IMPROVING SECURITY IN ROAD TRANSPORTATION OF HAZARDOUS MATERIALS

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ABSTRACT

A great variety of hazardous materials (HazMat) are transported by road and, with a few exceptions, no particular restrictions are posed to their routes and no surveillance is exerted during their trip. On the other hand, it is recognized that the potential consequences of an accident involving these materials may be severe or even catastrophic. Such road tankers may therefore represent an attractive target for terrorists, as also recognized by the A.D.R. regulation, which identifies some high consequences dangerous goods (HCDG) classes, requires the adoption of security measures and lists the essential elements to be included in the security plan, which should be prepared when transporting such materials. However, as a matter of fact, the HCDG list includes practically all fuel tankers (gasoline, LPG, kerosene, etc.) so that providing all these vehicles with proper security devices may be impracticable and rather expensive; moreover, workers' privacy should be safeguarded. The present work focuses on critical security issues to be addressed when transporting HCDGs and considers some devices and procedures aimed at reducing the risk. The complexity of the system can be modulated based on the available resources and specific circumstances (type of dangerous good, route features, and others). An attempt is also made to further subdivide HCDG classes into three large groups, based on the type of consequence (fire, overpressure and missiles, toxic cloud) and on the expected impact areas associated with a deliberate release of the product into the environment. This will allow to properly scale the complexity of the proposed security apparatuses and procedures.

Keywords: High consequences dangerous goods (HCDG), road transport, safety box, security apparatuses, security procedures, terrorism.

1 INTRODUCTION

A number of recently occurred events, especially after September 11, 2001, such as the Glasgow and London attacks in 2007 (both fortunately unsuccessful), as well as many others, almost daily reported by newspapers, have focused the attention of public and experts on terrorist activity possibly related with the transportation of sensible and hazardous materials. Despite the many differences with respect to more 'traditional' targets, this activity has been recently recognized as a significant possible threat to public safety. Therefore, increasing attention has been devoted to the specific issue of the security in Hazardous Materials (HazMat) transportation [1–3]. In fact, it is generally assumed that a high level of technical expertise and knowledge, as well as highly sophisticated equipment and tools, are not needed for such a kind of action. Nonetheless, the consequences possibly generated by an accident involving the release of such materials can be catastrophic. At the same time, the intrinsic complexity of the logistics and the non-standardized shipment procedures open the door to a large number of sensible exposure points along the transportation chain, which cannot be totally eliminated. Therefore, this kind of activity presents a rather high level of vulnerability.

Given the complexity of the transportation systems, in terms of means of transportation, infrastructures, procedures, stakeholders involved, and so on, many issues to be taken into account belong to areas of very different nature: political, technical, management, human

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relations, and others. In the following analysis, specific attention will be devoted only to technical and procedural aspects, while prescriptive and political issues will be disregarded. Following this assumption, a preliminary list of issues to consider when dealing with the security of the transportation of hazardous materials can be as follows:

- the specific type of material,
- the characteristics of the selected route (population distribution, presence of critical points such as tunnels, bridges and so on),
- the driver (criminal background checks have been proposed, as already required by the U.S. Federal Aviation Administration regulations [4]),
- the loading/unloading facility and site,
- the transportation rules,
- the information exchange among the shippers, the transporter and the public authorities,
- the alarming policy,
- others.

Depending on the specifically assumed point of view (accident prevention, safety for the exposed population, optimization of the route, etc.), different approaches have been adopted in the recent years to address the issue of risk reduction in HazMat transportation: risk analysis, vulnerability analysis, cost/benefits analysis, etc. In particular, the issue of security in the routing of HazMat transports has been addressed either in the framework of a more general approach, as an 'extended' risk analysis (see, for example [5,6]), or considered alone.

However, accounting for security aspects of the transportation of hazardous materials in a more general approach is not straightforward. For example, the term 'hazardous material' itself may indicate a quite broad range of products with very different characteristics. In fact, while in traditional risk analyses the hazard is associated with toxic chemicals, explosives, or generic flammable substances, in the case of terrorism or even for more general criminal activities, this meaning can be extended to a broader range of chemicals: biological materials, corrosive or oxidizing substances, pesticides (for example, to contaminate water sources), or more generic noxious materials. Nuclear materials (fuels or, more properly, wastes) are usually already subject to specific restrictions and regulations, so the present discussion will not address this kind of dangerous materials. The possible actual use of one of these materials by candidate terrorists will depend on a large number of issues such as: its availability, the easiness of coming into possession of it, the capabilities (skill, knowledge and level of organization) of the terrorists, the selected target, the intended results, the security level of the transportation company, and many others.

As an example of the differences between the use of traditional hazardous materials and those of general interest for candidate terrorists, we can mention the following:

- The vehicle transporting the dangerous material may be attacked and 'triggered' at the specific site where the release is intended to occur, or may be moved to a distant different target site, and possibly used to cause the accident even after a time delay (from hours to months).
- The probability of release, which in this case is coincident with the attack probability, is not uniform [7], but it is dependent also, even though not exclusively, on what we might call the 'attractiveness' of the location, characterized by the expected damages.

- Some of the tools that are implemented with the aim of increasing the safety of the transportation activity can be exploited by terrorists with the opposite intention, e.g. the whole information and communication systems (shipping documents, the placards on the trucks and so on), which are originally intended to facilitate the emergency procedure, may help terrorists to identify the dangerous material transported.

In case of flammable materials, the main consequences may be represented by a fire or an explosion. In the case of liquids, the fire is intense, rather localized, and long-lasting, so that it can cause serious structural damages (both to metal and concrete structures), trigger domino effects, by igniting further substances, and impact people, if not able to escape. In the case of a flammable gas, similar localized consequences are obtained following the immediate ignition of a substantial catastrophic release (fireball), even though, here, the influence of buoyancy is important. Conversely, in the case of a delayed ignition, the extension of fire is markedly influenced by the atmospheric conditions (wind velocity and direction, presence of obstacles, and so on), so that even locations relatively far away from the release site can be impacted. Furthermore, even though only under proper conditions, in the case of a gas cloud a much stronger combustion with explosive effects (VCE, vapor cloud explosion) can occur, causing also overpressure. In this case, the consequences will be more serious, and the impact distances larger, compared with the case of a 'pure' fire. On the other hand, since a number of external conditions need to be met at the same time, the probability of occurrence of a VCE is much lower compared with a fire. The chemical reactivity of the specific substance plays also a fundamental role and, for highly reactive materials, the above external conditions can be less restrictive. This becomes particularly true in the case of real explosives, which in most of the cases are in the solid state, mainly as powders (such as TNT, nitroglycerine, PETN, and others) and can cause extended structural damages possibly involving a high number of victims and injured people. As in the case of VCEs, the extension of the impact area of this kind of events is markedly influenced by the configuration of the explosion site: confined and congested areas are particularly susceptible, therefore representing sensible targets.

Differently from the material types mentioned so far, which usually cause damages both to structures and people, toxic substances represent a rather different case. In fact, when released into the atmosphere, they have almost no effect on the structures, but due to the very large impact areas possibly generated, they can cause very high numbers of casualties and injuries within the population. Under this respect, gases and low-boiling (high volatility) liquids are potentially most dangerous, being more easily dispersed, even if, besides the physical conditions, the most important parameter is represented by the toxicity threshold of the particular substance. For a given released mass, the area actually impacted by the toxic cloud is strongly influenced by weather and wind conditions, being thus quite unpredictable without detailed on-time data. However, when a toxic chemical is released in the open, its concentration inside buildings with doors and windows closed (the so-called indoor concentration) will hardly reach very high and dangerous values. Generally, its value will remain much lower than outside, unless the toxic is released in liquid phase and enters the sewers. On the other hand, while in the open the substance will be rapidly diluted with air, in closed spaces, with limited air recirculation rates, the lower concentration will persist for longer thus increasing the exposure time. As a consequence, the most dangerous scenario is represented by the release of a toxic substance directly within a confined space (for example, a tunnel, a building, etc.) where it will cause the worst effects on the exposed population, due to the combination of high concentration (caused by a lower dilution with air) and longer exposure time.

With specific reference to the security issue, a number of projects, based on very practical approaches, have been implemented in the recent years.

The U.S. Research and Special Programs Administration (RSPA), a division of the U.S. Department of Transportation (DOT), has asked all those involved in this activity (during transport, storage, etc.) to review and, if necessary, improve their security measures [8]. The recommendations and security requirement issued by the US RSPA cover many aspects of the transportation activity: registration certificates, personnel security and training, facility security, security plans, documentation, en-route security and others. With specific reference to the en-route security, the main topic of the present paper, both procedural and technical issues are highlighted, and the main recommendations are:

- make use of a reliable carrier;
- make use of the most proper transportation mode;
- make use of the most proper route (avoid tunnels, bridges, densely populated areas, etc.);
- minimize stops en-route and check for the need of additional security measures (e.g. two drivers, adoption of guards or escorts);
- adopt advanced technologies to track or protect shipments during travel (e.g. satellite tracking or surveillance systems);
- establish a redundant (both primary and backup) communication system among the shipper, carrier and law enforcement and emergency response officials with the transport vehicles and operators, including an emergency one.

In 2004, the U.S. Federal Motor Carrier Safety Administration completed a study, which was intended at determining whether the use of already existing technologies, such as Global Positioning System (GPS) tracking, wireless modems and on-board computers, could improve the security of HazMat transportations. The conclusion was that the so-called 'smart truck' technology can be quite effective in reducing the vulnerability of security-sensitive materials shipment from hostile voluntary actions. In addition, it was also demonstrated that the adoption of the smart truck technology can provide a positive return on investment for the HazMat carriers. Based on these results, in 2007 the U.S. Transportation Security Administration was asked to develop a program enabling the tracking of motor carrier shipments of hazardous materials, which confirmed some preliminary considerations already reported in the literature [9].

In a recent study [10], the influence of different available technologies on various aspects of the transportation of hazardous materials has been analyzed, ranging from safety to security and efficiency. A strong positive effect was found after the introduction of wireless communication systems and GPS positioning, not only in terms of vulnerability reduction but also of a higher benefit/cost return. Furthermore, the reduction in the information exchange time also has a marked benefit on the emergency and security response. With specific reference to the vulnerability issue, which, together with threat and consequences, is considered as one of the three main aspects related with security; it was found that increasing benefits can be obtained by adopting an increasing number of technological tools, i.e. wireless communication, panic buttons and vehicle disabling, respectively.

In 2007–2008, the Kentucky Transportation Center of the University of Kentucky, carried out a project aimed at assessing the feasibility of establishing a Transportation Security

Center (TSC), to be operating in North America [11]. The model HazMat regulatory program required:

- HazMat carriers to install 'smart truck' technology on their vehicles;
- both shippers and transporters to send e-manifests and e-route plans to the TSC;
- carriers to report vehicle location and alerts to the TSC;
- companies to pay HazMat regulatory fees.

The detailed structure and the operation of the TSC are reported in the cited work [11]. The transportation fleet should be composed of 'smart trucks' equipped with on-board computers, GPS receiver and wireless connection. The internet connection with both the TSC and the fleet tracking data center will allow to know the location of the truck at any time, as well as of the type and quantities of the material transported. The pre-selected route plan can be electronically submitted to the TSC and alarms can be generated in case of unexpected events.

The introduction of further security systems, based on well-known technologies already adopted in higher value materials transportation (e.g. cigarettes!), such as vehicle tracking and remote immobilization, has been strongly supported in a recent and comprehensive report by the Mineta Transportation Institute [12] where a critical and detailed analysis of both the possible aims of a terrorist organization and the available means (also in terms of seizing easiness) is reported.

2 SECURITY ASPECTS OF ROAD TRANSPORT OF HAZARDOUS MATERIALS

The largest amount of hazardous substances are transported by ship or transferred by pipeline, but road transport is preferred for local and medium range distribution of these products, within a country as well as between neighboring countries. Road transport is largely used in the E.U. to transfer any type of goods: a total of about 1730×10^9 t-km[1] were transported in 2010, the main contributors being Germany, Poland, Spain, France, Italy and U.K. In Italy, road transport concerned 168×10^9 t-km in 2010, about 6% of which (1.13×10^9 t-km) were HazMat [13]. The main types of hazardous substances traveling by road within Italy are flammable liquids, about 68% of the total, followed by compressed gases (which also includes flammable gases, such as LPG) at 10%, and corrosive liquids, around 11%; products of greater concern, such as toxic compounds, present lower, but still significant, percentages (1.8%, equal to 0.2×10^9 t-km).

In Europe, road transport of hazardous substances is ruled by the ADR code [14], which divides these products into nine main classes and includes provisions concerning packing and tanks, consignment, requirements for construction and testing, conditions of carriage, loading, unloading and handling, requirements for vehicle crews, equipment, operation and documentation, or concerning the construction and approval of vehicles, and special provisions and exemptions related to dangerous goods packed in limited quantities. ADR also includes some specific security provisions (Chapter 1.10) intended as measures or precautions to be taken to minimize theft or misuse of dangerous goods that may endanger persons, property or the environment. It is required to properly identify and register carriers, securing temporary storage sites and performing safety inspections, and to provide involved personnel with specific security awareness training about security risks, their nature, methods to

[1] 1 t-km represents moving 1 t of material to a distance of 1 km.

recognize, address and reduce such risks, and actions to be taken in the event of a security breach. A list of 'high consequences' dangerous goods (HCDG) is issued: HCDGs are those with the greatest potential for misuse in a terrorist incident and which may, as a result, produce serious consequences such as mass casualties or mass destruction. HCDGs include all classes from 1 to 8, and a substance may be classified as HCDG or not, depending on the amount transported or on the packaging group. Highly hazardous products (such as toxics) are classified as HCDGs, for any transported quantity, while less hazardous ones (such as flammable liquids and gases, and corrosive substances), only for transported quantities exceeding 3000 L. The carriers and the other people engaged in the carriage of HCDG shall adopt, implement, and comply with a security plan addressing some specific elements: (a) specific allocation of responsibilities for security to qualified persons with appropriate authority to carry out their responsibilities; (b) records of dangerous goods concerned; (c) review of current operations and assessment of security risks (including stops, keeping of dangerous goods in the vehicle, intermediate temporary storage of dangerous goods); (d) clear statement of measures that are to be taken to reduce security risks, commensurate with the responsibilities and duties of the participant (training, security policies, operating practices, equipment, and resources to reduce security risks); (e) effective and up to date procedures for reporting and dealing with security threats, breaches of security, or security incidents; (f) procedures for evaluating security plans and procedures for periodic review; (g) measures to ensure the physical security of transport information contained in the security plan; (h) measures to ensure that the distribution of information relating to the transport operation contained in the security plan is limited to those who actually need to have it. It is also required to apply all measures to prevent the theft of a vehicle carrying HCDG, to control that the devices are properly operating and, when appropriate and already fitted, to use tracking apparatus to monitor the movement of HCDGs.

In the USA, the Department of Transport has issued an Hazardous Materials Regulation (HMR) requiring persons who transport a given amount of certain hazardous materials to develop and implement security plans [15]. The thresholds are largely variable: for example, 55 kg of explosives, 1 L of material poisonous per inhalation, and 3000 L for less hazardous products, such as flammable liquids and gases, and corrosive substances. To making a rule [16], a qualitative risk evaluation was carried out, which considered the following factors: (1) physical and chemical properties of the material and how those properties could contribute to a security incident; (2) quantities shipped and mode of transport; (3) past terrorist use; (4) potential use; and (5) availability. One of the most significant security vulnerabilities involves the potential for an individual or group to take control of a conveyance containing a high-risk material and move it to a site where the material could cause maximum physical or psychological damage. For some hazardous materials, the primary security threat involves theft or hijacking of raw materials for use in developing explosive devices or weapons. The final list of hazardous substances requiring a security plan is almost the same that defined by the ADR.

Hazardous materials, including not only explosives or munitions but also different fuels, are also transported according to Armed Forces needs: ADR is always taken into account, but in some 'militarized' version. This means that, depending on the quantity and type of HazMat to be transported, and on the probability of attacks in the zone to be crossed, it can be decided to use armed escorts, or two drivers instead of one (anyway, weapons-provided).

However, it is obvious, from the cited HazMat transportation data [13], that more than 70% of the transported amounts of dangerous substances, expressed as t-km, refer to HCDGs, mainly due to the presence of liquid and liquefied fuels in the list. Therefore, it may be appropriate to further group HCDGs based on their expected attractiveness for terrorists, usually defined in terms of their potential for producing catastrophic consequences and large impact areas. Chemicals susceptible to explode (such as substances belonging to ADR Class 1 or Class 5.1, but not Classes 4.1, 4.2 and 4.3) are, obviously, the best candidates, while corrosive or toxic substances (such as ADR Class 8, 6.1 or 6.2) appear less attractive, based on the considerations summarized in Section 1. As far as the remaining classes are concerned, flammable gases (belonging to Class 2) are susceptible to explode throwing fragments of the vessel at some hundred meters, thus resulting more suitable for terrorist uses than flammable

Table 1: Attractiveness for terrorists of HCDGs belonging to different ADR classes.

ADR class		HCDGs	Consequences	Impact area	Domino effects	Attractiveness
1	1.1	Explosives	Explosion	Large	Possible	High
	1.2	Explosives	Explosion	Large	Possible	High
	1.3	Compatibility group C explosives	Explosion	Large	Possible	High
	1.5	Explosives	Explosion	Large	Possible	High
2		Flammable gases	VCE, fire	Large	Possible	High
		Toxic gases	Toxic cloud	Large	Not possible	Medium
3		Flammable liquids of packing groups I and II	Fire, VCE	Medium	Possible	Medium
		Desensitized explosives	Explosion	Medium	Possible	Medium
4.1		Desensitized explosives	Explosion	Low	Possible	Low
4.2		Packing group I substances	Explosion, fire	Medium	Possible	Medium
4.3		Packing group I substances	Explosion, fire	Medium	Possible	Medium
5.1		Oxidizing liquids (packing group I)	Explosion	Medium	Possible	High
		Perchlorates, ammonium nitrate and ammonium nitrate fertilizers	Explosion	Large	Possible	High
6.1		Toxic substances (packing group I)	Toxic cloud	Large	Not possible	Medium
6.2		Infectious substances of category A	Infection	Small	Not possible	Low
7		Radioactive material	Contamination	Large	Not possible	Not considered
8		Corrosive substances (packing group I)	Burns	Large	Not possible	Low

liquids (Class 3). The estimated 'attractiveness' of HCDGs belonging to the different ADR classes for terrorist's use is listed in Table 1.

The type of expected consequences mainly depends on the hazardous characteristics of the material and on its physical state during transport. The impact areas have been estimated as 'large' for all explosive and radioactive materials (belonging to classes 1 and 7). For substances belonging to the other ADR classes, reference was made to the database of SIGEM SIMMA software [17], used by Italian Fire Brigades, based on the estimated zones of 'immediate danger' following a severe road accident, causing the material to spread over a diameter of 7.5 m. The impact area is then assumed as 'large' when its estimated diameter exceeds 500 m, 'low' when it is below 100 m, and 'medium' in between.

When the consequences of a release include explosions or fires, domino effects are also possible, as indicated in Table 1. This point, together with the type of consequences and the extension of the impact area, has been considered to assume the 'attractiveness' of the material for possible use by terrorist, listed in the last column of the table.

The transport of radioactive materials (for civil uses) has not been considered here, since it is already subjected to a great number of limitations and precautions, including specific security regulations, issued by IAEA, the International Atomic Energy Agency [18,19], so that it may be assumed as safe enough.

In examining security aspects of hazardous materials transportation, it should be considered that, presently, practically no limitation is posed to the routes, which, accordingly, may cross built-up areas, as well as brush past crowded locations. This may occur especially when gaseous and/or liquids fuels are distributed to scattered users within towns, which makes rather complicated to avoid the tankers passing close to any populated site. In a number of cases, a road accident occurred to a truck transporting hazardous substances originated multiple fatalities following the (non-intentional) release of the product: for example, in the well-known accident of Los San Carlos de la Rapita (Spain) of 1978, the ignition of propylene spilled from an overfilled tanker killed more than 200 persons in a camping site [20].

Managing the route of the vehicles carrying hazardous materials to avoid 'hot spots' where more people gather together (for example, trading centers, markets, gardens, camping sites, etc.) can be a very difficult task and omissions are very likely to occur. A complete list should include also railway level crossings (more then 6000, presently, in Italy): in Aquitaine (France) in 1997, the crash of a petrol tanker into an express train caused 13 train passengers to die carbonized.

Fuel tankers are frequently used by insurgents as weapons in war theaters, such as Afghanistan or Iraq: they are easy to find and their explosion, which may be triggered also by a small explosive charge, will cause many fatalities due to burns, shock wave, debris from collapse of buildings and projection of fragments of the vessel itself. Tankers carrying liquefied flammable gases may be an even better choice, from a terrorist point of view, since they may cause a more powerful explosion. Road transport of toxic substances seems less suitable for attacks, taking into account that these materials represent a very small fraction of the overall road transport of dangerous goods, so terrorists have fewer opportunities to catch a tanker. Furthermore, the intentional release of toxic materials is less likely to cause multiple fatalities in open places, becoming actually dangerous only inside buildings or tunnels.

However, as far as terrorism groups and the existent threat they would use HazMat transports are concerned, it is not easy to say whether this opportunity will really tempt such organizations, even if, it is well known that terrorists 'passions' are the means of transports in all their facets. Terrorism is a dynamic human phenomenon [21], ready to change its shapes according to geographic position and time of acting.

On the other hand, carrying out a risk and vulnerability analysis for HazMat transports is not a simple task and requires a great number of parameters to be listed and analyzed [22]: (1) the legal or illegal possibility to collect explosives, or chemicals which can be mixed to give an explosive, in order to make homemade bombs; (2) the ability of making operable and efficient IEDs (Improvised Explosive Devices), which depends on the availability of appropriate know-how and technology; (3) the easiness of attacking a HazMat transporting vehicle, which may depend on the frequency of passage and on the presence of measures of prevention; (4) the possibility for a HazMat transporting vehicle to become a weapon, and the fatalities it can cause, which depend, primarily, on the characteristics of the chemicals, but also on the location where its content might be intentionally released. A recent paper [23] focuses attention on the emergency management following a terrorist attack in the transport of hazardous materials in urban areas.

3 SECURITY DEVICES AND PROCEDURES

A preliminary scheme aiming at increasing the security level of the transportation of hazardous materials has already been presented [24]. In the present section, a more detailed analysis of some security devices and procedures will be discussed. Regardless the specific devices to be selected, it is proposed to provide the vehicle transporting HCDGs with a 'security box', including a selection of hi-tech devices with the aim of enhancing the security in the transportation of hazardous materials. A complete 'security box' will not necessarily be required on all vehicles transporting dangerous goods: smaller companies may properly reduce the number and complexity of devices, and the same can be done for vehicles transporting less hazardous, or less attractive, materials. Nevertheless, devices and procedures description, and some cases examples, will allow to give the right attention to the potential of the security system and to the types of materials/transports the different types of 'security boxes' can be referred to.

In this view, a preliminary HazMat classification would be very useful according to the level of risk relevance. The list of HCDGs, in fact, includes too many products (e.g. fuels) and transport activities: as a consequence, providing each vehicle with all the available or suggested safety devices, or implementing all the proposed security procedures, may be very expensive. From this point of view, a preliminary guideline to properly graduate the amount of devices and the complexity of procedures to be adopted in each specific case may be obtained grouping the HCDGs according to the rank suggested in the previous section. It should be considered the importance to apply the most proper technological devices to HazMat transport, as already suggested by Tate and Abkowitz [25] who distinguished them based on the different areas of application, safety and security. In the following, the adopted classification is presented.

3.1 Security system

The core of the proposed system is a remote central control room which interacts with a 'security box', installed on the vehicle.

The remote control room may be located in the main office of the transport company, or of the delivering or receiving ones, and may survey the trips of a number of vehicles. It is supposed to be looked after and monitored by a 24/7 real-time operator (a shorter period might be adopted depending on the needs of the specific transportation case). The room operator should register and watch over all the data concerning the HCDG vehicle trip before and during the motion, receive the alarms, activate the remote operating devices and interact with the driver, when needed or requested.

The 'security box' may be composed of a number of modules, which can be added on a case-by-case criterion, according to the requested protection level for the vehicle under consideration, connected to a main module, which can integrate already existing functional modules to reduce the final cost as much as possible. The main module should be powered by an internal battery, charged by the electrical system of the vehicle, in order to be totally autonomous and to be working even in the case of loss of the main electrical supply.

The devices included in the main and/or in the additional functional modules may be grouped according to their intended purpose and may require or not the intervention of the driver or of a remote operator to be activated. Devices located on the vehicle, and working non-stop, may include a tracking apparatus, sensors to measure the speed of the vehicle and its distance from the preceding and following vehicles, and bumping sensor. These devices may allow the remote operator to know at each time the position of the vehicle, and to be informed about problems encountered during the trip, such as traffic jam or an accident. Some of these devices are rather common, and are already often installed, for example, to obtain a reduction of insurance fees.

Other devices may require to be activated, either by the driver or by a remote operator, or only by a remote operator. For example, the driver may activate an emergency button or a biometric interface; both driver and remote operator may separately activate communication and antitheft devices (blocking the doors, preventing that the vehicle is set in motion, or activating an automatic procedure to slow down the vehicle until it stops); the remote operator may activate video surveillance, should a problem occur (accident, theft attempt, etc.). The additional modules and devices that may be included in the security box are listed in Table 2; their relevant aspects are analyzed in the following paragraphs.

Thanks to its modular and flexible structure, it is possible to graduate the complete security box into a number of devices characterized by different levels of functionalities, according to the hazard posed by the materials transported by the vehicle to protect and to the available budget. A basic arrangement of the security box, including a tracking device (GPS), cellular communication, fingerprint detection and emergency button, may cost just about 1000 €; the expenses for a full optional security box, including also satellite communication, sensors, antitheft devices and video surveillance will rise to about 3500 € (for further details about costs, see [24]).The suggested configuration of the safety box for the transport of low, medium and high attractiveness HCDG is also reported in Table 2.

3.1.1 Tracking apparatus

The first type of safety devices to be considered (as also suggested by ADR) is a tracking apparatus, which may be a normal GPS providing the geographic coordinates both to the driver and to the remote operator, and allowing the latter to monitor the movement of the HCDG vehicle. A GPS may be already installed on some vehicles transporting HazMats, but, in Italy, it is not routinely installed on all such carriers: this choice may be motivated based on financial resources and on the insurance policies. GSM devices were already considered suitable in the past for particular scenarios (for example, theaters of war, such as Afghanistan) and, on the civilian side, they may be useful, especially when the vehicle has to deliver goods to different spots, even if problems arise concerning the workers' privacy. In 2010, a worker at Telefonia Alto Adige s.r.l. lodged a complaint against her employer, because every van of

Table 2: Additional modules that may be included in the security box and suggested configuration for the transport of low, medium and high attractiveness HCDG.

		HCDG attractiveness			
Module	Operation	High	Medium	Low	Activation
Tracking	GPS module	X	X	X	Always on
Communication	Cellular phone	X	X	X	By the driver or the remote operator
	Satellite communication	X			
Biometric interface	Fingerprint detector	X	X	X	By the driver
Emergency button	Sends an alarm to the remote operator	X	X	X	By the driver or the remote operator
	Activates video surveillance (if available)	X			
Vehicle modules	Bumping sensor	X	X		Always on
	Front-rear vehicle distance sensor	X	X		
	Vehicle velocity module	X	X		
Antitheft module	Sends an alarm to the remote operator	X	X	X	By the driver or the remote operator
	Progressively slows down the velocity until the vehicle stops	X	X		
Video surveillance	In case of emergency allows the remote operator to see what happens inside and/or outside the vehicle	X			By the remote operator

the firm had a GPS mounted on, which was used not only to inform about the localization of the vehicle but also to give information about staff's idle times, fuel consumption and driving speed. In the end, authorities prohibited the use of global positioning devices on Italian firms' vehicles in the absence of the approval from Labor Unions and the Provincial Labor's Head Offices. As shown above, security can clash with privacy, and their relationships should be properly taken into account, since cargo tracking is the first aspect to be considered in HazMat transport security.

3.1.2 Communication devices

Mobile phones can be used for both voice and data communication, which can be very useful for security purposes: they are widespread and any driver is usually provided with a company cellular phone. Cellular phones can be used to communicate possible inconveniences of any type (traffic jams, need of detours, bad weather conditions, health problems of the driver, etc.) to the remote operator, as well as to transmit data (alarm, videos, etc.). One problem is that the signal coverage may be poor or null, especially in narrow valleys, mountains routes, and inside most of the tunnels, conditions that are not infrequently encountered in Italy. Satellite communication can be used in such cases, being also useful to increase the availability of means ensuring phone contacts in all situations. Satellite may generally represent a redundant channel with respect to the cellular communication, while may become the primary transmission channel in areas where the cellular service is not active.

An important aspect to deal with is the possible inattention caused by the use of hi-tech devices while driving: in this view, the impact of cell phones use on drivers' attention (focusing on text messaging, in particular), on driving performances, and on possible consequent road accidents has been investigated [26].

3.1.3 Driver identification

Ensuring that the vehicle carrying a dangerous material is driven by the expected person is of paramount importance, and a simple biometric interface may fit this scope. The device will be composed by a touch screen and the biometric interface: fingerprint detection will ensure reliable results with low costs. Driver identification may be required at any time the engine of the vehicle is started, to ensure that the appointed driver is actually at the wheel. This device should be activated by the driver before starting the engine of the vehicle: should the driver identification procedure fail, the engine will not start and an alarm may be automatically sent to the remote operator.

3.1.4 Emergency button

This button, to be located in an easily reachable place on the dashboard, may be activated by the driver in any case of emergency, including problems related to the vehicle (for example, in case of accident) but also situations posing security problems (for example, the vehicle being blocked by armed persons).

3.1.5 Vehicle modules

These devices may include sensors of front-rear vehicle distance and bumping, and a velocity module. Their scope is to allow the remote operator to identify if any problem is occurring to the vehicle during the trip and behave consequently. Detecting vehicle velocity, and distance from the preceding and following vehicle, will allow to understand if the vehicle is slowed down by heavy traffic, or blocked in a queue. Bumping sensors will let to immediately detect if an accident occurred, allowing the remote operator to contact the driver and eventually alert the competent authorities for rescue. The velocity module can also be activated by the remote operator to progressively reduce the speed of the vehicle until it stalls: this function can be useful, for example, to safely stop the vehicle when it is not driven by the expected person.

3.1.6 Antitheft module

This module may be used either by the driver or by the remote operator to check and prevent theft of the vehicle and of the transported material. The basic tasks are to send an alarm to the remote operator and: to block the doors, or to avoid that the engine of the vehicle may be started, or to slow down the engine progressively after a predetermined time interval. This device is mainly intended for those situations when the driver may be forced to enter and drive the vehicle under the threat of armed people. In such cases, the driver may be forced to positively activate the driver identification check, since his/her life may be threatened if he/she is unable to start the engine. A simple method to deal with this problem may be to install an accurately hidden safety button, to be pushed within a predetermined time (for example, 2 min) from the start of the engine. If the button is pushed within this time, the vehicle will proceed regularly with its trip, but if this step is not properly performed, an alarm will be automatically sent to the remote operator. Then, the operator can activate the velocity module, causing the vehicle to automatically decelerate as long as it stops. In this case, precautions should be taken to avoid that the vehicle is stopped next to a densely populated area.

The time delay between the start of the engine and the stop of the vehicle (and the distance traveled by the vehicle meanwhile) may allow the driver to go away safely, if he/she is released as soon as the vehicle is set in motion. Alternatively, if the driver is hold as a hostage, he/she may ascribe the stop after few minutes of regular travel to some mechanical failure, possibly avoiding to suffer damages and to endanger his life.

3.1.7 Video surveillance

Video surveillance, using cameras and microphones located outside the vehicle or inside the cab, may provide to the remote operator useful information, should a problem occur during the trip. The device may be composed of an internal video-camera and microphone, providing information of what is happening in the cockpit, and four external cameras, located on the front side, on the rear side and on the two lateral sides of the vehicle. The data will be transmitted by means of the available communication channels (cellular, satellite). The remote operator may activate the video surveillance in case of an emergency reported by the driver, or resulting from the sensors.

It is obvious that video surveillance, if not properly used, may pose severe privacy problems: therefore, its on/off state should be easily recognizable by the driver, for example by means of proper warning lights or acoustic signals.

3.2 Security procedures

The modules of the security box has been thought and designed to face different kinds of attacks, trying to imagine the various situations and the places where they might happen during the journey of the vehicle. The objective is preventing those events from occurring and, at the same time, avoid to complicate the driver's work too much, and preserving his/her privacy. Even if 'ad hoc' technological devices can be combined and used to improve security of people, vehicles and goods, at the same time, in order to achieve these objectives a mentality change towards work conditions and statements in HazMat transports is required.

The tasks requested to the remote operator ant to the driver are not expected to be very demanding; nonetheless, a specific training may be required. Basically, in this procedure, different scenarios can happen: in some situations, the alarm will be given automatically, in others a contact will be required between driver and the remote control operator and in others the alarm responsibility will be on the driver. The use of coded messages may be considered, although much easier to be confused or misunderstood. It is clear that procedure laboriousness and complexity can bother the driver somehow (they probably are reluctant to apply changes) but, at the same time, the application of prevention measures should not find hostilities.

In the following paragraphs, the most usual operating procedure will be outlined, assuming that the complete set of security modules are installed on the vehicle. All procedures, except those requiring the video surveillance system, the satellite communication and the vehicle modules, can be adopted also with the basic functions of the security box, and at a very moderate cost.

3.2.1 Planning the trip

The first task of the driver, before getting into the vehicle, is to accurately plan the trip and to inform the remote control operator about this route through the GPS the vehicle is equipped with. The path to reach the destination should be chosen in a very coherent and safe way, possibly avoiding/reducing the proximity with built-up areas, schools, critical points and any other places which could put in danger many people, should a spill occur. If the path is changed without informing the remote control, an alarm will start automatically.

3.2.2 Starting the vehicle

The second step the driver must comply with is the fingerprint check, which is the only way to verify that the right-driver is on the right-vehicle. If the fingerprint is not recognized the engine will not start and an automatic alarm will alert the remote operator. After passing this check, the vehicle can be set in motion. However, within a predetermined time interval (for example, 2 min), the driver should push a hidden safety start button, intended as a measure to guarantee the driver safety, if under threat by terrorists or criminals. If the button is not pressed after the biometric control confirmation, the remote operator will be alerted by an alarm and he/she may activate remotely operated velocity module to decelerate the vehicle as long as it stops.

3.2.3 During the trip

After the vehicle is in regime motion, a number of different controls will follow its travel. The driver should immediately inform the remote control operator about route change requirements (for example, due to ordinary traffic causes), otherwise an alarm will start.

A particular case is represented by tunnels, which are potentially critical spots, since GPS signal is generally not available inside. This issue may be faced taking into account that the itinerary has been preliminarily set on the GPS, where the presence of tunnels is highlighted. Based on the tunnel length (recorded in the GPS cartography), and assuming a reasonably low average velocity of the vehicle (for example, 30 km/h), the time required by the vehicle to travel through the tunnel can be estimated. When the vehicle enters a tunnel GPS signal will be interrupted, being resumed as the vehicle exits from it: if the vehicle takes longer than the expected time, the central operator may call the driver to check about the situation. Another way to deal with this issue may be that of getting information from the sensors on the vehicle, about its velocity, and to adjust the expected travel time inside the tunnel. Front-rear sensors, giving the distance from other vehicles, may also indicate whether the vehicle is trapped in a traffic jam. Due to the great number of tunnel encountered in Italy, and some other Countries, it seems reasonable to apply such procedures only to the long ones (for example, to those longer than 1 km).

Should an accident occur, the bumping detection module will automatically give an alarm to the remote operator, who will ask for proper aid (fire brigades, hospitals, etc.).

3.2.4 Parking

Another issue to be considered is the need of stopping the vehicle during the trip, to allow the driver to eat, take a rest or any other reason. In this case, the driver may call the remote control operator to inform that he/she is stopping the vehicle, and the approximate duration of this stop. Alternatively, a ‘standard’ rest time (for example, 45 min) can be set, and an alarm may be automatically sent to the remote control operator, if the GPS indicates that the vehicle is still parked in the same place after the planned rest time: the operator will call the driver to check what is happening.

3.2.5 Emergency

In any case of danger, and especially if threatened by means of weapons, the driver may give directly an alarm to the remote control through an appropriate emergency button. In this case, the remote operator will switch on audio (microphones) and video (inside and outside cameras) modules to have a clear idea of what is occurring, in that moment, inside and outside the cab. This will occur also every time an automatic alarm is given, on the assumption that an emergency situation is in progress. Depending on the cases, the operator may call the driver, remotely activate the procedure forcing the vehicle to decelerate until it stops, prevent the engine to start again or start directly the procedures to ask for aid.

4 CONCLUSIONS

A great number of conventional substances, such as fuels, are commonly used in many civil and industrial applications and are transported almost everywhere by different means of transportation. In case of release, they can cause severe consequences either to structures and infrastructures, and to the possibly exposed population: this makes conventional hazardous materials very attractive from a terrorist's point of view. Some of the main security issues associated with the transportation of these High-Consequences-Dangerous-Goods have been addressed in the present paper.

A flexible system characterized by a modular structure has been proposed, based on already existing technologies, which are relatively inexpensive. The complexity of the system, in terms of required modules, supporting technologies and relevant procedures should be adapted to the particular needs and to the level of hazard posed by the specific transportation case under investigation. In such a way, the proposed methodology might markedly improve the security of many transportation activities. Besides the main issue of the vulnerability to external threats, other aspects have also been taken into consideration, aiming at limiting the complexity of the procedure, its interference with the ordinary transportation activities and at protecting the privacy of the involved working personnel.

The analysis has shown that even if the risk associated with possible terrorist attacks cannot be totally eliminated, nonetheless the adoption of proper actions, such as an accurate choice of the route, the identification of the most vulnerable spots and the adoption of adequate security measures, suitable devices and proper procedures, can sensibly reduce the hazard.

The main limitation to a widespread and full application of the proposed procedure, or of other possible alternative security measures, is probably associated with budget reasons: it may be initially deserved to the most hazardous products only. To this end, the different classes of HCDGs have been ranked based on their potential attractiveness for terrorists. In spite of this, the number of transport activities to be protected can remain still extremely high: just to give an example, the most attractive materials include flammable gases, such as LPG, that is frequently and capillary transported. Nonetheless, thanks to the continuously decreasing costs of the hardware components of the security systems, even smaller companies, local or short range transfers, or less hazardous materials, may progressively benefit from the adoption of such security measures, with a marked reduction of the target vulnerability and a corresponding increase of the security for the possibly exposed population.

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