Transportation Research Part A 118 (2018) 280–291

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Design solutions to improve resilience of metro vehicle to blast events

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ARTICLE INFO

Keywords:
Terrorism
Railway safety
Security
Resilience
Human factors
Explosions

ABSTRACT

Considerable effort is being devoted by researchers and stakeholders in order to improve the safety of metro systems with regard to terrorist attacks. The issue has been addressed by many researchers, taking into account the bow-tie model of safety management, in which the node is the terrorist attack, with on one side the causes of the attack (e.g. political issues, technical weaknesses) and on the other side the consequences (e.g. human, organisational, economical). The common goal is to implement a line of defence to isolate these causes and consequences, in order to prevent the attack from occurring and, should it happen, to mitigate its consequences as much as possible. This work takes into account the identified common attack methodologies and the behaviour of the surviving passengers in order to improve the situation management, assist the evacuation of and rescue to survivors. Moreover, technological improvements to the structure and critical systems of the vehicle have been devised and tested in real situation. This paper focuses particularly on the behaviour of people in blast situation, and presents the conclusions of the project on these effects and the related improvements of the vehicles design in order to improve resilience and survivability to blast.

1. Introduction

Considerable effort is being devoted by researchers and stakeholders in order to improve the safety of metro systems with regard to terrorist attacks. The issue has been addressed by many researchers, taking into account the bowtie model of safety management, in which the node is the terrorist attack, with on one side the causes of the attack (e.g. political issues, technical weaknesses) and on the other side the consequences (e.g. human, organisational, economical). The common goal is to implement a line of defence to isolate these causes and consequences, in order to prevent the attack from occurring and, should it happen, to mitigate its consequences as much as possible. A general discussion of this approach is given in (Khoudour et al., 2011).

Several research projects have addressed specific elements, or full sets of integrated solutions implementing technological and organisational measures to increase the effectiveness of this line of defence. An example of such current project is SECUR-ED (http://www.secur-ed.eu) which aims at providing and demonstrating a full, interoperable set of tools. Another example is PROTECTRAIL (http://protectrail.eu) which aims at designing a scalable solution integrating a modular set of sub-mission protection tools for railway security, such as passenger clearance control, electrical or communication systems. A last example is MODSAFE (http://

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https://doi.org/10.1016/j.tra.2018.09.015
Received in revised form 10 July 2018; Accepted 11 September 2018

www.modsafe.eu), focused on the establishment of a common European strategy including safety and security measures.

In this scheme, our goal is to improve the preparedness by mitigating the consequences of an attack to metro vehicles, which we show to be a particularly sensitive target in terms of both attractiveness and consequences. In the framework of the European FP7 SECUREMETRO project (http://www.securemetro.com/), researchers from different fields are studying various improvements to metro vehicles in order to improve the resilience and survivability of the vehicle, its passengers and the transport system as a whole, in order to minimize the material and human damage caused by a bomb or a fire, improve the capacity to resume normal operation, and thus make public transport systems a less attractive target for terrorist attacks. A notable part of the efforts is devoted to improving the immediate response after the blast, in order to ensure the capacity of the survivors to alleviate fear, avoid panic, facilitate rescue, and more generally to improve the situation management. Our work is based on past experience of metro bombings, as well as similar works in related domains such as building fires.

2. Analysis of past threats and evolution

This work was carried out for a good part using the Data-base of Worldwide Terrorism Incidents of the Rand Corporation (RAND Corporation database, 2013) and the University of Maryland's Global Terrorism Database (University of Maryland's Global Terrorism Database, 2013). We have chosen to distinguish two timeframes covering the last 5 decades (1960–2010), in order to assess the long-term trends as well as the recent evolution.

As the databases include all the types of terrorist attacks perpetrated during the period, we disaggregated data according to the aim of the SECUREMETRO project. Considering the *target* of the attack as the main filter for the selection of relevant cases, we focused on events involving strictly rail-based public transportation assets.

Although SECUREMETRO is a project aimed at increasing the safety and security of metro vehicles, we extended the survey also to terrorist attacks perpetrated to train systems (national, regional and suburban surface railways), due to the belief that techniques adopted and trends emerged in the train sector are easily (and usefully) comparable with those of characterizing the subway systems.

Over the last decades, the number and nature of terrorist attacks in rail-based transports have evolved in considerable proportions. An exhaustive survey based on databases covering the 1960–2010 period, has found that in 50 years 833 attacks killed about 3500 people and injured more than 15,000. Moreover, it has been found that both attacks and victims have known a sharp increase since around 1980 (Fig. 1).

The tactic used for perpetration is of particular importance to devise ways to mitigate the effects of the attack. Out of the 833 attacks in the data bases, bombing is used in 73% of the cases. If we consider the weapons (Table 1), bombs are by far the most used way to carry out attacks, not only bombings *per se*, but also other types of attacks such as sabotage, threat or mixed tactics. These proportions have not significantly evolved over the last decade.

This appears even more clearly in the number of victims (RAND Corporation database, 2013; University of Maryland's Global Terrorism Database, 2013), with 70% of the fatalities (2541 out of 3457) and 77% of the injuries (7832 out of 10,682, if we don't take into consideration the 5 killed and 5205 people injured in the sarin gas attack against the Tokyo metro in 1995, which remains the only one of its kind so far) caused by bombing during the considered period, making it the deadliest type of attack.

3. Key systems to increase resilience

This section deals with the measures that can be implemented to promote the resilience of the vehicle and passengers during and after the event, in order to carry out the best possible evacuation and rescue operations. The SECUREMETRO project has devoted its efforts to defining a generic method of mitigating the effects of attacks. It has however appeared that the use of data from well-selected specific examples allows to gather useful data and devise measures that can then be assessed for effectiveness in general

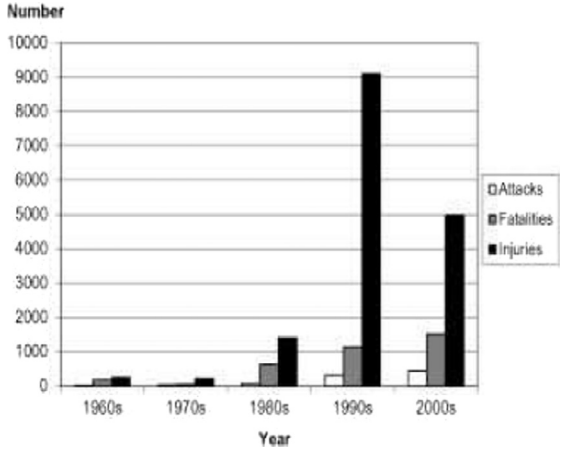

Fig. 1. Historical evolution of attacks, fatalities and injuries.