SENSE4METRO: A BI-NATIONAL MULTI-DISCIPLINARY PROJECT FOR MONITORING UNDERGROUND METRO ENVIRONMENTS IN DISASTER EVENTS

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Abstract

The current trend towards global urbanization and the resulting migration to underground mass transportation has resulted in an increase in security related challenges, whether due to terror attacks or natural disasters. Such mass transportation systems are highly vulnerable and require new approaches to minimize vulnerabilities and limit damage in the event of disasters.

Since 2015, several German and Indian institutions have been engaged in the bi-national and multi-disciplinary project SenSE4Metro as part of the “Indo-German Initiative for Civil Security Research (IGI-CSR)”. The overall objective of the project is to improve the security of persons in urban underground trains and stations in emergency situations, specifically terrorist attacks and natural disasters.

This paper presents the multi-disciplinary approach applied, a discussion of the state-of-the-art and the initial results of the project, including the threat and requirements analysis.

Keywords: structural monitoring, energy harvesting, critical infrastructure.

1 INTRODUCTION

Global urbanization contributes significantly to the economic, social and cultural development of nations. At the same time, the requirements for urban transportation systems are increasing. The result is a migration to underground mass transportation systems, whereby new security-related challenges arise. The most recent examples of terror attacks [Madrid, 2004 and London, 2005, Moscow 2010, Minsk 2011, Brussels 2016] and natural disasters [Prague 2002, New York 2012] or other fatal accidents

[Valencia 2006, Moscow 2014] demonstrate the high vulnerability of mass transportation systems. In order to minimize such vulnerabilities, intelligent situational awareness systems and a better understanding of the behavior of passengers and rescue forces during such events are necessary.

2 PROJECT OBJECTIVES

The overall objective of the project is to improve the security of persons in urban underground trains and stations in emergency situations and catastrophes. The emergencies and catastrophes in the context of the proposed project are the result of:

- Terrorist attacks on underground trains and train stations leading to casualties and fatalities as well as massive mechanical damages in the building structure of the underground construction,
- Natural disasters such as earthquakes and flooding, as well as other large-scale disasters leading to structural damages, water ingress, outbreak of fire and/or smoke generation.

3 MULTI-DISCIPLINARY APPROACH

The multi-disciplinary approach to attaining this objective involves the engagement of consortium institutions in research ranging from basic material physics to technological development to individual and group sociology. The project is organized in four research areas defined as specific research objectives:

Analyses of metro environments in terms of vulnerability to explosions, carried out by combining physical material experiments with numerical models of blast effects and propagation, the objective of which being the development of solutions for minimizing the effects of explosions both in terms of prevention of casualties and mitigation of damage to the load-bearing structure.

The development of a security management and emergency response system composed of a wireless sensor network and an information distribution system, undertaken in order to acquire relevant situational monitoring data in tunnels, assess emergency situations and levels, calculate safe access and escape routes and effectively communicate the necessary information to the participating stakeholders (metro operators, rescue forces and passengers).

Sociological and psychological studies of first responder and general population groups through the use of behavioral games, providing insight into and ultimately recommendations for the improvement of rescue protocols and first responder training and the development of man-machine interfaces of emergency management systems.

An historical assessment of social behavior in underground installations in extreme situations, focused on the influence of demographics, as well as national and sub-cultures, on mass behavior, incident management and disaster preparedness in order to design improved communication procedures going forward.

The research in all four areas is regarded in an international context and the consideration of differences in culture, construction and environment are considered central to the advancement of the state-of-the-art offered by the project.

4 STATE-OF-THE-ART

The development of real-time information for passengers and emergency response forces requires precise knowledge of the situation and environment, train location structural health and conditions and movement of threat situations. With the exception

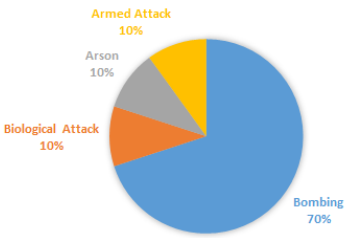
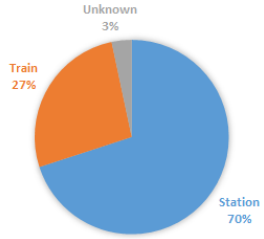
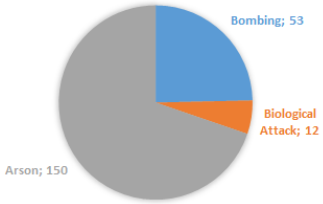
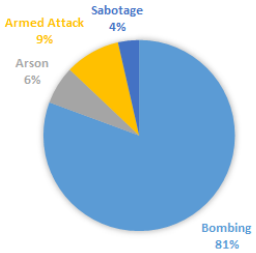
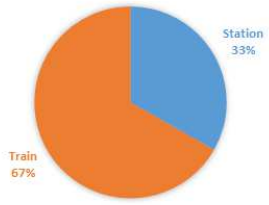
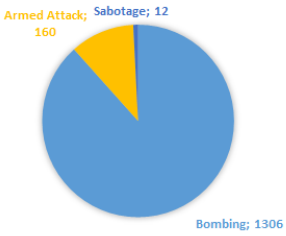
of the release and spread of biological agents [1], such comprehensive situational awareness information for underground trains and stations does not currently exist. The development of system to provide such information represents a significant advancement on the state-of-the-art, as far as mitigating damage during emergency events.

5 THREAT ANALYSIS AND INITIAL SYSTEM DESIGN

A past assessment of terrorist attacks against underground, tunnel and rail infrastructure was performed with the intention of gaining an understanding of the trends in strategy, targeting and effectiveness of such attacks. The assessment was performed using the EMI developed Terror Event Database (TED) and TED Analysis Software (TEDAS). The goal of the assessment was the establishment of event scenarios for the configuration of the security and emergency management system.

The database contains reports of 339 attacks on underground, tunnel and rail infrastructure since the early seventies. The attacks were assessed based on tactic, target, number of casualties and, depending on the tactic, success rate of detonation. The tactics involved: explosives, chemical or biological agents, arson (fire or firebombing), armed attacks and sabotage. The distribution of the data regarding the terror event assessment can be seen in Table 1.

Table 1: Distribution of past terrorist events and fatalities by tactic and target.

	Events by Tactic	Events by Target	Fatalities by Tactic
Underground			
Rail Infrastructure			

It can be observed from the data that both biological and arson attacks in underground environments demonstrate significantly higher casualty rates than other tactics, or the same tactics in the above ground environment. Whereas the deadliest attack tactic in the above ground environment is bombing, averaging approximately 6.5 deaths per successful detonation, in the underground area, a single biological attack and a single arson attack resulted in 12 and 150 deaths respectively.

From the results of the threat analysis, a series of scenarios were defined and rated in terms of relative probability and criticality, from which bombing and arson attacks were considered foremost, due to the combination of frequency and criticality (attacks with biological agents have been assessed in previous studies and lie outside the scope of this project). Although not indicated in the results above, an assessment of the individual events indicated that criticality (in terms of deaths per event) was higher in

the event that underground trains, as opposed to underground stations, were targeted, can likely be attributed to the enclosed nature of the environment. As the project is not limited to terrorist events, earth quakes, flooding and general malfunctions have also been added as scenarios.

The security and emergency management system has been tentatively designed as a series of tunnel-based energy-autarkic wireless sensor networks (WSNs), which report to a central security management and emergency response system (SMERS) server, which handles the distribution of the appropriate information to the relevant invested parties (metro operators, first responders and, tentatively, passengers). The WSN concerns itself primarily with the gathering of raw environment-related situational data. From the raw data, the developed data processor establishes the situational data regarding alarm levels, tunnel segment traversability, and safest access / escape routes based on stranded train location. A superficial system data flow can be visualized in Fig. 1.

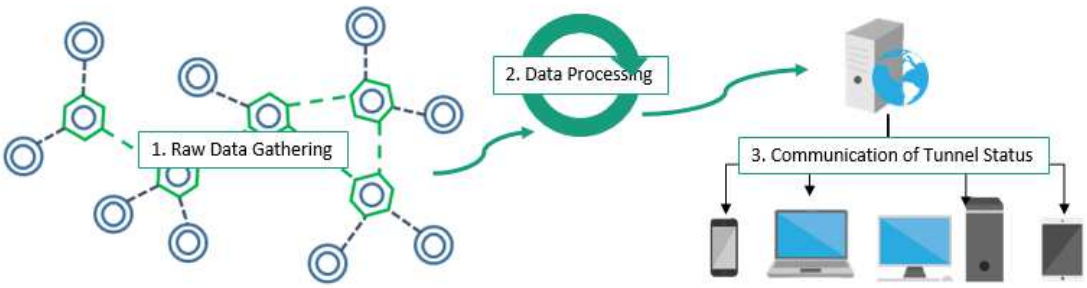


Figure 1: Simplified SMERS data chain.

6 CONCLUSIONS / OUTLOOK

The increased vulnerability of underground transportation infrastructure can be demonstrated anecdotally (see “Introduction”) and statistically (“Threat Analysis”). In general, due to its enclosed nature, the tunnel environment provides significant obstacles to the safe and efficient evacuation of passengers following an event.

The improved understanding gained from the novel multi-disciplinary approach shall in the future lead to a more efficient response to potentially fatal emergency events in underground metro environments. This improved understanding is attainable through the integration of results of the individual tasks, specifically an improved understanding of: potential threats and event scenarios; the physical effect of explosions in underground environments; the effect of rescue and training protocol on first responders; and the behavior of passengers in extreme situations.

The results of these individual studies, informed additionally by cultural differences between Germany and India, will inform the design of the security management and emergency response system and be combined with the developed demonstrator for the evaluation of new rescue protocols and the performance of large-scale field tests in an underground metro environment.

REFERENCES

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