leaking, the dangerous substance enters into the plant by foliage (Simonich and Hites 1995). The contaminated soil has less oxygen, that is, has greater concentration of hydrocarbons, which can further cause plant stress (Noomen 2007). In addition, the color of the plant changes, which clearly shows a loss of photosynthesis pigments (Yang et al. 2000).

Fig. 6 The skin after the exposure to dangerous substances



Accidents can lead to fire, in some cases the fire can last several days (Oggero et al. 2006). However, it can also lead to the explosion of a cistern containing an overheated flammable fluid, where it leads to the release of fluid and vapor mixture and after that it leads to the formation of a fireball, which can leap several meters above the ground (Casal 2008), see Fig. 7. In this case, fire burns only on the external surface of the ball, because inside the ball oxygen does not exist. By further combustion, droplets vaporize, and the density of the mixture reduces, while the diameter of the ball increases. As a consequence of the fireball (which can be visible around 10 s), with a radius close to 50 m, the vegetation can burn completely, while on 90 m where there is a pine forest, the needles underwent pyrolysis (Planas et al. 2015). On a tree 90 m from the fireball, the foliage that was turned to the fireball completely dried and pyrolyzed, see Fig. 7. Although the vegetation was not directly exposed to fire, it partially burned because of the heat radiation (Landucci et al. 2011).

The consequences on the infrastructure caused by accidents with dangerous goods

A great number of accidents during transport happen on bridges and highways (Liu et al. 2017). Bridges are very important for transport and are essential elements of highways, magistral roads, and railways because they are needed to pass over rivers, deep canyons, etc. Because of this, the entire traffic flow could be interrupted if there is an accident on the bridge, which further will cause traffic congestion and chaos (Kaabi et al. 2012; Gang et al. 2021). On January 5, 2002, a cistern transporting 37,000 L of gasoline rolled over and caused a fire involving a bridge (Zhang et al. 2022). In this case, the fire caused a great amount of damage and concrete-steel composite carriers were deformed, see Fig. 8a. Also, the concrete pillars that hold the bridge were destroyed in the fire. The reparation of the I-65 Bridge required 54 days. One of the fires responsible for the destruction of a bridge (Fig. 8b) happened April 29, 2007, in Oakland, USA, where the cistern transporting 32.6 m^3 of gasoline rolled over and caused a fire (Garlock et al. 2012). It cost 9 million USD to repair the damage, which includes 4.8 million for demolition and removal of the section of I-580 and 2 million for the traffic control. It took 26 days to finish all construction work and to open the bridge again. In addition, the accidents that happen on bridges and highways very often happen on the intersections (Inanloo and Tansel 2015).

One study dealt with the prediction of consequences of accidents in the case of ammonia transport. Depending on the weather conditions, such kind of accident can lead to material damage at a distance from 1708, 1206; 3742, 3527 feet (Inanloo and Tansel 2015).

Damages can happen to houses; for example, the houses in Fig. 9a were 15 m from the place of accident – explosion of a cistern transporting LPG. That is, damages are the consequence of the pressure wave from the explosion, and after of the subsequent fire (BarihaaIndr et al. 2016). Figure 9b shows damage

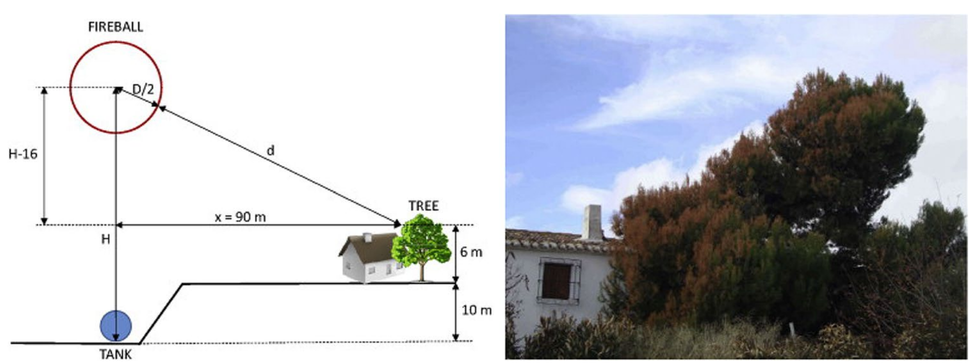


Fig. 7 The tree hit by fireball (Planas et al. 2015)

(a) (b)

Fig. 8 (**a**) I-65 bridge (**b**) Oakland highway bridge collapse in California (Kodur and Naser 2015; Garlock et al. 2012)

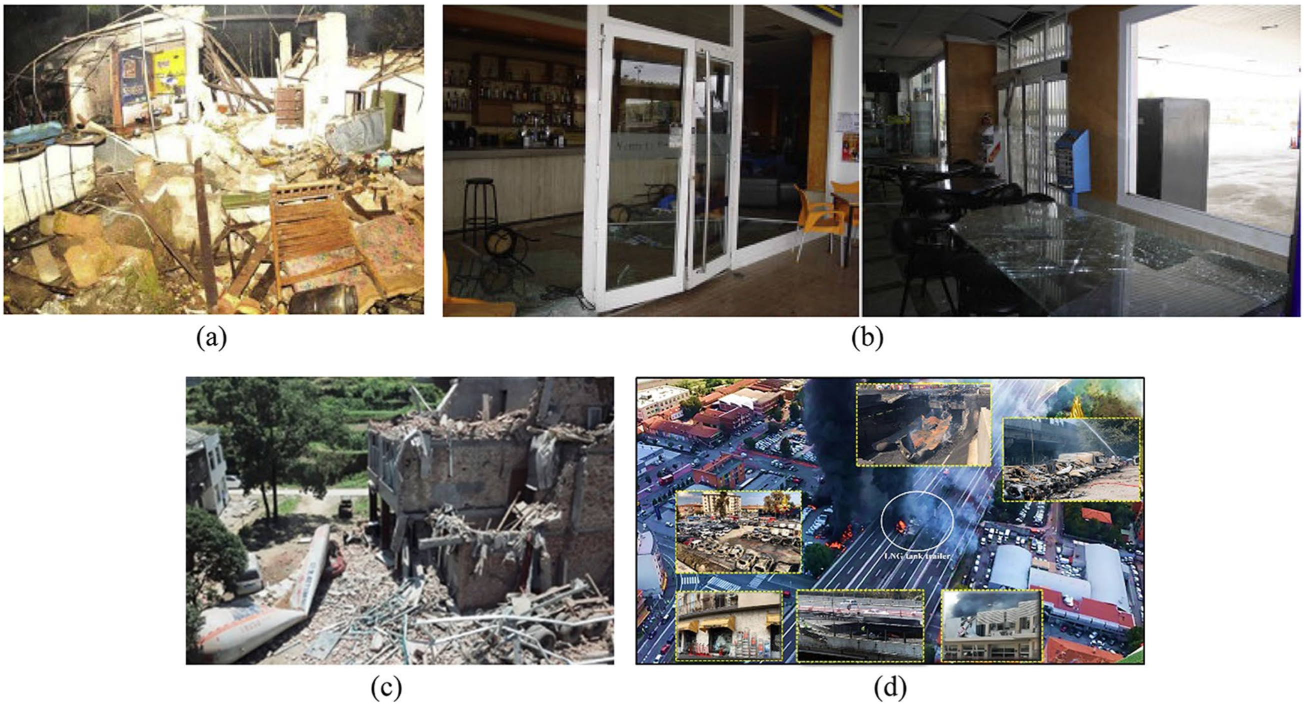


Fig. 9 Photograph (**a**) of a heavily damaged house; (**b**) of a damaged shop; (**c**) of a damaged building, and (**d**) of a demolished road after the accident of a vehicle transporting a dangerous substance (BarihaaIndr et al. 2016; Planas et al. 2015; Lyu et al. 2022; Wang et al. 2022)

from the explosion pressure wave on the premises/shops that were 125 m from the place of accident (Planas et al. 2015). It can be said that the accidents involving cisterns transporting LPG impact the near objects (Bhattacharya et al 2013) because of the pressure wave (Planas-Cuchi et al. 2004). In the case of one accident involving LPG, the tank flew 400 m from the place of accident (Fig. 9c), the gas ignited, which further caused an explosion, which further caused serious material damage (Lyu et al. 2022). The energy released during the explosion manifests as the breaking and deformation of the cistern and truck. Also, it impacts the road where the vehicle was when the cistern exploded, and it can lead to road destruction and pit formation (Wang et al. 2022), see Fig. 9d. In the case of the vehicle explosion on December 17, 2013, in Drevja, Norway, during the transportation of ammonium nitrate, the fire lasted almost two hours. However, a characteristic of this accident is that parts of the truck were thrown at different distances from the place of accident during the explosion, see Fig. 10.

The measures for the reduction of traffic accidents during the transport of dangerous goods

The existing risk during the transport of dangerous goods represents a serious threat; therefore, a strategy and a tool to reduce the risk for society, the environment, and assets is necessary. Requirements include routing with minimal costs for the transporters, as well as to avoid the high-risk routes (Mahmoudabadia and Seyedhosseini 2014), even to change the routes (Bubbico et al. 2006), and besides all this, the risk related to the transported dangerous substance should not be forgotten. The routes that are optimal from the aspect of minimizing risk and losses should be used (Bęczkowska 2019; Holeczek 2021). Transport of dangerous substances often is redirected around the cities, that is, the tendency is for the vehicle transporting dangerous substance to not enter the city/populated area. This is because driving such vehicles in populated areas increases the risk of accidents (Chakrabarti and Parikh 2013a, b), and the consequences can be catastrophic, for the people and for the infrastructure. However, in the case of the transport of gasoline, diesel, or some other automotive fuel, the vehicle transporting these fuels must enter the city to reach the fuel stations (Vlies 2021). Therefore, the research of Conca et al. (2016) provides a possibility to the transporter, to determine the quantification of risk for each concrete travel, in addition to operative costs. During the transport of dangerous goods, densely populated areas should be avoided, especially during the transport of explosives and compressed gases (Xing et al. 2020). Also, tunnels should be avoided because the consequences of an accident could be of catastrophic proportions (Benekos and Diamantidis 2017), including collapse and trapping of people and vehicles in the tunnel when the

Fig. 10 The parts of the vehicle that were thrown at different distances due to the vehicle explosion (Due-Hansen and Dullum 2017)

accident happens (Wasantha et al. 2021). Also, roads with long and steep inclinations should be avoided as much as possible when selecting routes for transport, that is, it is recommendable to use alternative roads, which are ranked on the basis of substance being transported (AlRukaibi et al. 2018). The transport of dangerous substances through tunnels is safe only if advance defined criteria of risk acceptance are fulfilled (Kohl and Žibert 2010). Lundin and Antonsson (2019) presented a simplified risk analysis method for when the vehicle should go through the tunnel, which can be used in the categorization of existing and new tunnels. Also, results of the research of Ingason and Li (2017) are very useful for the designing of fire protection systems in tunnels, which include ventilation systems, fixed system for fire extinguishing, and systems for draining. Also, during the designing of tunnels, road inclination (Klein et al. 2018) and road roughness (Guo et al. 2022) should be considered.

Mapping is a method that can reduce the number of traffic accidents during the transport of dangerous goods (Flodén and Woxenius 2021). Also, during the planning of dangerous goods transport, the timing of vehicles distribution is a very important parameter to reduce the number of traffic accidents. Ahmad et al. (2021) used the InSafE (inherent safety and economic graphical rating) method to propose the safest route with the greatest economic potential. Izdebski et al. (2022) showed that the ant colony and genetic algorithm are very useful tools for those who deal with the organization of dangerous goods transport, with the aim of minimizing risk for the vehicle transporting dangerous substances. Lukai and Xuesong (2021) have come to the same conclusions. Also, it is necessary to conduct a preliminary test, which will provide the estimation of the proposed model and show if the model is adequate and capable of simulating a real situation, which further makes a very convenient tool for decisions. The risk map for the environment is a very useful tool to identify areas with a high risk of accident occurrence, and also can be applied for the orientation of urgent operations, to measure conduction for the risk reduction, or to help during the determination of higher risk areas and to avoid possible accidents (Cordeiro et al. 2016; Martínez-Alegría et al. 2010). Also, the risk map can be used to minimize risk reduction and accident consequences (Milazzo et al. 2010) involving the transport of dangerous goods.

With the aim to improve road safety, the opinions of drivers of heavy-duty vehicles should be heard because they can provide very useful information about risk factors on the road (Khadka et al. 2021). Also, it is necessary for drivers to undergo periodic training (Fizal et al. 2019). In addition, a key factor for transport of dangerous goods is satellite navigation because the merchandise can be followed, and important data can be collected, which can be further analyzed, with the aim of a statistical report and accident prevention (Fazio et al. 2016). The MITRA (monitoring and intervention for the transportation of dangerous goods) following system has shown to be a very useful tool during merchandise following, providing the operative support to the rescue teams in the case of an accident or some other emergency situation (Planas et al. 2008). It is important to invest in infrastructure, that is, the infrastructure should be improved because it can influence the possibility for a reduction in accident occurrence (Saat et al. 2014). In addition, lessons need to be learned from the examples of accidents that occurred earlier to improve the safety during the transport of dangerous goods (Planas et al. 2015). Useful knowledge can be gained from the history of events which happened during the transport of dangerous goods. The possibility of accident occurrence can be determined (Raemdonck et al. 2013). Also, the tree of events should be used to take into consideration all possible outcomes during the transport (Ronza et al. 2007), or some other methods used, which will give a good compromise between the economy and safety (Men et al. 2022), as well as congestion avoidance (Zhang et al. 2019).

Additional propositions are to mount barriers or concrete walls along roads that are along a river. Also, one proposition is to change the route geometry and to manage and control the speed (Lee 2014). In the case of outflow from the cistern, the contamination of soil along the road/highway is unavoidable, and the proposition is to include drains in road construction, in order to direct dangerous substances into the special drain (Machado et al. 2018b). Therefore, no matter the terrain inclination, the outflowed dangerous substance will not go into the soil. Also, if it is possible, organize the transport of dangerous substances by pipelines (Ghazinoory and Kheirkhah 2008). This way is quite economic and ecologically acceptable. If this is not possible, then it should be determined if the applied design of the cistern has an impact on the risk reduction during the transport (Liu et al. 2013).

Conclusion

Accidents during the transport of dangerous goods can affect people's health, the preservation of the environment, and infrastructure. The possibility an accident can happen always exists during the transport of dangerous goods, but it does not have to. How substances with different chemical compositions are transported will determine their potential impact on people, the environment, and infrastructure. In addition, the consequences will depend on the amount transported. After conducting the review of studies by other authors from the subject field, we have come to the following conclusions:

– Dangerous goods are very harmful for the environment and people in the case of accidents, or if unintentionally released into the environment. In addition, dangerous goods can damage the infrastructure of roads/settlements depending on where the accident happened.
– Accidents during the transport of dangerous goods are influenced by the behavior of the driver, the reliability of the vehicle, route of the vehicle, the time of day or of the year, when dangerous substance is transported, etc.
– Lessons should be learned from past events to avoid repeating the same errors because some events have taken many lives and have had long-term consequences on the survivors. Also, all the events have impacted the environment and infrastructure of roads and settlements.
– With the aim to reduce the number of accidents, the proposed possibilities are: optimization of routes with less risks during the transport; the avoidance of tunnels, inclinations, roads along rivers and urban areas; investments in road infrastructure; definition of alternative routes with the aim of minimizing risk.

The shown conclusions are very useful for planning safe transport of dangerous goods. Also, this paper presents the causes of accident occurrence, problems which can cause injuries to people, and damage to the environment and infrastructure, and at the same time shows the measures for risk reduction during the transport of dangerous goods. The listed measures for the reduction of accidents during the transport of dangerous goods are very useful; however, some of them also have some disadvantages. The limit of this paper is that the working experience of the drivers as well as their psychical condition were not taken as parameters, which also can influence the reckless actions that lead to traffic accidents. Future research should remove these disadvantages, to improve the transport safety for people, the environment, and infrastructure. Also, the important information in this paper can serve as the base for future research for authors who deal in this field. Future research should take into consideration the most critical sections of the road, where traffic accidents often happen, and conduct the analysis and develop models for these sections of the road, all with the aim to reduce the number of traffic accidents. An additional recommendation for the reduction of traffic accidents is the application of intelligent transport systems, which should be given appropriate attention during future research. Using intelligent transport systems will not only reduce the number of traffic accidents but will also influence the reduction of emissions that originate from vehicles, as well as provide faster and more comfortable transport of goods.

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