

A GIS tool for the emergency management of terrorist actions in the transport of hazardous substance

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The management of the terrorism risk is very complex, it requires a systematic and structured methodology that permits an exhaustive analysis of the possible modes of attack and the definition of the vulnerability for the system concerned.

This work shows the application to a case study of an effective approach that allows the estimation of the possible damage due to a terrorist action during the transport of dangerous materials and gives some fundamental elements for the management of the emergency. For the correct management of the emergencies the knowledge of the time evolution of some events is an essential element. Thus the study of the evolution of accidental events is the main objective of this paper.

1. Review of accidents

Terrorist attacks have increased in recent years. As result of the attack to the Twin-Towers and the Pentagon, it has been considered necessary to develop and implement counter terrorist measures for all activities involving the handling and transport of dangerous substances. Particular attention must be paid to the transport of dangerous substances as the hazard may be greater than that for chemical plants because of territorial vulnerability.

There are also other meaningful events that have taken place in transport systems, in particular the incident of the 11/03/2004 in the suburban rail system of Madrid. There were a series of explosions aboard trains and in some railway stations, with a total of 198 dead and 1274 injured.

On the 07/07/2005, the first day of the 31st G8 Conference, three bomb explosions occurred on London Underground trains, and another bomb destroyed a bus in the city centre, 56 people were killed and 700 injured in the four explosions. Some days later, on 21/07/2007 there were three small explosions on the London Underground system and on a double-decker bus.

It is also necessary to mention the incidental scenarios caused by terrorist attacks or sabotage during the transportation of dangerous substances. On the 22/07/2005, in Iraq, there was a very serious terrorist action, an attack caused the explosion of a road-tanker transporting gasoline, while it was parked near the Shiite Mosque of Musayyib, south of Bagdad. At least 60 dead and 82 injured were reported. More recently, on 27/03/2007 in

Tal Afar, Iraq, the explosion of two road-tankers transporting a toxic product, probably chlorine, killed 152 people and injured 347. Chlorine has been used in suicide attacks in Iraq 5 times. In May a suicide truck bomb killed 50 people and injured 115 in Makhmur, in June a truck bomb blast on a square near to a mosque in Bagdad killed 75 people and wounded 204.

Another important event happens in June 2007: police found two car bombs in central London and were able to prevent their explosion. Less than 38 hours later two men rammed a jeep into the terminal building of Glasgow airport. The three car bombs contained large amounts of propane and gasoline. The bombs were possibly meant to be an explosive-actuated incendiary devices. Such devices, more commonly called firebombs, work by using a relatively small low-intensity explosive charge to ignite a more volatile flammable material. This results in an intense, rapidly spreading fire that can quickly engulf a confined space such as a building, or a semiconfined space such as an urban area. The amount of flammable gas apparently recovered in these incidents would have been sufficient to create a massive fireballs.

2. Aims

This paper shows the application of a methodology for the analysis of incidental scenarios caused by terrorist attacks to a case-study. At the same time the work gives some fundamental elements for the management of the emergency, in order to make this, the knowledge of the time evolution of some events is an essential element.

The study of the evolution of accidental events is the main objective of the paper because the dynamics of these scenarios is essential for a rapid and realistic perception of the evolutions of these events in space and time. To achieve this aim dynamic scenarios have been constructed using a GIS software.

3. Risk Assessment

The approach used for the application to the case-study can be summarized in the following phases:

- Characterization of the areas considered potential targets for terrorist actions;
- Definition of the characteristics of the area (manufacturing site and/or characterized by transport of dangerous substances);
- Qualitative study (identification of incidental scenarios);
- Quantitative study of the incidental scenarios.

The first and the second phases of the method regard the census of all the information characterizing the area in which there is the potential terrorist target, such as a manufacturing site which can also be characterized by the transport of dangerous substances.

3.1 Identification of potential target

The aim of sabotage or terrorist attack is not only to create the greatest possible damage, but also to destabilize normal life. Generally the sites, considered potential targets, are characterized by some strategic elements.

In order to identify potential terrorist target it is necessary to develop a methodology based on an index method. In 2003 the API-NPRA (American Petroleum Institute and National Petrochemical & Refiners Association) have developed a methodology to provide assistance by facilitating the development of sector-specific guidance on vulnerability analysis and management for critical asset protection for the chemical manufacturing, petroleum refining and liquefied natural gas (LNG) sectors. A second approach to the problem of the vulnerability of chemical plant to terrorist attack is described in a report by the SFK (Stör-Fall Kommission, German Hazardous Incident Commission).

In Italy, a project supported financially by the Italian Department of Civil Defence is in course, the aim of this project is the mapping of potential objects of terrorist attack in Italy. The study is carried out by the CONPRICI Consortium (CONsorzio interuniversitario per la PREVENZIONE e la Protezione dai Rischi Chimico Industriali), an association of seven Italian Universities (Bologna, Messina, Politecnico di Milano, Napoli, Padova, Pisa and Roma "La Sapienza"). The consortium is a scientific and technical consultant to the Italian Department of Civil Defence and the National Commission for the prevention of Major Hazards. The impact areas including data of population and vulnerable centres has been determined, the data has been implemented in a GIS (Geographical Information System) platform.

An evaluation of the risk of an installation against terrorist attacks, called "Attractiveness" of the target, has been carried out using a multi criteria approach based on:

- Quantity and physical/chemical properties of dangerous substances in the site;
- Characteristics of the plant;
- Vulnerability of the surroundings.

Using this approach sites at greatest risk (Highly Attractive) in Italy can be selected.

The project will have a profound and positive impact on all sectors when it is fully developed and implemented. It will help define the facilities and operations of national and regional interest for the threat of terrorism, define standardized methods for analyzing consequences, vulnerabilities, and threats, and describe best industrial security practices. This study has provided the damage curves derived from incidental scenarios caused by terrorist attacks for the examined area. The effects map can constitute an important source of information for those have to enact specific emergency civil defence plans and also for those have to apply protection and/or mitigation measures for the exposed population.

3.2 Description of accidental scenarios from terrorist actions

Recently Lisi *et al.* 2007 have proposed an approach which allows the description of the sequence of events following a terrorist action. This approach has the aim of describing the overall scenario, defining the evolution of such actions starting from the initial cause and ending with the final catastrophic event, thus the overall scenario can be studied

considering it a sequence of simple steps. The study of the incidental scenarios caused by sabotage or terrorist attack can be made by considering these phenomena as primary events whose consequences hit a target. The hit target generates a secondary event which is able to widely spread the hazardous consequences of the first one. The primary event causes the release of a great amount of energy or toxic substances, thus the final consequences cause serious effects to the population, infrastructure and environment.

3.3 Quantitative risk assessment

Quantitative risk analysis including terrorist actions can be executed using the classical procedure adopted for chemical plants and the transport of dangerous goods (CCPS, 1995 and Advisory Committee on Dangerous Substances, 1991), furthermore this methodology must take into account also the scenarios caused by terrorist attacks and therefore it must quantify the increased risk due to this type of event. This methodology must include the following phases:

- Frequency evaluation for the primary event;
- Frequency evaluation for the overall scenario;
- Consequences evaluation for the overall scenario.

4. The application to a case-study

The proposed methodology has been applied to a real but anonymous area. It is an urban area of high density of population, with a number of vulnerability centres distributed along the main road routes. Chemical plants and storage tanks are not present in this area, however, a large number of road-tankers transporting dangerous substances cross the downtown, for this reason the area is characterized by high level of risk.

The route under investigation, is the connection between the main urban road and the highway exit, approximately the traffic flow is 1.200 vehicles/hour, this meaningfully increases the number of subjects exposed to potential incident scenarios. The high population density, the characteristics of the route (steep slopes), the presence of a great number of centres of vulnerability distributed along the route are some of the factors that make this area a potential target for terrorist attack.

The identification of the critical areas for terrorist actions can be made on the basis of a census of the substances and the targets.

In order to mitigate the effects of the incidental scenarios it is necessary to define the damage zones and to produce a map of the effects. In this study attention has been focused on two types of incident, toxic dispersion and explosion, since these can be considered the most catastrophic events.

4.2 GIS tool for emergency management

The damage map can constitute an important source of information to develop specific emergency civil defence plans and to apply protection and/or mitigation measures for the exposed population. A very efficient tool is represented by the implementation of the map of the consequences on a GIS platform. Two examples of this kind of application are reported.

Figure 1 show the scheme of car bomb containing propane and gasoline similar to those found in central London in June 2007.

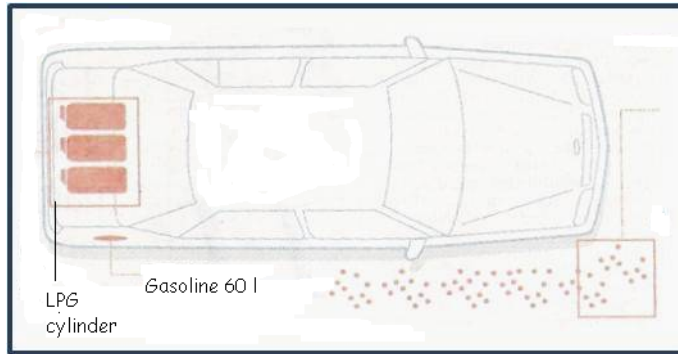


Fig. 1. Scheme of a car bomb.

Figure 2 shows the results of a simulation of the consequence of a fireball generated by the car bombs in the case of complete success of the event. The map of the consequences of the attack is shown in figure 3. The circle represents the area in which an high probability of fatalities is observed. The GIS interface permits an immediate visualization of the target area including the presence of vulnerable centres.

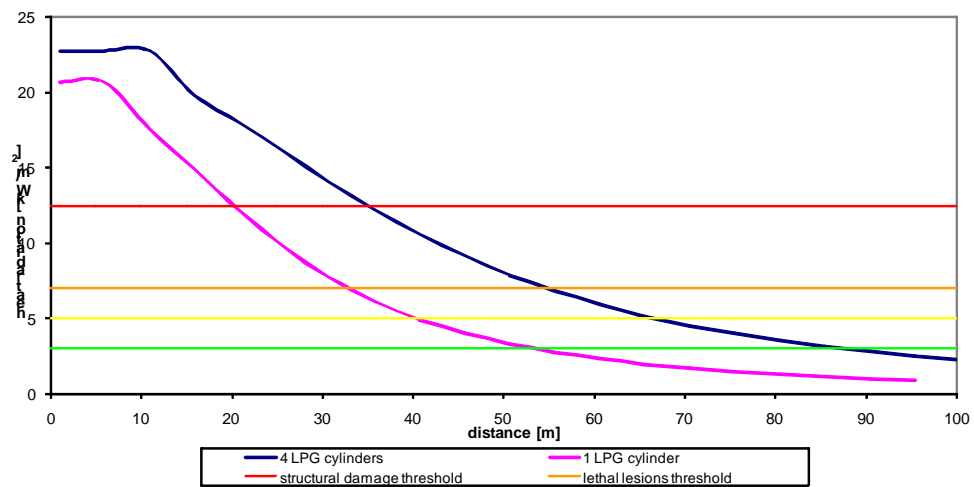


Fig. 2. Consequence of a fireball generated by the car bomb.



Fig. 3. Map of of the consequences of the attack.

4.3 Dynamic description of the dispersion

Concerning the case-study, Lisi *et al.* 2007 have produced the effects map for a dispersion of chlorine. In this work, using a GIS tool developed in our laboratory, it has been possible to have a dynamic description of the time evolution of the plume generated by the incident and as a consequence the determination of damage area as a function of time. This kind of dynamic effects map can constitute an important source of information for those who have to enact specific emergency civil defence plans and, moreover, also for those who have to apply protection and/or mitigation measures for the exposed population. Figure 4 shows an image of the dynamic simulation of a catastrophic release of chlorine due to the explosion of a road tanker in an urban area (case-study).



Fig. 4. An image of the dynamic simulation.

5. Conclusions

The problem considered in this paper is of great interest, because in recent years the areas susceptible to terrorist attacks have been widening. The methodology applied in this work has the aim of outlining the scenario associated with a terrorist attack or sabotage. The case study is a city characterized by the transport of a large quantities of hazardous materials. Even if it may not be the principal object of a terrorist attack, this kind of city has all the characteristics of a potential target in terms of territorial vulnerability. The high number of road and rail tankers transporting dangerous substances in the urban area and the presence of numerous vulnerable centres along the main transportation routes are typical of areas subject to terrorist attacks.

This study has provided the damage curves that would derive from incidental scenarios caused by terrorist attacks for the examined area. The effects map can constitute an important source of information for those who have to enact specific emergency plans of civil defence and, moreover, also for those who have to apply protection and/or mitigation measures for the exposed population. The damage curves also allow considerations to be made regarding possible alternatives in the transport of dangerous substances using different routes at different times of the day. In particular in this study, the continuous monitoring of road/rail tankers and the typologies of substances crossing the urban areas has been suggested. This is possible using appropriate control systems located at the motorway exits or at critical points along the main routes used for the transport of dangerous goods.

The methodology applied needs to be implemented in order to improve the use of safety methodology also for security problems. In this work the definition of probability classes for the primary event relative to the targets has been proposed. Combined with the consequences results, this permits the identification of risk indices. These indices could be useful in emergency planning and for the location of the protection measures for the possible targets.

6. References

- Advisory Committee on Dangerous Substances, 1991, Major Hazard Aspects of the Transport of Dangerous Substances. HM Stationery Office, London, Great Britain.
- American Petroleum Institute and National Petrochemical & Refinery Association, 2003, Security Vulnerability Assessment Methodology for the Petroleum and Petrochemical Industries.
- CCPS, 1995, Guidelines for chemical transportation risk analysis. AIChE, New York, USA.
- Lisi R., Maschio G. and Milazzo M.F., 2007, Terrorist actions in the transport of dangerous goods in urban areas. IChemE SYMPOSIUM SERIES NO 153, proceeding of 12th International Symposium "Loss Prevention and Safety Promotion in the Process Industries", Edinburg, Great Britain.
- Stör-fall Kommission (SFK), Report of the German Hazardous Incident Commission, SFK – GS – 38, www.sfk-taa.de.