

Preparedness for mass-casualty attacks on public transportation

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Umeå 2016

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ISBN: 978-91-7601-407-3
ISSN: 0346-6612
Cover: Angelica Nerpin
Electronic version available at <http://umu.diva-portal.org/>
Printed by: Service Center KBC
Umeå, Sweden 2016

“True courage is facing life without flinching. I don’t mean times when the right path is hard, but glorious at the end. I’m talking about enduring the boredom, and the messiness, and the inconvenience of doing what is right.” – in *Mad Ship* by Robin Hobb

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Abstract

Background: Public transportation constitutes a vulnerable sector in modern day society with a high probability of generating mass casualties if attacked. By preparing for mass-casualty attacks (MCAs), response can become more effective and public transportation can become a less rewarding target. However, preparedness for attacks, much like response, implies resource constraints, and this dissertation pinpoints some major dilemmas that inhibit achieving preparedness for MCAs on public transportation in Sweden.

Aim: The aim of this dissertation was to investigate preparedness for mass-casualty attacks on public transportation. This allowed for identification of major challenges for preparedness and response with a particular focus on the Swedish context.

Methods: Study **I** included 477 MCAs identified through searches of the Global Terrorism Database, journals, newspapers and websites, which were examined with descriptive statistics. Study **II** thematically analyzed 105 articles attained by systematic searches of the PubMed and Scopus databases. Study **III** and **IV** statistically analyzed data from 864 responses to a purposive-designed questionnaire, from operational personnel of the Swedish emergency organizations. Study **V** entailed validation of a finite element (FE) simulation model of a bombing in a train carriage compared to the bombings in Madrid 2004.

Results: International trends of MCAs (≥ 10 fatally injured and/or ≥ 100 non-fatally injured) on public transportation, during the years 1970-2009 (**I**) showed that the average number of injured increased considerably, despite a quite stable incidence rate since the 1980s. High numbers of injured people were connected to attacks on terminal buildings, multiple targets and complex tactical approaches. Few MCAs occurred in Europe, but the average number of fatalities per incident and injured per incident were the second highest among regions. The literature study (**II**) of previous on-scene management showed that commonly encountered challenges during unintentional incidents were added to during MCAs, implying specific issues for safety, assessment, triage and treatment, which require collaborative planning and specific training. The study regarding the Swedish emergency organizations' perceptions of terrorist attacks (**III**) showed significant differences on perceptions of event likelihood, willingness to respond, estimated management capability and level of confidence in knowledge of tasks to be performed on scene. The police respondents stood out; e.g., fewer

police personnel had high estimates of their organizations' management capability and knowledge of tasks on-scene compared to the other organizations. The study of factors that influence responders' perceptions of preparedness for terrorism (IV) showed that these were influenced by the responders' sex, work experience, organizational affiliation, various training arrangements and access to personal protective equipment (PPE). Investing in amenable factors, such as terrorism-related management training and provision of PPE, could improve responders' perceptions of preparedness for terrorism. A finite-element (FE) model of an explosion in a train carriage (V) was developed and showed that FE modeling techniques could effectively model damage and injuries for explosions with applicability for preparedness and injury mitigation efforts, but, also, there was room for improvement of the model in terms of injuries.

Conclusion: Achieving preparedness for MCAs on public transportation is a multiple choice balancing act between ostensible dilemmas regarding investments, disaster plans, training, response strategies, collaboration and inventions.

Sammanfattning

Bakgrund: Kollektivtrafik utgör en sårbar sektor i dagens samhälle, med hög sannolikhet att generera en situation med många drabbade vid attentat. Genom att förbereda för masskadeattentat (MCA) kan hanteringen bli effektivare och kollektivtrafiken utgöra ett mindre givande mål. Beredskap för attentat, liksom själva hanteringen, innefattar dock resursbegränsningar och denna avhandling belyser somliga avgörande utmaningar som hämmar utvecklandet av beredskap för MCA mot kollektivtrafiken i Sverige.

Syfte: Syftet med avhandlingen var att undersöka beredskapen för masskadeattentat mot kollektivtrafik. Detta möjliggjorde identifiering av stora utmaningar för beredskap och insatser, med särskilt fokus på den svenska kontexten.

Metoder: Studie I innefattade 477 MCA som identifierades genom sökningar i Global Terrorism Database, vetenskapliga tidskrifter, tidningar och webbsidor, som sedan undersöktes med deskriptiv statistik. I Studie II genomfördes en tematisk analys av 105 artiklar, funna genom systematiska sökningar i databaserna PubMed och Scopus. I Studie III och IV genomfördes statistisk analys av data från 864 respondenter till en ändamålsenligt utformad enkät, utskickad till operativ personal inom blåljusorganisationerna. Studie V innebar validering av en finita element (FE)-modell av en explosion i en tågagn genom jämförelse med bombningarna i Madrid 2004.

Resultat: I den internationella utvecklingen av MCA (≥ 10 dödsfall eller ≥ 100 icke-dödligt skadade) mot kollektivtrafik, under åren 1970-2009 (I) visade det sig att det genomsnittliga antalet skadade ökade kraftigt, trots en tämligen stabil incidens av antalet händelser sedan 1980-talet. Skadadeutfallet var ofta stort vid angrepp på terminalbyggnader, multipla mål och användning av komplexa taktiska metoder. Få MCA inträffade i Europa, men det genomsnittliga antalet dödsfall per fall och skadade per fall var den näst högsta bland regioner. Litteraturstudien (II) av skadeplatshantering vid tidigare attentat visade att vanligt förekommande utmaningar under oavsiktliga masskadehändelser utökades under MCA med särskilda svårigheter kring säkerhet, bedömning, triage och behandling, vilket i sin tur kräver gemensam planering och särskild utbildning. Studien om de svenska blåljusorganisationernas uppfattningar om terroristattacker (III) visade signifikanta skillnader på uppfattningar om sannolikhet av olika händelser, viljan att respondera, beräknad hanteringskapacitet och förlitan till kunskap om uppgifter som ska utföras på skadeplats. Polisernas svar utmärkte sig; t.ex. hade färre inom polisen höga uppskattningar av sin organisations hanteringskapacitet och sin egen kunskap om uppgifter på plats, jämfört med de andra organisationerna. Studien av vilka faktorer som

påverkade respondenternas uppfattning om beredskap för terrorism (IV) visade att uppfattningar påverkades av deras kön, arbetslivserfarenhet, organisationstillhörighet, olika former av utbildning och tillgång till personlig skyddsutrustning. Investeringar i åtgärder såsom terrorismrelaterad träning och personlig skyddsutrustning skulle kunna förbättra uppfattning om beredskap för terrorism inom blåljusorganisationerna. En FE modell av en explosion i en tågagn (V) utvecklades och visade att FE metoden skulle kunna modellera materiella skador och personsador av explosioner, med tillämpning för beredskap och skadelindrande åtgärder, men visade också att det fanns utrymme för förbättring av modellen avseende personsador.

Slutsats: Förverkligandet av beredskap för masskadeattentat mot kollektivtrafik utgör en balansgång i beslutstagande mellan vad som förefaller vara dilemman om investeringar, krisplaner, utbildning, responsstrategier, samverkan och innovationer.

List of abbreviations

CBRNE	Chemical, Biological, Radiological, Nuclear, Explosive
EMS	Emergency Medical Services
EOs	Emergency Organizations
ETA	Euskadi Ta Askatasuna (Basque separatist organization)
FE	Finite Element
GTD	Global Terrorism Database
IRA	Irish Republican Army
MCA	Mass-Casualty Attack
MCI	Mass-Casualty Incident
MT	Management Training
OR/MS	Operations Research and Management Science
PPE	Personal Protective Equipment
SWAT	Special Weapons and Tactics

Definitions

Emergency organizations (EOs): the police, rescue service and emergency medical service organizations.

Emergency responders: collective term for personnel from the police, rescue service and emergency medical services.

Emergency management action levels: operative (triage and treatment of casualties), tactical (coordination and command during the response) and strategic (planning and administration) (Lennquist Montán 2015).

Disaster medicine: a science aimed at obtaining and conveying such knowledge that loss of life and health, as well as physical and psychological suffering, are eliminated or reduced as much as possible (Lennquist 2009).

Mass-casualty attack (MCA): a mass-casualty incident of antagonistic origin. The incident implies a man-made incident that may be compensated or uncompensated depending on the incidents scale and the corresponding capability to respond.

Mitigation: the application of measures that prevent incidents or diminish the potential consequences should they occur (Colle & Rubin 2012).

Personal protective equipment (PPE): all equipment that is intended to be worn or held by a person at work that protects him or her against one or more risks to his or her health or safety; e.g., clothing for adverse weather conditions, gloves, eye protectors and breathing apparatus (Calland 2000).

Public transportation: pre-organized, regularly available means of transportation where passengers are not traveling in their own vehicles. This includes local, regional, national and international modes of transportation such as trains, buses, trams, trolleys, subways, ferries and airplanes, but it excludes chartered buses, private car-sharing and taxis.

Prehospital care: physical and psychological care provided before arrival to the hospital.

Preparedness: protective and precautionary activities and behaviors that can be harnessed to protect from and help lessen the impact of incidents threatening life and property, including development and exercise of plans and stockpiling supplies (Colle & Rubin 2012; Mishra & Suar 2007; Paton, Smith, & Johnston 2005).

Response: on-scene management and efforts to minimize consequences of an attack by the emergency organizations (and other crisis management actors as needed).

Original papers

- I. Holgersson, A, Björnstig, U. Mass-casualty attacks on public transportation, *Journal of Transportation Security* 2014, 7 (1):1-16
- II. Holgersson, A. Review of on-scene management of mass-casualty attacks. *Journal of Human Security* (submitted)
- III. Holgersson, A, Strandh, V. Emergency organizations' diverging perceptions of terrorist attacks. *International Journal of Emergency Services* (submitted)
- IV. Holgersson, A, Sahovic, D, Saveman, B-I, Björnstig, U. Influencing factors on responders' perceptions of terrorism preparedness. *Disaster Prevention and Management* (submitted)
- V. Larcher, M, Forsberg, R, Björnstig, U, Holgersson, A, Solomos, G. Effectiveness of Finite Element modelling of damage and injuries for explosions inside trains, *Journal for Transportation Safety and Security* 2015 (online), DOI: 10.1080/19439962.2015.1046619

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Introduction

This dissertation concerns mass-casualty incidents caused by antagonistic violence, referred to as *mass-casualty attacks*, directed at public transportation, and it further problematizes derivable challenges to preparedness for such events. This introductory chapter has two main goals: firstly, to clarify why this is crucial research to conduct with a focus on public transportation, and, secondly, why the research is particularly relevant within the Swedish context.

A vulnerable, essential and target-rich sector

There are many potential targets of antagonistic acts, in different places, for diverse reasons and by various means. This dissertation focuses on public transportation as a means and target of attack. Public transportation modes are inherently vulnerable to attacks due to their openness, predictability, anonymity and availability. These properties coupled with their essential and symbolic nature in the functioning of daily life, as well as large numbers of passengers, can make them rewarding targets for people with malicious intent (Jenkins 2001; Wilson, Jackson, Eisman, Steinberg, & Riley 2007). Modern society is more dependent on critical infrastructure (Boin, Ekengren, & Rhinard 2008), which is why the failure of these systems will have more severe immediate and long-term effects. Additionally, the vulnerability of the public transportation sector is tied to broader societal developments that come with modernization and urbanization. As Crenshaw (1981:381) puts it: “Modernization produces an interrelated set of factors that is a significant permissive cause of terrorism, as increased complexity on all levels of society /.../ creates opportunities and vulnerabilities. Sophisticated networks of transportation and communication offer mobility and the means of publicity for terrorists.” Attacks against the public transportation sector are not novel to the 21st century, but the sector’s vulnerability was highlighted during the “9/11” attacks against the Pentagon and the World Trade Center in the U.S. on September 11, 2001, which resulted in the death of nearly 3,000 people. Since then, several mass-casualty attacks (MCAs) have occurred on public transportation and associated buildings, e.g., in China in 2002, the Philippines in 2004, Spain in 2004, the United Kingdom in 2005, India in 2006, Russia in 2009 and Belarus in 2011. Public transportation seems to have become a target of choice for antagonistic attacks throughout the world, especially in the urban setting (Loukaitou-Sideris, Taylor, & Fink 2006). Due to the high demand for mobility in contemporary life, these areas are also very densely populated at times, which amounts to high probabilities of causing numerous injuries and fatalities when targeted. Mass-casualty attacks on public transportation

constitute something of a worst case scenario, not only in terms of the direct harm to people and property but due to challenges for management and minimizing consequences that come with all mass-casualty incidents. The intentionality of an attack adds issues of security for response personnel, e.g., by secondary attacks. Additionally, they cause injuries that most civilian physicians are not accustomed to treat (Frykberg 2002). Furthermore, the public transportation setting enhances concerns with environmental hazards that demand special tactics and technique during response (Björnstig & Forsberg 2010; Boyd & Sullivan 1997; Calland 2006). The transport setting also adds complexities due to operation across jurisdictional boundaries, the interconnectedness of the transportation system and a structural reluctance among some transit agencies to consider security and emergency issues, thus placing undue emphasis on day-to-day operations (Boyd & Sullivan 1997). In relation to the transportation sector, a large network of crisis management actors also become involved when something goes awry, often with unclear roles of responsibility and little to no experience in dealing with a truly extraordinary crisis (Strandh 2015).

The extent, limits and arenas for security

While one may consider them a unified sector of society, the four public transportation modes (bound by air, water, rail and road) also have significant differences that make them more or less easy to secure from antagonistic acts. The less “closed” the transport system, the more difficult it is to control because it is easier for external forces to affect the transportation mode (Andersson & Vedung 2010; O’Malley 2012). Altering those risk factors to mitigate the potential effects would require broader societal changes (Andersson & Vedung 2010). The difference between road and air-bound traffic can be used to exemplify two opposite points of a spectrum regarding security measures. Bus traffic could be considered the most vulnerable public transportation mode, as it is out on the road with other vehicles, which can be used against it; roads can be blocked or manipulated; the driver is integrated into the passenger cabin, thus making the bus easier to hijack; and passengers may bring weapons with them on board. Meanwhile, air transportation modes are much less used by private individuals, and the air space is tightly controlled by national and international agencies while the ground is fenced off and monitored. The aviation industry is known for its prioritization of security, e.g., seen in the introduction of various forms of passenger and baggage scanners after 9/11 as well as restrictions of fluids in hand luggage later on. Similar security measures have been discussed and implemented in several places in relation to the other transport modes, even though there are diverging thoughts on their actual efficiency (and costs) (Abeyratne 2010; Akhtar, Bjørnskau, & Veisten 2010; Frimpong 2011; Ghobrial & Irvin 2004; Pico 2007; Turney,

Bishop, & Fitzgerald 2004). Furthermore, the full extent of aviation security would not be feasible in relation to the other transportation modes used for daily transportation. The vast difference in the volume of passengers is but one of many prohibiting factors (Jenkins 2012). Determining the type and extent of security measures to counter security threats is also a balancing act. If the number of police or security guards is perceived as “too many,” people could suspect that something is wrong. That is, increased security measures may decrease the broader public’s perceptions of security. However, too few staff members seen in the control or management of the public space can also decrease confidence in the system (Dunmore 2009). Raising public awareness and putting transit terrorism risks into a larger context constitute ways of allowing individuals to make more well-informed security and risk assessments (Litman 2005). This can be done by presenting factual data on the temporal and spatial developments of MCAs (see Study I) and countering the myths about terrorism¹ (LaFree 2012). Furthermore, one may raise awareness by highlighting some dangerous consequences of unsuitable reactions by the public. One such example was seen after 9/11, when fears of further terrorist attacks caused people to drive instead of fly to their destinations. This caused hundreds more casualties than normal due to car crashes (Litman 2005), as the safety and security of public transport is very high when compared to private modes of transportation such as cars. In summary, the various modes of public transportation have several vulnerabilities, some of which may be reduced by balanced security measures and some that could be considered build-in to the sectors’ nature and purpose. The answer to securing public transportation is not simply implementing more security but implementing smart security (Jenkins 2012).

Preparedness as protection and reduction of consequences

The Swedish government has defined information and communication systems as one essential sector for the proper functioning of society. With regard to strengthened crisis preparedness, it has further been stated that vulnerabilities in various civic functions cannot entirely be prevented, which justifies efforts for preparedness and functional crisis management structures in society (Ministry of Defence Sweden 2008). This is reminiscent of Wildavsky’s (1988) claims that all risks cannot be prevented and that by

¹ Examples of those myths are: (1) “No location is safe from terrorism”; (2) “Terrorist attacks are incredibly lethal”; and (3) “Terrorism depends on sophisticated weaponry.” The truth is: (1) Terrorist attacks are highly concentrated in relatively few places; (2) Less than half of terrorist attacks since 1970 involved any fatalities; and (3) A majority of attacks rely on unsophisticated, readily accessible weapons such as explosives and firearms (see LaFree 2012).

trying to create an extremely safe society, one would have to forego other aspects of life that are valued. If society cannot be completely secured, one may infer that society must have a functional response system, which in turn implies that research about the emergency organizations (EOs) is vital. As stated by Awasthy (2009:91): “The uniqueness of disaster management agencies is that their goals are directly related to preventing the loss of life and property. It is for this reason that a great deal of attention must be paid to such organizations, as their success or failure has a direct impact on our survival.” When dealing with aspects of antagonism, such as terrorism, the EOs constitute essential actors in the official societal response, which on the one hand subjects them to expectations from the public, while on the other hand gives them power to influence the publics’ (and the terrorists’) interpretation and subsequent reaction to events. This is because, in addition to directly involved individuals and their families, attacks can also affect individuals who have not been personally involved through feelings of fear, anxiety and suspicion. For this reason, the management of a single incident is even more important – it too will affect the overall view of the severity of the situation, faith in the societal response and experience of fear. Preparedness can thus be said to be especially important when dealing with terrorism due to its nature and aim to spread fear (see Terrorism studies). Consequences on the community level must be minimized as they may constitute a reward for terrorists wanting to weaken society or the ruling power (Neumann & Smith 2005). An appropriate response can lessen fear and reactive demands on the political system (Boin, ’t Hart, Stern, & Sundelius 2005) while a disproportionate response can benefit aims such as generate attention for terrorists’ cause, foster fear and helplessness in the population, and undermine faith in authorities (Peleg & Shenhar 2014). Timely and appropriate medical care (Haddon & Baker 1981) is one way to mitigate consequences of attacks, by saving the lives of severely injured and preventing deterioration of injuries in others. Another way to mitigate effects is through adaptations and alterations of the built environment. In the public transportation arena, mitigating effects on the passengers, staff and infrastructure has been proposed to lessen the risk of attacks, since less rewarding targets become less attractive (O’Neill, Robinson, & Ingleton 2012). Examples of such injury preventive measures include intelligent design of landscape architecture for protection of public spaces and altered construction of vehicles to mitigate injuries if a bomb explodes or to ease evacuation afterwards (Gebbeken, Döge, & Larcher 2011; O’Neill et al. 2012). Developing methods to predict the injury effects of attacks on public transportation and evaluate injury preventive measures is another piece of the puzzle to increase preparedness (see Study V). Focusing on the capacity to deal with dangers, once manifest, is also referred to as resilience (Wildavsky 1988). According to Wildavsky (1988), resilience constitutes one

strategy to achieve security (Perrow 2006). Gearson (2012:186) similarly stated that “by emphasizing resilience (the ability to cope with unexpected events) and preparedness, even if attacks do take place, little of the desired effect will occur and doubt can be inserted into the minds of would-be terrorists that this method is not working, offering long-term benefits if done properly.” Protective measures can thus reduce the probability of an attack, unlike those for natural disasters (Gearson 2012). Seen from this perspective, focused efforts in preparedness for MCAs could lessen the consequences if an attack does occur as well as a re-occurrence of attacks.

A country with increasing risk factors

Researching preparedness for MCAs is important within the Swedish context for several reasons. It is crucial to consider that the country has had limited experiences with large-scale antagonistic acts. The most notable exceptions to this were seen during the 1970s with a seizure of an embassy and an airplane attack. There was also a suicide bombing in Stockholm in December 2010, where part of the explosive worn by the perpetrator detonated prematurely and fatally injured him. A car rigged with explosives nearby was disarmed, and no further casualties resulted due to the incident (Hanson & Holmström 2011). After this example of Islamic terrorism on Swedish soil, some expressed that such incidents would likely occur again due to perceived discrimination and segregation of Muslims in Sweden (Burns 2010). Dingley and Mollica (2007) have correspondingly highlighted the need for integration if the multicultural trend in the West continues, and one wishes to avoid it leading to the emergence of segregated, thus threatening communities within the larger society. The Swedish Security Service has also warned that increased polarization can intensify feelings of discrimination and stigmatization, which in turn can facilitate radicalization and recruitment to “violent environments.” Moreover, their report detailed that a majority of the people considered to belong to those engaging in violent Islamist extremism were registered in the three major cities, where environments marked by exclusion and challenging social circumstances were more common. It can thus be described as an urban problem (The Swedish Security Service 2010), and as previously stated, the urban setting has also become a more common arena for staging attacks on public transportation (Loukaitou-Sideris et al. 2006). The Swedish national terrorism strategy from 2011 further stated: “attacks that were carried out and planned attacks that were thwarted have shown that there is as real risk of terrorist attacks in Sweden or against Swedish interests” (Ministry of Justice Sweden 2012:3). In the new counter-terrorism strategy, the threat from terrorism actors inspired by al-Qaida or closely related organizations’ ideologies are pinpointed as the main threat. Moreover, an increasing number of people travel to conflict areas to participate in terrorist training or

perpetrate violent acts that increase risks as they return with the ability to commit attacks, not just in terms of the capability to handle a weapon but a transgressed threshold for the use of violence (Ministry of Justice Sweden 2015). Indeed, the Swedish Security Service decided to upgrade the threat level from elevated to high in November 2015, for the first time in Swedish history, after a man suspected of fighting for ISIL in Syria and for planning a terrorist attack in Sweden possibly entered the country (Flores 2015; The Swedish Security Service 2015; Wierup, Delin, & Svahn 2015). Another potential threat to Sweden is the so-called lone-wolf terrorists (Ministry of Justice Sweden 2015; Spaaij 2010; The Swedish Security Service 2012). This cannot help but bring to mind the school attack in Trollhättan, Sweden on October 22, 2015, where a sole assailant stabbed staff and students. Three were fatally injured from the attack including the perpetrator, making it the most lethal of the few school attacks that have occurred in Sweden to date (Göteborgs-Posten 2015).

A research gap on emergency response and preparedness

The attacks in Norway in the summer of 2011 also constitute examples of lone-wolf terrorism. A single perpetrator bombed the executive government quarter of Norway and went on a shooting spree in a youth summer camp at the island of Utøya, leading to a total of 77 fatalities and 172 injured with need of medical treatment (Norwegian Directorate of Health 2012; The National Board of Health and Welfare 2012). At the time, those events provided something of a wakeup call for Sweden as it hit so close to home and had such tragic outcomes in the lost human lives. While some may have doubted the threat from antagonistic actions in Sweden, even after the 2010 suicide bombing in Stockholm, the events in Norway seem to have led some to question those assumptions and question the Swedish preparedness status. For one, it spurred the Swedish Government to request an investigation of the Swedish preparedness for a similar event in terms of trauma care (Ministry of Health and Social Affairs 2013). In a report following the attacks, the National Board of Health and Welfare in Sweden provided some insights of which to learn from regarding weaknesses and areas in need of improvement to increase MCA preparedness. Compared to Sweden several of those observations seem to indicate that Norway had better conditions for a functional response seen in of resources (such as ambulance helicopters), a differently structured health care system (that reduces risk of over-load of emergency rooms), with staff more extensively educated in trauma care and more physicians with prehospital experience (The National Board of Health and Welfare 2012). Some of the involved investigators also noted that the high medical competence required during early triage on-scene would be difficult to assure all over Sweden (Riddez & Örtenwall 2012). In November 2015, the National Board of Health and

Welfare made its requested investigation of trauma care available to the public (The National Board of Health and Welfare 2015). Unfortunately, despite the amount of effort that went into trying to fulfill the task given to it by the government, the final report contains little insight that is applicable in a true MCA. Based on the events in Norway, the report starts by underlining the importance of having a system that assures that those who normally handle severe trauma, such as detonation and gun injuries, also handle them during disaster situations and the urgency of triaging and treating those injuries. The report also points out the difficulties in determining safety at the scene of an attack (The National Board of Health and Welfare 2015). These are but some of the challenges that emergency responders have to face when responding to a MCA (see Study **II**). As far as recommendations and concrete gaps in preparedness, the report details, e.g., the “efforts needed” within the area of prehospital care, a lack of educated nurses and trauma educated surgeons as well as the ability to manage CBRNE incidents (The National Board of Health and Welfare 2015). However, no details were given on the present competence level with regard to the detonation or gunshot injuries among hospital or prehospital staff and neither were any hints given regarding the emergency responders’ perceptions of threats from terrorism, preparedness for attacks or capability to manage such an incident (see Study **III, IV**). This dissertation regarding preparedness for MCAs in Sweden was funded by the National Board of Health and Welfare, and may be seen as a crucial addition to its report on Swedish trauma care.

Related research

This section highlights key concepts, terms and debated issues that relate to the research subject in order to clarify its complexities and provide a context for the appended studies. The research conducted has been multi-disciplinary because the attainment of preparedness for mass-casualty attacks on public transportation can be approached at several *phases*, *places* and *planes*, through different *procedures* and by various *people* with diverging *perspectives*. This is a problem in and of itself as it leads to theoretical, methodological and practical fragmentation, which thwarts preparedness efforts. I have thus made it a point not to provide some overarching overview on every body of relevant science nor merge these disparate fields but show the essential pieces of research pertaining to the overall aim (Fig. 1).

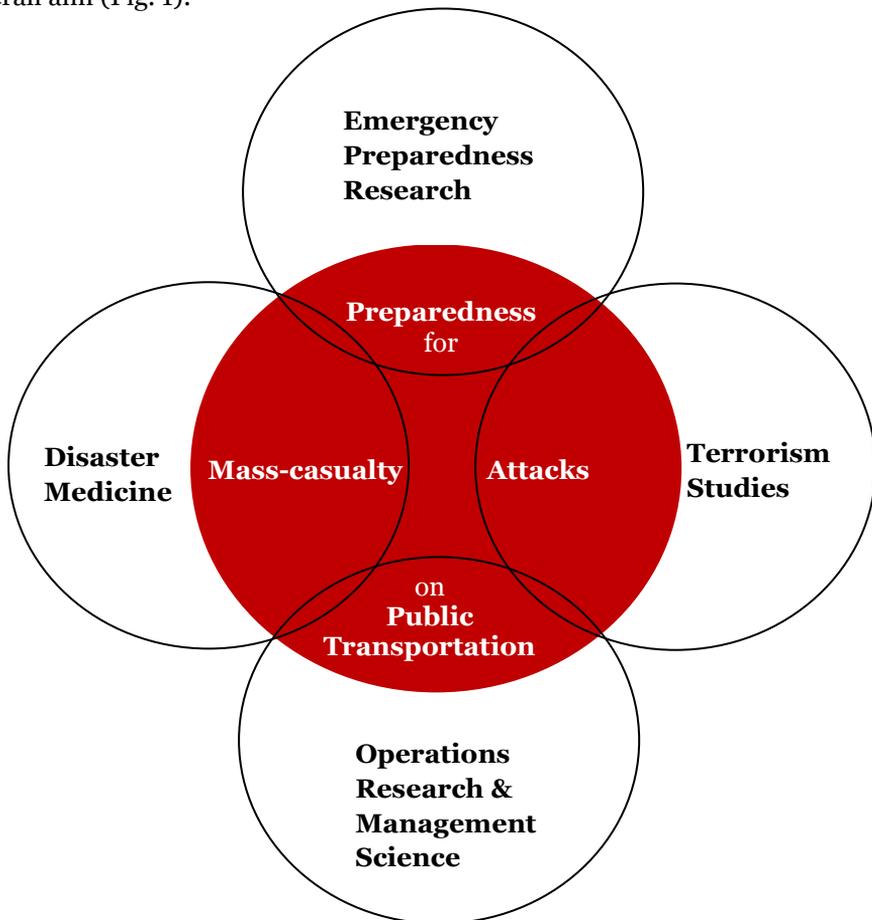


Figure 1. Research sub-fields for theoretical and methodological guidance

The first subfield is *emergency preparedness research*, which provides a breadth on the issues of national and community preparedness based on research of natural and man-made emergencies. The second field, *operations research and management sciences (OR/MS)*, adds quantitative methods to enable decision making for preparedness and response efforts. The fields of *disaster medicine*, in turn, add depth to the elements relevant for on-scene management of MCAs. Lastly, *terrorism studies* highlight the importance of having balanced approaches to MCAs due to the severe consequences that could result from excessive response actions. Taken together, this research emphasizes the need for a more cohesive, multi-disciplinary and systematic tactic in both preparedness and response efforts to MCAs if negative consequences are to be effectively minimized.

Emergency preparedness

The inherent unpredictability of emergencies impedes efforts to determine a perfect response to a particular incident in advance. Even the shortfalls that can be identified cannot all be addressed because, “if everything is a priority, nothing is a priority” (O’Malley 2012; Vidali & Hutchens 2012). Due to resource constraints, it is rarely possible to achieve ideal preparedness. This entails asking fundamental questions about whether we are ready, what we need to be ready for and what we need to do in order to become ready. Answering such questions is vital in order to make informed decisions about the allocation of resources and signal to decision makers and the public what they can and cannot expect during an emergency (Vidali & Hutchens 2012). Proactively, one can employ practical ways to assess readiness, which requires differentiating between capacity and capability. *Capacity* focuses on quantifiable assets such as equipment, vehicles and radios. *Capability* includes qualitative measurements of, e.g., personnel skills, training and coordination. These both must be accounted for if the resources are to be ready for use,² and failing to do so can amount to poor investment decisions as well as a false sense of security regarding the readiness level. Furthermore, the fragmentation of the crisis management and public safety system and its actors constitutes a major hindrance to readiness measurements and capability aggregation (Vidali & Hutchens 2012). It is very difficult to attain an overview of the total of response assets, critical skills, training, availability of personnel and the status of emergency supplies due to partitions of the crisis management community under the rule of different departments governed at national, regional and local levels of society including state, private and volunteer actors (Strandh 2015; Vidali &

² Example: if one has 10 sets of full personal protection equipment (capacity) but only two staff knowledgeable in how to use them (capability), the actual deployable resources will be the smaller number.

Hutchens 2012) (see Study context). Mental gaps between distinct professionals, with different training and background, who have a function in the public safety arena, augment challenges for collaborative and effective preparedness ambitions (Lindberg & Sundelius 2012). One such gap can be found between security and safety professionals, e.g., in how they work with information. Security officials are used to working with closed information and the management of classified intelligence materials, while safety officials are not and may not see the need for “intelligence-based” information (Lindberg & Sundelius 2012). I will return to the fragmentation problem caused by the division between safety and security professionals later on.

During the 21st century, an *all-hazards approach* has become a standard for creating and maintaining preparedness and management of events in many countries around the world. This is because several harmful effects of incidents are similar regardless of whether they are deliberately man-made or unintentionally induced or caused by nature, which implies that management practices will largely be the same (Gin, Stein, Heslin, & Dobalian 2014; Lindberg & Sundelius 2012; Rüter, Nilsson, & Vikström 2006). According to the approach, it is easier and more efficient to adopt a basic core framework of preparedness measures that concurrently address several sources of risk (Gin et al. 2014). The similarities in emergency response functions provide multiple use opportunities for personnel, facilities, equipment and procedures (O’Malley 2012; Perry & Lindell 2003). The all-hazards approach implies that the same capabilities can be used for several types of incidents, but some events call for specific prevention, response and recovery capabilities. Lindberg and Sundelius (2012) maintain that these events, such as MCAs, thus demand an *all-hazards plus* approach.

Stern and Sundelius (2002) have developed analytical themes, based on case studies of crises; three of which I find particularly useful for providing perspective on the research subject: (1) preparedness, prevention and mitigation; (2) problem perception and framing; and (3) value conflict. The *preparedness, prevention and mitigation* theme deals with how well prepared crisis managers and their organizations are to respond to extraordinary incidents. It includes aspects such as prior experience, mental awareness that incidents can occur and whether planning and investment in the necessary infrastructure takes place (Stern & Sundelius 2002). In terms of pre-emptive and preventive action prior to incidents, these take place in contexts requiring action by various actors. One example may be that an organization is too caught up in day-to-day operations to consider planning for more extreme events, which has been claimed in connection to transit agencies (Boyd & Sullivan 1997). While one may consider it possible to do something, another aspect is mental preparedness or experience-based

awareness, as opposed to thinking that “it won’t happen here” (Fors 2005) or not being able to fathom the scale of an extraordinary crisis (Strandh 2015).

Problem perception and framing is a reoccurring issue in crisis decision making. This usually takes place semiconsciously or intuitively. Full and accurate information is not available during the initial stages of response, which implies that actors, e.g., emergency responders, do not act on objective facts but rather on their interpretations and perceptions of what is occurring. Once a situation has been given a certain problem framing it exerts a weighty influence upon choice, and alternative actions are discarded (Stern & Sundelius 2002). Cognitive and social structures and processes, such as historical reasoning, institutional logics and organizational culture, heavily affect problem perception and framing (Stern & Sundelius 2002)(see Study III). This can in turn make on-scene response more difficult for three reasons: different organizational and individual experiences; diverse scene interpretations; and action path dependency. Experience in dealing with certain events, during situations with a lack of information, is very important for the reasoning regarding what actions to take (e.g., after receiving secondary information about a bomb threat) (Fors 2005). During scene response, diverging problem perceptions can amount to incongruous actions being taken by the emergency responder groups. On the one hand, this can make collaboration more difficult, and on the other hand, it makes it all the more necessary. In team training literature (Ford & Schmidt 2000), this aspect is referred to through the concept of shared mental models, which are implicated as vital for success in managing emergency situations. The literature further highlights that cross-training is important for the forming of compatible models, e.g., regarding roles and responsibilities, and has been empirically shown to enhance team effectiveness. What is more, early problem framing, converted into action, can lead to what Berlin and Carlström (2008) label “first initiative” effect. This can set the stage for the rest of the work on an incident site, even if it is not the optimal management choice. This form of path dependence can lead to issues down the line if the first choice and action made were not intended to be used as a base point. An example of this can be the placement of a vehicle by the first emergency responders arriving on scene, thus effecting where the command post is later placed (Berlin & Carlström 2008).

Additionally, problem framing is integral in the identification of values that are implicated in a given crisis, which may be a potential source of tension if it amounts to a *value conflict*, where several values are simultaneously at stake (Stern & Sundelius 2002). Steinbruner (1974) similarly describes complex problems in decision making as a zero sum game, where one choice takes place at the expense of another (under various degrees of uncertainty

with decision-making power dispersed between several actors). Emergency management can be defined as “a function of values (what ought to be done) and of capability (what can be done)” (May 1985:46). Dealing with that equation is an inherent challenge to any truly large-scale crisis, when what one wishes to do and what one can actually accomplish are at odds (see Disaster medicine). A value conflict is when fundamental values such as human life, democracy and rule of law are at odds, and it may also be complicated by more parochial values like personal or political benefits (Stern & Sundelius 2002). An example of a situation where value conflicts often arise is on scene when the safety of emergency personnel clash with the interest to save the injured (Fors 2005). Furthermore, a point made by Farnham (1997) is that the “best” solution is not always sought, but the one which is most acceptable (Fors 2005). Emotions and pressures to act may also influence decisions about on-scene safety and following investigations, through instinct among emergency responders to act, expectations of action by responders from the public and pressures from politicians to speed up investigations and return to normal (Fors 2005). During the high-pressure atmospheres that often accompany events, such as MCAs, it is very difficult for emergency responders to appear to be “doing nothing” (Perry & Lindell 2003). Lewis et al. (1999) have examined some of these issues from an ethical perspective, demonstrating the dual messages sent by ambiguous operational and ethical guidelines, when a courageous response could imply a disregard for standard procedure yet a retrospective reward with the highest organizational honor. They point out that this may place unnecessary burdens on responders and question whether the practice of labelling responders as heroes allows for the evasion of responsibility for the long-term effects on some responders. So, we know that many values compete for attention during the response to MCAs. While challenging, the predictability nevertheless implies that such issues can be taken into consideration and trained beforehand.

Operations research & management science

Predominantly based on methods from mathematics, computer sciences and economics, Operations Research and Management Science (OR/MS) denotes the scientific study of complex systems for the purpose of better decision making and management (Altay & Green 2006; Stilianakis 2013). Several fields come together in OR/MS, which are useful for preparedness and response to emergencies (Larson, Metzger, & Cahn 2006; Stilianakis 2013). Operations research entails a range of quantitative methods that can provide important tools in decision making for various actors (e.g., emergency responders), in different geographic settings (e.g., public transportation), about different management strategies (e.g., prevention and mitigation of incident effects) and outcome evaluation (e.g., morbidity and

mortality)(Stilianakis 2013). When considering the need to prioritize what money is spent on OR/MS offers scientifically valid frameworks for considering multiple aspects of various emergency scenarios and for assessing the consequences and tradeoffs associated with alternative decisions; thus making it a valuable tool for prioritizing and decision making on emergency response and preparedness (Larson 2004). To achieve the goal of providing analytical support to decision makers, operations researchers have a collection of analytical techniques available to them. These analytical techniques include problem structuring methods, queuing theory, decision analysis, game theory and optimization. Another technique available to an operations researcher is modeling and simulation (M&S) (Collins & Currie 2012).

Modeling and simulating constitute important techniques for planning and optimizing responses to possible emergencies and training personnel to perform their roles (O'Hara, McLean, & Lee 2010). Fawsett and Oliveira (2000) may provide one example, as they have presented a mathematical model of the regional health-care system response to an earthquake event, with regard to the casualty treatment problem. By inputting the numbers and locations of casualties rescued alive, the scale of prehospital care, the post-earthquake hospital capacity and the transport system, the model simulates the movement of casualties from the stricken areas to hospitals and predicts, e.g., the number of casualties who die and the waiting time before treatment. The authors conclude that the model may be used as a tool for decision making on planning and preparedness training. As another type of simulation tool, hi-fidelity, computerized mannequins have been used in medicine for teaching and assessing psychomotor skills (Jacobson 2010). These mannequins can be used in hands-on mass-casualty simulations that are calculated to overwhelm staff with victims while limiting time and resources. Such exercises reveal that the time and resources spent on one patient will be taken from another victim, thus training staff in the application of triage, resource use and decision making. Previous exercises of mass-casualty scenarios have, e.g., showed the difficulty for participants to adjust to the reality of mass-casualty situations, thus causing time and resources to be wasted on single individuals and leading to the death of several others (Jacobson 2010). There is also potential to apply OR/MS in incident management through realistic role-playing game interfaces and technically correct simulations that include different actors, scenarios and major aspects including physical phenomena, the environment, social behaviors, organizations and infrastructure systems. Gaming examples exist, e.g., for training emergency vehicle drivers and on-scene response and triage by emergency medical personnel (Jain 2010).

A challenge regarding the applicability of simulations for emergency preparedness research is that agencies on different levels are involved and responsible for aspects of emergency response; each with different needs for and perspectives on modeling and simulation techniques. Additionally, there are issues with the interoperability between modeling and simulation products and datasets (McLean 2010). The Center for Integrated Emergency Preparedness encourages the integration of modeling and simulation tools into the planning process, e.g., to inform incident action plans (operational level), emergency operations plans (tactical level) and concept plans (strategic level). However, it is also highlighted that the modeling and simulation tools must be useful, usable and used if they are to help end users (Hewett 2010). While the implementation of published models occurs less frequently than OR/MS researchers may hope for, the area of emergency response systems is an exception where the research has led to implementation of new policies and practices (Green & Kolesar 2004). In Sweden, for example, a functional simulation model as a scientific, educational and quality assurance tool for response and preparedness for mass-casualty incidents has been developed and tested (Lennquist Montán 2015; Lennquist Montán et al. 2014). Modeling and simulation tools also have a long, proven history to solve problems in transportation engineering related to public transportation systems (Robinson 2012).

The preparedness challenges and consequences of the all-hazards approach and fragmentation of the crisis management system have also been discussed by OR/MS researchers. Altay and Green (2006) debate the all-hazard approach, generalized policies and plans for all kinds of emergencies, claiming that they may find different optimal approaches for different specific incidents. They point out that the same action would have different implications depending on if the incident was intentional or not. While the response to unintentional MCI often results in a concentration of resources, this could potentially be a tempting target for a secondary attack in the case of terrorist incidents. Altay and Green (2006) further highlight the need to study the connectivity between critical infrastructures and how to incorporate survivability into building maintenance and design. Thus, studies of the survivability in bombings and design of vehicles in the public transportation sector appear desirable (see Study V). Furthermore, regarding fragmentation, a disconnect among professionals from multiple disciplines has also been pinpointed as an obstacle by Haimes and Longstaff (2002) as the professionals “conceive, plan, design, construct, operate, maintain, and manage” interconnected infrastructures from their respective, isolated domains. This implies that multi-disciplinary research is highly suitable to gain further insights on subjects related to preparedness and public transportation, as will be shown in the next section.

Disaster medicine

The discipline of disaster medicine is relevant to the research subject, as it provides vital concepts for on-scene management of MCAs and delineate issues commonly faced at the operative level. The research adds detail to the more overarching preparedness research found in the emergency preparedness field described earlier. It provides vital insights on ways to increase survival and decrease morbidity, on an individual, group or population basis (Rüter et al. 2006). Disaster medicine describes methods to allow the health care system to perform effectively in situations with a lack of resources, i.e., ways to manage the response capabilities in the affected area when the medical needs have been exceeded by a large number and/or severity of injured or ill victims (Nilsson 2012). The highly relevant sub-discipline “terror medicine” came about in 2006, when Shapira and Cole wrote an article titled *Terror Medicine: Birth of a Discipline*. In 2009, together with Hammond, they edited the book *Essentials of Terror Medicine*, founded on their and others’ research of dealing with terrorist acts. These texts have been very useful in the forming of this dissertation, but due to the largely Israeli origin of that research, certain strategies and principles may not apply in Sweden. The differences that may have implications for management of attacks, aside for the differences in experience between Israel and Sweden, include: country sizes, population density, level of integration of the military in management of incidents, degree of prehospital use of doctors and hospital personnel experience in dealing with the special injury panorama after attacks.

One may note that both the concepts mass-casualty incident and mass-casualty attack have been used in the dissertation so far. The reason is that some of the general disaster medicine research is applicable even though it does not only contain antagonistically induced cases. There is no universally accepted term for a deliberately induced mass-casualty situation. However, the dissertation specifically concerns such incidents, which prompted the development of the *mass-casualty attack* concept in order to distinguish such events, as they contain elements and challenges the unintentional incidents do not. The MCA concept also holds important differences from other terrorism-related research in that it focuses on antagonistic act(s) that have resulted in mass-casualty incident(s), i.e., the direct consequences of an attack seen in injuries and fatalities. This can be contrasted with research on *who* perpetrated the act, *whom* it was perpetrated against or *why* and the *long-term consequences* of attacks; all of these aspects are beyond the focus of this dissertation. The interest in effective management of MCAs through societal response is why the science of disaster medicine is highly relevant.

With regard to response to MCAs, the scale of the attack and its immediate repercussions must be contrasted with the response capability, as a lack of resources to meet the need for aid constitutes the main characteristic of a *disaster*. Incidents where the local society's organized medical structures have been destroyed, *major medical disasters* must be distinguished from limited *mass-casualty incidents* (Almogly & Rivkind 2007). In other terms, a major medical disaster implies an uncompensated incident where the demands exceed the capability to respond and normal levels of ambition for medical treatment cannot be maintained. More limited MCAs, the focus of this dissertation, can often be compensated for through rerouting of resources, change in tactics and organization (Hodgetts & Mackaway-Jones 1995; Hodgetts & Mackaway-Jones 2004; Rüter et al. 2006). The scale of an event may require decisions about reducing the *level of medical ambition* and quality of treatment for the individual patient. This may imply ethically difficult choices regarding the survival and wellbeing of the many before single individuals. In such, and smaller scale scenarios, different forms of *triage* can be an important tool in deciding who to prioritize given the limited resources, personnel and transportation possibilities (Rüter et al. 2006).

Focusing on optimizing care for a majority of patients deemed “salvageable,” at the expense of critically injured, might be justified in extreme major medical disasters, but it may result in the loss of potentially salvageable critically injured if such an approach is taken during MCAs (Almogly & Rivkind 2007). MCAs may entail some diversions from standard prehospital treatment, as these may not be devisable given the resource limitations. Recommendations hold that treatment is to be kept to a minimum, in correspondence with triage priority, in an effort to get the living casualties to a facility where they can be fully assessed and treated as quickly as possible (Hodgetts & Mackaway-Jones 1995). Injuries caused by antagonistic actions, such as shootings and bombings, bring specific medical challenges due to blast injuries, for example, which few civilian physicians have experienced treating (Frykberg 2002; Leibovici et al. 1996; Page 2011; Shapira & Cole 2006) (see Study II). This creates treatment challenges in both the prehospital and hospital setting in countries like Sweden. Sufficient information gathering and the ability to make balanced decisions regarding the level of ambition for appropriate *level of care* and continuous re-evaluation of the situation constitute as integral parts of efficient MCA management, as does scene safety. Safety for personnel in MCA response could mean the difference between a mass-casualty attack and a major medical disaster as dead or injured responders cannot take part in management, thus highlighting the importance of the proper use of

appropriate personal protective equipment (PPE) and a well-deliberated response tactic.

One of the major issues for response to MCAs on public transportation is that of *safety* and *security*. Within the realm of transportation, it is common to differentiate between the two, where safety refers to measures to avoid or reduce unintentional mishaps while security refers to protective measures against antagonistic acts (UITP Security Commission 2010). While the division may simplify certain work, as previously mentioned, it also hampers preparedness efforts. As professionals from different perspectives risk failing to recognize that their “piece of the puzzle” is part of an interconnected system, it may cause opportunities for dual-use to be lost and impede the estimates of readiness. In this dissertation, the issues of physical wellbeing of responders during formal response to MCAs are referred to as *on-scene safety*, in agreement with terminology used in the Major Incident Medical Management and Support (MIMMS) framework (Hodgetts & Mackaway-Jones 1995).

Thompson et al. (2014) showed that while on-scene safety after a terrorist attack includes direct threats (e.g., active shooter, secondary attack, undetonated device and contamination), the dominant causes of mortality and morbidity in responders after such incidents have been due to indirect environmental hazards (e.g., electrical current, dangerous substances, collapse, falling or tripping hazards, traffic, and extreme temperatures). Determining whether a scene is safe to enter is not as straightforward as it may seem though (Wild et al. 2012). Meanwhile, exsanguination due to hemorrhage, e.g., due to gunshot, may occur in less than 5 minutes (Jacobs et al. 2013). As stated, this amounts to a value conflict and demands different tactics compared to an unintentional incident. According to recent discussions on tactics, a more offensive, highly inter-organizational response is recommended by a number of authors in order to save critical casualties (Autrey, Hick, Bramer, Brendt, & Bundt 2014; Jacobs et al. 2014; Jacobs et al. 2013)(see Study II). Jacobs et al. (2014; 2013) and Autrey et al. (2014) however differ with regard to the level of collaboration required in response to hostile incidents. Autrey and colleagues discuss inter-agency collaboration as a method of enabling the other organizations to do their own tasks, while Jacobs et al. go a step further to training law enforcement officers to perform initial hemorrhage control procedures, thus taking on tasks that are traditionally performed by EMS. These different levels of collaboration and inter-dependence require different types of training for emergency personnel and possibly legislative changes regarding authority to perform certain tasks.

Planning, training and exercising must address inter-organizational collaboration if functional coordination and an effective response to MCAs are to be achieved (Boyd & Sullivan 1997; Perry & Lindell 2003; Singer, Singer, Halperin, Kaspi, & Assaf 2007). Pre-planning ought to cover the basic information on the jurisdiction, structure, resources and roles of the organizations involved in response as well as essential terminology (Almogly & Rivkind 2007; Jacobs et al. 2014; López-Carresi 2008; Perliger, Pedahzur, & Zalmanovitch 2005; Perry & Lindell 2007). While deciding on common vocabulary may seem trivial, the matter of fact is that wordings used for different levels of the response chain (strategic, tactical and operative) differ between the emergency organizations along with many other terms. A case in point can be provided of situations of inter-organizational collaboration in Sweden, where EMS and rescue service may misinterpret the police expression “site cleared” by thinking that it means that the scene is safe to enter, while the police may simply mean that the site has been cordoned off and further access is controlled (Berlin & Carlström 2011). Interpretations of terms differ and, in MCAs, it could mean the difference between life and death. Pre-event planning, training and exercising could clarify these issues beforehand, thus minimizing this source of uncertainty. Rådestad (2013) has also pointed out that the lack of a common vocabulary and the lack of standards for collecting and reporting data constitute a limitation in research on disaster medical management, as a common language is essential in order to compare results. Thus, such basic matters constitute a hindrance to development of knowledge and preparedness.

The antagonistic feature of a MCA implies a threat environment that requires changes in thinking and practice. Strategies, tactics and equipment used in smaller scale emergencies of a natural and technological nature can often be adaptable to larger scale disasters. When introducing an antagonistic element, possibly with the use of CBRNE agents, the “rules of the game” change. What does not change is the need for planning, training and exercising (Gillespie & Colignon 1993; Perry 2004; Perry & Lindell 2007). Certain strategies and equipment, to counter the threat aspect, must be adjusted for in the content of plans, training programs and exercises (Perry & Lindell 2007). In terms of good preparedness practices, Kartez and Lindell (1987) have even shown that jurisdictions with limited experience in disaster management but effective planning were significantly more likely to have adopted good preparedness practices compared to those who did not plan effectively. However, a lack of experience and low priority given to planning often present barriers to good preparedness practices. Because plans cannot account for everything creativity and improvisation are also essential for decision makers during a crisis (Fors 2005; Sundelius, Stern, & Bynander 2001). Moreover, it is important not to narrow the definition of

preparedness into the existence of a written plan, or to confuse the planning process with the written plan (Kartez & Lindell 1987; Perry & Lindell 2003; Quarantelli 1984). There are, however, often undue emphasis on the technical aspects of the process, particularly the production of written plans, in funding requirements, as opposed to the social dimensions of sharing experience and knowledge among participants, and developing effective organizations (Kartez & Lindell 1987). Preparedness plans should be based on principles, which can be modified to each situation, and not focus on specific details (Perry & Lindell 2003; Pinkert et al. 2008; Quarantelli 1984; Raiter et al. 2008). In cases of antagonism, one can furthermore hold that too strict plans and procedures would be predictable and limiting (Fors 2005). Yet there must obviously be a balance in flexibility. Practices from the experienced London police, for example, have shown the useful application of checklists over actions to take in certain situations, standardized evacuation areas and well-practiced routines for collection of information (Fors 2005). With regard to the balance between planning and improvisation, Czarniawska et al. (2007) present some insights and conclude that *practiced improvisation* has merits. Practiced improvisation does not mean to make things up as you go but to consider beforehand the different options in a response that might be needed and a practice to piece these options together. Improvisation is made possible when there are standards (structures) that everyone is aware of and can work around in order to achieve the overarching goal. Practiced improvisation requires training.

If plans and equipment are to be functional when needed, personnel must have exercised using them (O'Malley 2012). Training and exercises have been shown to enhance providers' comfort level and perceptions of teamwork, response network effectiveness, job risk and equipment adequacy (Jones, Kue, Mitchell, Eblan, & Dyer 2014; Peterson & Perry 1999; Reilly, Markenson, & DiMaggio 2007). Regularly scheduled exercises can be expensive in terms of both time and money but result in both new and old personnel being well versed in their function and that plans can be continuously improved based on new insights and organizational changes (O'Malley 2012). Exercises also allow personnel from different responder groups and agencies to develop working relationships (Perry 2004). Exercises constitute the simultaneous practice and testing of emergency preparedness aspects. That presents opportunities to observe problems and conflicts in order to later resolve them (Perry & Lindell 2003). If exercise benefits are to reach their full potential, exercises must be carefully designed and evaluated in order to truly validate the equipment capacity and personnel capability to deal with a realistic and challenging event as well as the accuracy of emergency plans and procedures (McCreight 2012; Vidali & Hutchens 2012). Publicizing exercises may furthermore convey to the public

that efforts to enhance preparedness are being taken, which is a particularly important function in the case of MCAs, as it attributes credibility to the emergency management system and increases the probability that the public will comply with recommended emergency measures (Perry 2004; Perry & Lindell 2003).

Terrorism studies

While this dissertation focuses on mass-casualty attacks, the research field of terrorism studies is highly relevant because terrorism is a closely connected issue that has been researched quite extensively and because focusing on a narrow area of research could be counterproductive in the case of terrorism. This field thus adds to the dissertation's subject by highlighting possible pitfalls to response and preparedness to MCAs. Terrorism research includes many aspects the most relevant of which are (1) the definition(s), (2) how terrorism as a method is formed to work strategically and its objectives and (3) the essential function of the media.

There are a multitude of definitions used for terrorism, and in order to form a workable definition, one must address its targets, possible perpetrators and its purpose. Civilians are an intentional part of the terrorist strategy of pressure and coercion since they are considered valuable and worthy of protection. Their rights to be immune from attacks are governed by the Geneva Convention are thus consciously ignored by the use of terrorism, which is deliberately designed with civilians as targets. There are significant differences between the killings of civilians by mistake in war compared with the conscious targeting of civilians. While murder for other reasons is usually directed toward the affected victim, terrorist acts carry an indirect approach; random or representative victims are killed in public to reach a wider audience. Thus, terrorist violence is committed for the effect it has on others rather than the direct victim (Schmid 2004). Some claim that terrorism can only be perpetrated by sub-state actors (Hoffman 2006) while others hold that states can also commit acts of terrorism (Gibbs 1989). Wilkinson pointed out that several obvious terrorist campaigns during the 20th century have historically been much more lethal when perpetrated by regimes (e.g., Hitler and Stalin) than by sub-state actors. In light of that, the exclusion of state actors in the definition of terrorism would be "blatantly dishonest and self-serving" (Wilkinson 2011). Gibbs (1989), however, clarified that the state judiciary sometimes requires elements of violence in order to be functional, i.e., the state holds certain rights to conduct "legitimate violence and force" against its citizens. The exclusion of states as perpetrators of terrorism was one of the reasons why the Global Terrorism Database was considered too narrow as a data source for Study I. Gibbs holds that terrorism involves a normative aspect, stating that terrorism is an

action that contributes to “maintenance or alteration of some law, policy, arrangement, practice, institution, or shared belief” (Gibbs 1989:331). Terrorists primarily choreograph their attacks to intimidate, create panic and alarm the citizens to require national leaders to somehow correct the errors (Crenshaw 1990, cited in Shughart 2006). The leaders’ response to the terrorist campaign is of utmost importance because terrorism itself is a method that can be experienced as forced by power asymmetry. If the terrorists succeed in manipulating the other side to use similar tactics, the moral differences between the attacker and defender quickly erode, which has serious consequences for society (Schmid 2004) when the terrorist struggle is legitimized (Crenshaw 1981; Wilkinson 2011). Historically, governments’ use of unexpected and unusual crackdown in response to protests or reforms often forced retribution by terrorism (Crenshaw 1981). After taking this into consideration, I have come to agree with Wilkinson’s definition, including five characteristics that distinguish terrorism conceptually and empirically from other forms of violence and conflict: (1) it is premeditated and designed to create a climate of extreme fear; (2) it is directed at a wider audience than the immediate victims; (3) it involves attacks against random or symbolic targets, including civilians; (4) it violates standards for the regulation of disputes, protests and dissent in the targeted society; and (5) it is used primarily, but not only, in order to influence the political behavior of governments, communities and specific social groups (Wilkinson 2011:5).

Neumann and Smith (2005) identify three distinct parts of the process of how terrorism is strategically used to fulfill the terrorists’ political goals. Unlike conventional warfare, terrorism is not primarily used to kill and destroy but to subdue and create a sense of fear in an audience, which then initiates political change. Terrorism can thus be classed as a form of psychological warfare. The first part of terrorism as a strategy is known as *disorientation*, which is about alienating citizens from the authorities by demonstrating its inability to control and protect civilians from attack. The second part, called the *target response*, means that the desired population or group is manipulated to react in a way that benefits the perpetrators of the attacks. The third part involves *obtaining legitimacy* by making use of the violence emotional power to convey an alternative political message (Neumann & Smith 2005). Sedgwick (2004) adds perspective on terrorism as a strategy by clarifying the distinction between *immediate objectives* versus *ultimate aims* related to religious terrorism with the example of Al Qaeda. This distinction is important, especially with regard to the current “wave of terrorism” (Rapoport 2004, in Sedgwick 2004) dominated by religiously inspired terrorist organizations. According to Sedgwick, it would be a mistake to assume that the immediate objectives of religious terrorists

are not political even though their ultimate aim is religious. He furthermore warns that it is generally “a dangerous fallacy to suppose that people intend the consequence of their actions” (Sedgwick 2004). The desired and anticipated response from the terrorist’s point of view can be extremely difficult to figure out because of its indirect and asymmetric nature. Deciphering the desired response is however required if counterterrorism strategies are to be effective (Kydd & Walter 2006). To aid in finding effective ways to combat terrorism, learning from history is essential (Cronin 2003; Roberts 2005) in order to avoid making the same mistakes and risk making matters worse. Some terrorists’ objectives are to strike so hard that alarmed democratic governments adopt counterterrorism laws restricting revered civil rights, thereby weakening the foundations of which liberal democratic societies are based on (Nacos 2003). Wilkinson (2011) notes that, by abandoning the rule of law and violating the human rights of suspects, the foundations of the values and principles that are fundamental to democratic societies are betrayed. Hoffman (2004) goes further by stating that abandoning human rights in emergency situations is not only short-sighted but counterproductive. The Swedish national counter-terrorism strategy also makes references to this aspect and the importance of handling the consequences of an attack in a manner that does not have the effect of increasing radicalization and alienation (Ministry of Justice Sweden 2015).

Although it is not the focus of this dissertation, another important point on preparedness and response concerns the media. Schmid and Graaf (1980) hold that propaganda is an integral part of terrorism; stating that violence is aimed at changing behavior through coercion while propaganda makes it through persuasion. Terrorism combines the two. By engaging in violence against a specific person, another may be forced or persuaded to do something (Schmid 2004). Thus, the media is a crucial instrument (Lutz & Lutz 2007). As stated by Juergensmeyer (2003:141): “Terrorism without a horrified witness would be as useless as a play without an audience.” Media coverage preserves the terrorist’s temporary presence and gives the act a longer life span (Schmid 2004) while the worldwide media coverage also means an extraordinary widening of the audience (Juergensmeyer 2003). The media can also have a negative impact on response due to a lack of understanding in the operations of the actors involved, low levels of information verification and high pressure to meet deadlines and get their story out first (Boyd & Sullivan 1997). In a democratic society, it is of utmost importance to have a sensible and effective public information system that is utilized and managed during incidents (Boyd & Sullivan 1997; Wilkinson 2011). The media can then help by passing on warnings to the public from the police and provide practical instructions on how people should act (Wilkinson 2011).

Rationale

Public transportation constitutes a vulnerable, essential and target-rich sector that cannot be completely secured from antagonistic acts. Preparedness for such attacks can mitigate effects and decrease the risk of further attacks. However, the temporal and spatial developments of MCAs on public transportation internationally are unknown. Disentangling and depoliticizing MCA cases from differently defined terrorist attacks are essential in order to examine their scope, characteristics and direct response challenges. The societal response to MCAs on public transportation is demanding due to the risk of secondary attacks, uncommon injuries and environmental difficulties presented by the transportation environment. Analysis of previously encountered challenges during on-scene responses is required in order to inform future response and preparedness efforts. One should also explore opportunities to increase preparedness through method developments that allow for prediction of injury effects and the evaluation of injury preventive measures from bombings in the public transportation environment.

The Swedish case is of special interest as it is a country with increasing risk factors and its preparedness for attacks has been questioned. As Sweden has so far been spared from mass-casualty attacks on public transportation and elsewhere, personnel in the emergency organizations have no real-life experience in the management of such incidents. Much is unknown about preparedness for terrorism in Sweden, particularly regarding the views of the emergency responders. Yet they will be the ones to manage the direct consequences should an attack occur. No research has been done comparing Swedish police, rescue service and EMS' perceptions of terrorism-specific threats and preparedness or specifying what factors may affect these perceptions. This research is set to fill those gaps, and the dissertation as a whole will pinpoint some major challenges that inhibit achieving preparedness for MCAs on public transportation in Sweden.

Aim and research questions

The aim of the dissertation is to *investigate preparedness for mass-casualty attacks on public transportation*. This will allow for *identification of major challenges for preparedness and response with a particular focus on the Swedish context*. The research includes five studies, each of which provides essential pieces to answer the research questions below and ultimately the overall aim.

- How has the phenomenon of mass-casualty attacks on public transportation developed internationally over time? (Paper I)
- What can be learned from previous on-scene responses to mass-casualty attacks? (Paper II)
- What are the main differences among the Swedish emergency organizations regarding perceptions of terrorism threats and preparedness, how can they be understood and what does that imply for preparedness efforts? (Paper III)
- How is preparedness for mass-casualty attacks perceived among Swedish emergency responders and what influences these perceptions? (Paper IV)
- Can finite element (FE) modeling techniques effectively model damage and injuries for explosions and be used for the improvement of preparedness and injury mitigation measures? (Paper V)

Materials and methods

As should be clear after the introductory and related research chapters, this dissertation entails a highly multifaceted framework, which is also reflected in the methods and chosen research designs for each included study.

This section elaborates more on how the research has been conducted, what materials were used and how, and deliberations on methodological and ethical issues. Firstly, the study context is presented in order to give the reader insight on the structure of the Swedish crisis management system and an understanding of some resultant challenges for the preparedness and response to mass-casualty attacks.

Study context

The Swedish crisis management system is founded upon the three basic principles of responsibility, equity and subsidiarity. These denote that whoever is responsible for an activity under normal conditions is also responsible during an emergency; as far as it is possible, operations should function similarly to what they do during normal circumstances; and a crisis should be handled at the local level where it occurs.

According to Swedish law, the municipalities and county councils are responsible for providing assistance during emergencies (Ministry of Defence Sweden 2006), and the county councils are specifically responsible for maintaining preparedness in disaster medicine (Ministry of Health and Social Affairs 1982). The emergency organizations are governed through different administrative and regional divisions: the police fall under the Ministry of Justice, the rescue services under the Ministry of Defense and the ambulance service under the Ministry of Health and Social Affairs.

The state emergency response organizations are constituted of the Police, the Maritime and Aeronautical Search and Rescue Services, County Administrative Boards and the Coast Guard. The primary organizations conducting sea rescue and mountain rescue are both non-governmental organizations that conduct rescue in their areas of expertise through deals with the Swedish Maritime Administration and the police. As of 2015, the local level of the police force was consolidated into a single national police authority (The Swedish Police 2013a), when before they were divided into 21 different police authorities distributed evenly among the 21 Swedish counties (The Swedish Police 2013b). The rescue service is governed at the municipal level and there are 290 municipalities. In the rescue service, there are personnel employed full time, part time and on a voluntary basis (mainly in

rural areas). The ambulance service, in turn, is governed by the county councils, since it is part of the health care system, which falls under the responsibility of these 21 regional, self-governed units. Within the ambulance service, there are also private actors and a large number of companies working in prehospital care are contracted by tender. Lastly, it should be noted that the military in Sweden only plays a small role in the civilian crisis management system. While the use of the military in response to terrorism has been debated, as of yet it is restricted due to the present legislation (Örtenwall 2005).

The research process and design

The scientific process allows one to gauge what goes on in the world, and the research design helps one do so in a systematical manner (Lee Abbott & McKinney 2013; Rugg & Petre 2007). The overall research process was largely empirically driven in the sense that new vital issues to address were identified throughout the research process. Each study also implied a necessity to acquire knowledge of the diverse fields of research to shed light on findings in the data. In this way, the later studies were developed based on some of the conclusions from my previous studies as well as others' research. Different methods to select, collect and analyze data were used, as suitable to each research question (*Table 1*).

Table 1. Summary of methods and materials used

Study	Design	Data sources	Sample	Analysis
<i>I</i>	Epidemiological study	GTD Journals Newspapers Web pages	477 cases	Descriptive statistical analysis
<i>II</i>	Literature study	PubMed Scopus	105 articles	Thematic analysis
<i>III</i>	Comparative, statistical study	Questionnaire	864 respondents	Descriptive & bivariate statistical analysis
<i>IV</i>	Inferential, statistical study	Questionnaire	864 respondents	Multiple logistic regression analysis
<i>V</i>	Simulation validation study	Journals Videos	Fatalities & injured from Madrid attacks 2004	Finite element simulation

Data sources and materials

Databases

The three different databases, PubMed, Scopus and Global Terrorism Database (GTD), were used for the collection of data for the studies (**I**, **II**). The GTD was used in Study **I** to find cases of previous mass-casualty attacks on public transportation and associated infrastructure. For more in-depth deliberations regarding the GTD limitation and advantages, please see Methodological considerations. PubMed and Scopus were used to search for secondary data in publications and research conducted by others. More information on the selection process and criteria can be found in the reprinted version of Study **II**.

Complementary data sources

For the purpose of Study **I**, it was considered necessary to go beyond the GTD due to the database's inclusion criteria, absence of data from year 1993 and additional methodological issues discussed below. These complimentary data sources consisted of journals and magazines (n=8), reports (n=8), books (n=9), newspapers and news channels (n=31) and numerous websites (e.g., from the organizations Human Rights Watch, UNHCR, and Action on Armed Violence). Since the quality and accuracy of these different sources varied, at least three independent sources were considered necessary for inclusion. The data collected were used as a basis for backtracking incidents in the GTD. In this way, 52 additional cases could be found in the GTD, which would not have been found otherwise, as they had been categorized or counted differently. Moreover, 96 cases of MCAs were found in complimentary sources, which were not found in the GTD at all.

Additionally, several observations (n=5)³ of crisis scenario exercises, both of functional and table-top type, were supervised throughout the research process. These observations were conducted in order to gain insight of some of the major challenges regarding the management of mass-casualty incidents in connection to transportation or antagonism. The observations made from the exercises were mainly used as a basis for the ideas of what issues would need to be addressed in the research as a whole and not as a source of primary data. Thus, consent was not requested from students and professionals who were a part of these exercises, as these observations were

³ Dublin exercise (train crash); Emergency organization collaboration exercise (threat to emergency personnel and a bus crash); KMC Linköping table-top exercise (school shooting); and CBRNE exercise (radiological, antagonistic attack)

made in an informal manner and no names or positions were recorded. Nonetheless, the observations were part of the research process and the formation of the final dissertation and allowed for the interplay between practice and research findings.

Questionnaire

Data for Study **III** and **IV** were collected through a purposive-designed questionnaire sent out by mail along with an information letter and a reply envelope by Statistics Sweden (and possibly followed by a letter of reminder). The questionnaires were sent out to 1,421 people (1,090 men/ 331 women) who were strategically and randomly selected from eight counties to represent each subpopulation (i.e., the “operational section” of the police, rescue services and ambulance services). Sweden's decentralized management system, combined with differences in social conditions (distance and population density), meant that the target populations deemed most suitable were those on “external duty” or “operatives in the field” at the local level and not specialist units within each organization. Regarding the response to MCAs, researchers (Autrey et al. 2014) have claimed that the first arriving police departments, rescue services and EMS (not tactical responders like Special Weapons and Tactics or Tactical Emergency Medical Support) were the key to a timely and effective response because the standup time of specialized teams was not feasible for timely response to rapidly unfolding events. Thus, those who work within the emergency organizations locally will be first societal organizations on scene and have the potential to take life-saving measures in a time-critical situation. This made their perceptions of threats from terrorism and terrorism preparedness particularly interesting to survey in the Swedish setting.

The book *Constructing effective questionnaires* (Peterson 2000) provided guidance when designing the questionnaire. As to the amount of structure, the questionnaire had primarily structured close-ended questions with predetermined answering alternatives, since these are preferred when one wants to be able to generalize the answers to a larger population (The Swedish State Advisory Committee on Assessment of Health Care Interventions 2013). Regarding the content of the questionnaire, previous research conducted with similar populations internationally or with similar research questions (Alexander & Wynia 2003; de Zwart et al. 2009; Dimaggio, Markenson, Loo, & Redlener 2005; Goodwin, Willson, & Gaines Jr 2005; Juffermans & Bierens 2010; Markenson et al. 2007; Qureshi et al. 2005) and Study **II** were used as inspiration. After the background questions, regarding the respondents' demographic characteristics and experiences, the questionnaire was set to collect information about the respondents' education, training and experience with major incident

management and willingness to act when confronted with various CBRNE scenarios. An “average scenario” of an attack was presented (based on data from Study I), and the respondents were asked to estimate the capability of “their organization” to manage the scenario, taking knowledge and resources into account (on a uni-polar five degree scale from “Perfectly adequate-Totally inadequate”). The questionnaire was examined during the design process by both experts in the incident site management and laymen as well as experts from Statistics Sweden, and it was modified to ensure that the wording and answering alternatives to the questions were appropriate.

Data analysis

Descriptive statistics were used in the analysis of the data of Study I, III and IV in order to show numbers and proportions during comparisons. In Study III, Kruskal-Wallis bi-variate test was used to analyze the differences between the three groups of respondents. In Study IV, multiple logistic regression analyses were performed with each of the three preparedness variables. All regression models measured the relationship of each covariate to the outcome variables adjusted for confounding by the other variables – that is, the adjusted odds ratio with 95% confidence intervals. Data were analyzed using Microsoft Excel and Stata Statistical Software release 13 (College Station, TX, USA; StataCorp LP 2013).

In Study II, the seven defined management priorities in the “Major Incident Medical Management and Support (MIMMS) framework” (Hodgetts & Mackaway-Jones 1995; Hodgetts & Mackaway-Jones 2004) were used as a base for thematic analysis. Once the relevant information was categorized, as per the defined inclusion criteria (see Study II), the information was compounded into its core elements and synthesized under subcategories based on the data content.

The numerical simulations of Study V were performed with EUROPLEXUS 2014; an explicit finite element code for non-linear dynamic analysis of fluid-structure systems through use of an automatic algorithm (Casadei 2008). In order to examine both carriage damage and injuries to the passengers, the model considered fluid-structure interaction phenomena where several parameters were allowed to vary. These parameters were:

- Doors (open/closed)
- Location of the charge (near the door/between the seats)
- Number of passengers (0/100/150)
- Intersections (glass walls) at the vestibule (present/non present)
- Size of the charge (6/9/12 kg)

Calculations were made with a full fluid structure interaction model where the charge was represented by a compressed balloon model (Larcher &

Casadei 2010). The model contained two meshes, with about 460,000 fluid elements and 42,000 structural elements, and each simulation took approximately 5 hours on a normal desktop PC. The developed and tested simulation modeled two main outcomes of the blast wave when parameters were changed. The first main outcome was the structural damage, i.e., displacement, to the carriage. The second main outcome concerned consequences for humans: fatality (due to head impact, full body impact and lung hemorrhage) and eardrum rupture.

Methodological considerations

With the methods chosen in the studies have come both benefits and disadvantages, which will be discussed below. As previously alluded to, the data collection for Study I implied several methodological issues. These were inherent due to the use of the GTD as well as the broadened search of other sources. LaFree and Dugan (2007) have described some of the advantages and challenges with collecting data on antagonistic actions, such as terrorism and crime. One benefit of the GTD is that it is a database open for anyone to use over the internet and it includes domestic as well as international cases of terrorist incidents. Some of the downsides of the GTD are that it relies on media reports about terrorism, which can be affected by how “newsworthy” a case is deemed, level of media penetration in a region, “public interest saturation” and government censorship or propaganda (LaFree & Dugan 2007). As Neumann and Smith (2005) put it, targeted states or terrorist organizations may both have reasons to inflate or deflate the numbers or threats as part of their strategy to affect the credibility of their opponent and disorient the public (see Terrorism studies).

As for the additional data collected, while necessary to manage some of the issues with the use of the GTD, it also implies methodological considerations. The most important issue is that of *replicability*, which is an aspect connected to *reliability* of a study, i.e., whether the results can be trusted (Gerring 2001; Lee Abbott & McKinney 2013). Since the complimentary data were found through online sources, finding the exact same ones in another search would be unlikely. If one looks at Gerring’s (2001) condition for replicability, however, these can be said to have been satisfied. The first condition is that the procedures employed in the study have been carefully laid out and clearly described (see Study I), which would allow someone else to conduct a similar search. The second condition is that the cases chosen, or other cases like them in all relevant aspects, are available for future study. In relation to Study I, this implies that even if the exact same case was not found through a new search, I hold that there is no reason to believe that other cases would differ greatly in aspects regarding temporal and geographical patterns, attack type and resulting fatality and

non-fatally injured. Thus, the broad overall patterns would likely be similar, but details and precise numbers would differ. While much effort was put into finding three reliable and independent sources for each case, care should therefore be taken regarding putting too much emphasis on precise numbers, e.g., in terms of fatalities and injuries. The innate difficulties regarding accurate count in any given attack is a well-known problem for researchers dealing with similar subjects (Jenkins & Butterworth 2010), and this is why the numbers are imperfect and should be considered as estimates. Although this constitutes a weakness in Study I, one must also consider the benefit of including more data, especially as it leads to an extensive strengthening of the information found in the GTD and the backtracked cases, where the GTD had underestimated numbers or categorized cases differently.

The use of questionnaires and statistical analysis in Studies III-IV also entailed methodological difficulties that sometimes required innovative solutions. A major hindrance regarded sampling, as Statistics Sweden could not select those occupied in the emergency medical services. This personnel category was instead grouped together with nurses and other medical technicians into a total population of 110,000 people. Thus, the EMS personnel had to be found in some other way, and I decided to contact some of the bigger EMS entrepreneurs as well as all the county councils in Sweden. These all had different approaches to dealing with such requests, implying that some refused to give out this personal information while others sent some or all of the information requested. In the end, I received full information from seven counties, which Statistics Sweden could apply the same sampling procedure to. As information from one major urban region was denied last minute, the sampling was applied to eight counties for the police and the rescue service, but only seven counties for the EMS. It should be noted that only 35 fire fighters were sampled in one county because that was all that were available in the registry, while 63 people were sampled from each response group in all other counties. The mail questionnaire was sent to 1,421 people and filled in by 805 respondents (56.7% response rate). However, the EMS personnel in the eighth county had to be found in some other way: through conferences targeting EMS personnel and by personal delivery where the ambulances were stationed. The questionnaires were left at the stations, with fruit or buns for respondents to eat while filling it out, and collected a few days later. These two means of additional data collection amounted to 59 completed questionnaires by the EMS personnel from the targeted county. These sampling issues mean that one may question just how *representable* and thus *generalizable* (Lee Abbott & McKinney 2013) the data are with regard to the broader population of operational personnel of the emergency organizations in Sweden. In terms of the eight counties that

the sampling was based on, there is no reason to assume that the personnel from these counties differed from other Swedish counties, but, as this cannot be assured, one ought to bear this in mind before generalizing the findings of Study **III** and **IV** to the entirety of the emergency organizations' operational personnel. It should however be noted in relation to this that an effect of municipality type (derived from the counties) could not be proven to have any effect on the preparedness constructs in Study **IV**, as will be shown in the results section. Moreover, the *empirical generalizations* (Lee Abbott & McKinney 2013) from the study are still valid, i.e., what the data show in terms of whether the hypotheses were supported or not.

Another aspect of importance in terms of the questionnaire and analysis of the derived data related to the aspect of *validity* is whether it captured and measured what was intended (Gerring 2001; Lee Abbott & McKinney 2013). This is worthy of discussion from two viewpoints. The first is the interpretation of the questions by the respondents in relation to how I interpreted the resulting data. While the content and wording of the questionnaire were reviewed by laymen, experts in mass-casualty management and experts on statistics and questionnaires from Statistics Sweden, it is difficult to know how the questions were interpreted by the respondents. One example can be given by the question regarding "willingness to respond" to CBRNE incidents. Obviously, the questionnaire was written in Swedish, and there is some ambiguity to the wording, where "willing" could be interpreted as "prepared," i.e., understood as "I am ready to act ..." as opposed to "I am willing to act..." How to capture this aspect in an acceptable manner was discussed at length before the final questionnaire was sent out and the clarifications to the meaning of "willing" were provided. Although the question was meant to measure willingness to respond in Studies **III** and **IV**, it is nevertheless unclear whether the question captured only willingness and not the perceived individual preparedness or confidence in managing CBRNE incidents. The other issue relates to the analysis and interpretation of the data through data processing where the data were simplified to allow for the construction of multiple logistic models. This implied that approximations and dichotomizations of several variables were conducted where responses were divided into two response alternatives where there were previously many (see Study **III** appendix and Study **IV** method). Whether these constructs accurately reflect what the respondent meant may be debatable, but they were a necessity in order to be able to use logistic regression models (Study **IV**). This multiple statistical analysis adjusts for other variables and shows how one variable affects another, as opposed to only if it causes an effect or not (as is shown in a bivariate analysis). Thus, this simplification was vital in order to be able to achieve the aim of Study **IV**.

Ethical considerations

Although mainly used in medical research, and not a binding legal document, the Helsinki Declaration (World Medical Association 2008) is widely regarded as a cornerstone of human research ethics and is applicable toward other forms of research. Among other things, the declaration refers to the weighing of potential benefits of research over the risk or proof of harm.

There are some obvious, innate ethical issues to take into consideration when doing research of any kind and, possibly, this research subject in particular. Due to the connection with terrorism, as mentioned, the research may affect security perceptions and the spread of fear, much as the media might. It may however also counterbalance populist and sensational media reporting with more equitable information. While sticking one's head in the sand regarding the threat of antagonistic acts is no solution, it allows people's ideas regarding security to remain intact. Pointing out the need to clarify MCA management challenges and the necessity of educating, training and preparing emergency personnel for such an event risks shattering people's view of security. Simply asking questions concerning preparedness and response may cause alarm and lead some people to assume that preparations being made imply that an attack is imminent. One then inadvertently risks increasing fear instead of raising awareness. Needless to say, that is not the point of the research. Another aspect is concerned with highlighting the gaps in preparedness. On the one hand, this is necessary in order to make improvements possible, and on the other hand, there may be a risk that findings are used with malicious intent. A balanced and pragmatic approach is the answer to these ethical issues. It implies that careful deliberation has been taken regarding how to present the research and in what level of detail.

With regard to research involving humans, the Helsinki Declaration also safeguards the participants' rights of autonomy and self-determination. Research involving humans is almost always reviewed beforehand by an ethical review board. That prompted an application to be sent to the Regional Ethical Review Board in Umeå before the questionnaire was distributed. They saw no ethical problems with the project and judged that it could be exempted from ethical approval, as it was not subject to the Law of Ethical Approval.

Summary of studies

The following section summarizes the five studies conducted to answer the research questions and the overarching aim of the dissertation: to *investigate preparedness for mass-casualty attacks on public transportation* in order to allow for *identification of major challenges for preparedness and response, with a particular focus on the Swedish context.*

Study I

Study I, as stated, collected material from several sources and broadened the focus of terrorism used in the GTD to the more de-politicized issue of mass-casualty attacks. The importance of this is worth highlighting as many of the cases identified otherwise would not have been found and valuable information would have been missed (*Table 2*).

The international overview addresses how the mass-casualty attacks (≥ 10 fatally injured or ≥ 100 non-fatally injured) against public transportation and terminal buildings have developed between the years 1970-2009. With respect to geographical patterns, Asia was the most frequently targeted region (N=236; 50%), followed by the Middle East & North African region (N=104; 22%) and Sub-Saharan Africa (N=63; 13%). More than a third of all incidents were shown to only occur in the three countries India, Sri Lanka and Algeria. Regarding temporal patterns, airplanes were the most frequently attacked mode of transportation during the 1970s, but after the mid-80s, buses have been the most frequently targeted. Importantly, in terms of changes in the targets of these attacks, an alarming increase in attacks against terminal buildings was seen during the last decade (years 2000-2009). In total, throughout the four decades, the two most common types of attacks were bombings (N=264; 55%) and armed assault (N=158; 33%). As *Table 2* shows, the additional data collection particularly revealed a large proportion of the attacks against airplanes (i.e., 52% outside GTD). Moreover, the attack type of sabotage, which was exclusive to rail-bound attacks, was shown to be more common than the GTD data revealed (i.e., 87% outside GTD). These may point to a crucial area for future prevention efforts, which would not have otherwise been apparent. Analysis of how the attacks were carried out also exposed what was termed “complex tactical approaches,” which were used to achieve as much carnage as possible. These included efforts to maximize the number of exposed people (e.g., attack during rush hour), enhancing weapon effects (e.g., adding scrap metal in bombs), approaching victims one-by-one (e.g., execution style attacks with knives), over-kill techniques (i.e., combining several attack types) and

Table 2. Comparative percentage of data found in defined timespans, regions, transport modes and types of attack, by source (I).

Source	Timespan	Region	Transport mode	Type of attack
GTD (N=329; 69%)	1970-1979 (N=23; 66%) 1980-1989 (N=101; 74%) 1990-1999 (N=115; 72%) 2000-2009 (N=90; 62%)	Asia (N=158; 67%)	Airplane (N=27; 48%)	Armed assault (N=99; 63%)
		Europe (N=16; 84%)	Train/Subway (N=55; 71%)	Arson (N=4; 50%)
		Latin America (N=26; 87%)	Bus (N=179; 71%)	Bombing (N=202; 77%)
		Middle East & North Africa (N=68; 65%)	Ferry (N=15; 65%)	Hijacking/ Hostage taking (N=15; 63%)
		North America (N=2; 50%)	Terminal building (N=37; 80%)	Other/Unknown (N=8; 57%)
		Russia & NIS (N=13; 62%)	Multiple targets (N=16; 70%)	Sabotage (N=1; 11%)
		Sub-Saharan Africa (N=46; 73%)		
		Additional search ¹ (N=148; 31%)	1970-1979 (N=12; 34%) 1980-1989 (N=36; 26%) 1990-1999 (N=45; 28%) 2000-2009 (N=55; 38%)	Asia (N=78; 33%)
Europe (N=3; 16%)	Train/Subway (N=23; 29%)			Arson (N=4; 50%)
Latin America (N=4; 13%)	Bus (N=72; 29%)			Bombing (N=62; 23%)
Middle East & North Africa (N=36; 35%)	Ferry (N=8; 35%)			Hijacking/ Hostage taking (N=9; 38%)
North America (N=2; 50%)	Terminal building (N=9; 20%)			Other/Unknown (N=6; 43%)
Russia & NIS (N=8; 38%)	Multiple targets (N=7; 30%)			Sabotage (N=8; 89%)
Sub-Saharan Africa (N=17; 27%)				

¹ Includes all cases that would not have been found without the complementary data search; thus also the 52 cases that were backtracked in the GTD (previously excluded due to diverging count or categorization).

targeting rescue personnel (e.g., secondary attack on-scene or against treatment facility). The use of complex tactical approaches was more predominant during the last two decades (N=90 vs. N=11), and attacks against rescue personnel (N=6) were exclusive to the 21st century. In total, the MCAs resulted in over 18,000 fatalities and over 32,000 non-fatally injured. It also turned out that few incidents had a large impact on the total number of fatalities and injuries. Ten incidents accounted for 29 percent of fatalities and 55 percent of non-fatal injuries, respectively. The average

number of non-fatally injured increased considerably throughout the decades despite a quite stable incidence rate since the 1980s. In terms of incidents close to Sweden, only 19 MCAs occurred in Europe (4% of total) between 1970-2009. However, the average number of fatalities per incident and injured per incident in these MCAs was the second highest among regions after North America. Thus, while MCAs were rare, they have had very high consequences when they occurred in terms of injured and fatalities. This, in turn, implies that having the capability to respond is vital.

Table 3. Results from the literature review (II)

Prioritized task	Management challenges on scene
Command	<ul style="list-style-type: none"> ● Establishing a clear, unified scene leadership ● Collaborating across responder professions in planning & practice ● Coordinating multi-site incidents & multi-exit scenes ● Balancing needs for staff & resources
Safety	<ul style="list-style-type: none"> ● Knowing of & using personal protective equipment ● Being aware of risks & having realistic expectations of safety ● Cordoning off the scene ● Conducting dynamic risk assessments & deciding “rules of engagement” ● Approaching safety defensively or offensively ● Joining forces
Communication	<ul style="list-style-type: none"> ● Functioning equipment - overload, destruction & incompatibility ● Dialoguing - content, language & relay ● Informing - survivors, relatives & the public
Assessment	<ul style="list-style-type: none"> ● Viewing scene layout & interpreting environmental indicators ● Understanding setting-driven needs for specialist skills & resources
Triage & Treatment	<ul style="list-style-type: none"> ● Differing triage systems & labeling ● Directing & gathering casualties ● Encountering uncommon injuries ● Setting up field hospitals & personnel matters ● Determining ambition for level of care & treatment ● Providing psychological support ● Caring for the pediatric casualty
Transport	<ul style="list-style-type: none"> ● Accessing & leaving the scene ● Evacuating urban or rural scenes ● Distributing patients

Study II

Since Study I showed that MCAs during the last two decades resulted in increasing numbers of non-fatally injured, which test our societal response structures, the next step in the research process was to investigate on-scene responses to previous mass-casualty attacks with special attention to the public transportation environment. Thus, Study II included a broad range of existing research from previous management of MCAs (n=105). This was crucial in order to gain and convey insights of use for emergency responders and crisis management planners regarding response and preparedness for MCAs. As stated, the MIMMS framework regarding management priorities on scene was used as a starting point for the analysis of the 105 articles included for review. The label of the first management priority, usually labelled “command and control,” was however changed to “command and coordination” in better accordance with the content of the articles reviewed. Moreover, the vital aspect of the environmental setting, during assessment, was highlighted more in the review than in the original framework. In addition to specific challenges during scene assessment, other particular issues related to the prioritized tasks of safety, triage and treatment. While problems related to command, coordination and communication were the most commonly reported, these are also common in unintentional incidents. Considering the challenges found in the review (*Table 3*) in collaborative emergency plans and training, may decrease their impact on future responses.

Study III

As some of the literature in Study II suggested, the dilemma of safety for responders versus urgent care of injured could be countered through more tightly integrated inter-organizational collaboration another question regarding safety and the emergency organizations arose. How do the police, the rescue services and the emergency medical services perceive the threat of terrorism and preparedness for a terrorist-induced event? Thus, Study III set to determine the answer to that question within the Swedish context and to elucidate the differences among the emergency organizations as well as discuss the potential implications for emergency preparedness. To gain an understanding of organizational differences, the concepts of safety culture and institutional logics were highly influential. The statistical analysis showed significant organizational differences connected to all variables, except for consequence assessment (*Table 4*). All organizations graded terrorism as the event with the most severe consequences. It appeared that the responders’ “event probability assessment” was influenced by institutional logics. The events were estimated as more probable if they were within the organizations’ area of responsibility; i.e., more EMS staff graded MCIs as probable, more rescue service graded natural disasters as probable

and more police graded terrorist attacks and riots as probable. “Willingness to respond” differed depending on the type of incident, but the pattern was consistent across organizations. The highest willingness to respond was reported related to bombings, followed by chemical attacks, radiological attacks and biological attacks, in that order. The proportion that graded as willing to respond was highest among rescue service personnel and lowest

Table 4. Perceptions of threats and preparedness by organization (percent). Significant Kruskal-Wallis bivariate test in bold.

	EMS	POLICE	RESCUE SERVICE	Total sample
	(n=321)	(n=259)	(n=277)	(n=864)
High event probability assessment	48.0	66.8	49.8	54.3
<i>High probability of...</i>				
Natural disaster	52.6	64.1	72.6	62.6
MCI	42.7	38.6	36.5	39.5
Terrorist attack	24.0	31.3	22.0	25.6
Riot	50.5	89.6	47.3	61.6
High event consequence assessment	79.4	80.7	83.4	81.0
<i>High consequence of...</i>				
Natural disaster	54.2	63.7	66.1	61.6
MCI	71.7	74.1	78.3	74.7
Terrorist attack	89.4	92.3	91.3	90.9
Riot	51.4	44.0	52.3	49.7
High willingness to respond	56.7	65.6	72.9	64.6
<i>Willing to respond to...</i>				
Chemical attack	59.8	65.6	75.8	66.0
Biological attack	42.4	49.4	55.2	48.7
Radiological attack	44.9	57.5	61.7	54.3
Bombing	74.5	79.2	85.9	79.3
High estimated management capability	40.2	20.5	30.7	31.1
Enough resources	47.2	31.3	40.8	40.4
Enough knowledge	66.4	35.9	52.0	52.5
High level of confidence with tasks	34.9	27.0	40.1	34.5
Confident in knowledge of own tasks	17.1	13.9	14.8	15.6
Confident in knowledge of others' tasks	11.8	5.0	8.3	8.7

among EMS staff. In total, approximately 1/3 did not grade as willing to respond, and this possible lack has not previously been explored in other Swedish research on preparedness. All organizations graded that knowledge would be less of a problem than resources, but when grading their own “level of confidence with tasks” to be performed after a terrorist attack, only about 1/3 were confident in their knowledge of their own and the other organizations’ tasks. In total, the police staff’s responses stood out; they reported more personnel with experience of violence on duty and graded a high probability of terrorist attacks to a larger extent than the other organizations. Meanwhile, fewer police had high estimates of their organizations’ management capability and individual knowledge of on-scene tasks. The reason why they stand out, however, remains unclear and is worthy of more research, especially since the police’s role is so essential in response to a terrorist attack. The study showed differences in the perspectives of terrorism preparedness and response among the emergency services, which further emphasized the importance of enabling inter-organizational insights on institutional logics and safety culture in order to achieve an effective response to terrorism-induced emergencies. The study also highlighted the relevance of the responders’ perspective so as to attain realistic assessments of preparedness.

Study IV

Since Study III clarified that the emergency responders had different perceptions of the threat of, and preparedness for, a terrorist-induced event, Study IV went on to further explore what factors influenced these perceptions of preparedness. Three constructed aspects of perception of preparedness for terrorist attacks were studied: “willingness to respond”; “level of confidence with tasks”; and, “estimated management capability.” It was hypothesized that these would be influenced by characteristic and experience variables (sex, work experience, organization, experience of violence and municipality type) and education and equipment variables (general MCI training, terrorism-related management training (MT), table-top simulations, functional exercises, general and specific co-training and access to PPE). *Figure 2* shows the main findings of the study: lines between variables indicate a significant effect on perception, while the rectangles with dashed lines indicate that no significant effect was found to be related to that variable. “Willingness to respond” was positively associated with male sex, occupation in police or rescue services, training in first aid and dealing with mass-casualty incidents, terrorism-related management training (MT), table-top simulations and access to personal protective equipment (PPE); work experience was inversely related. Factors positively associated with

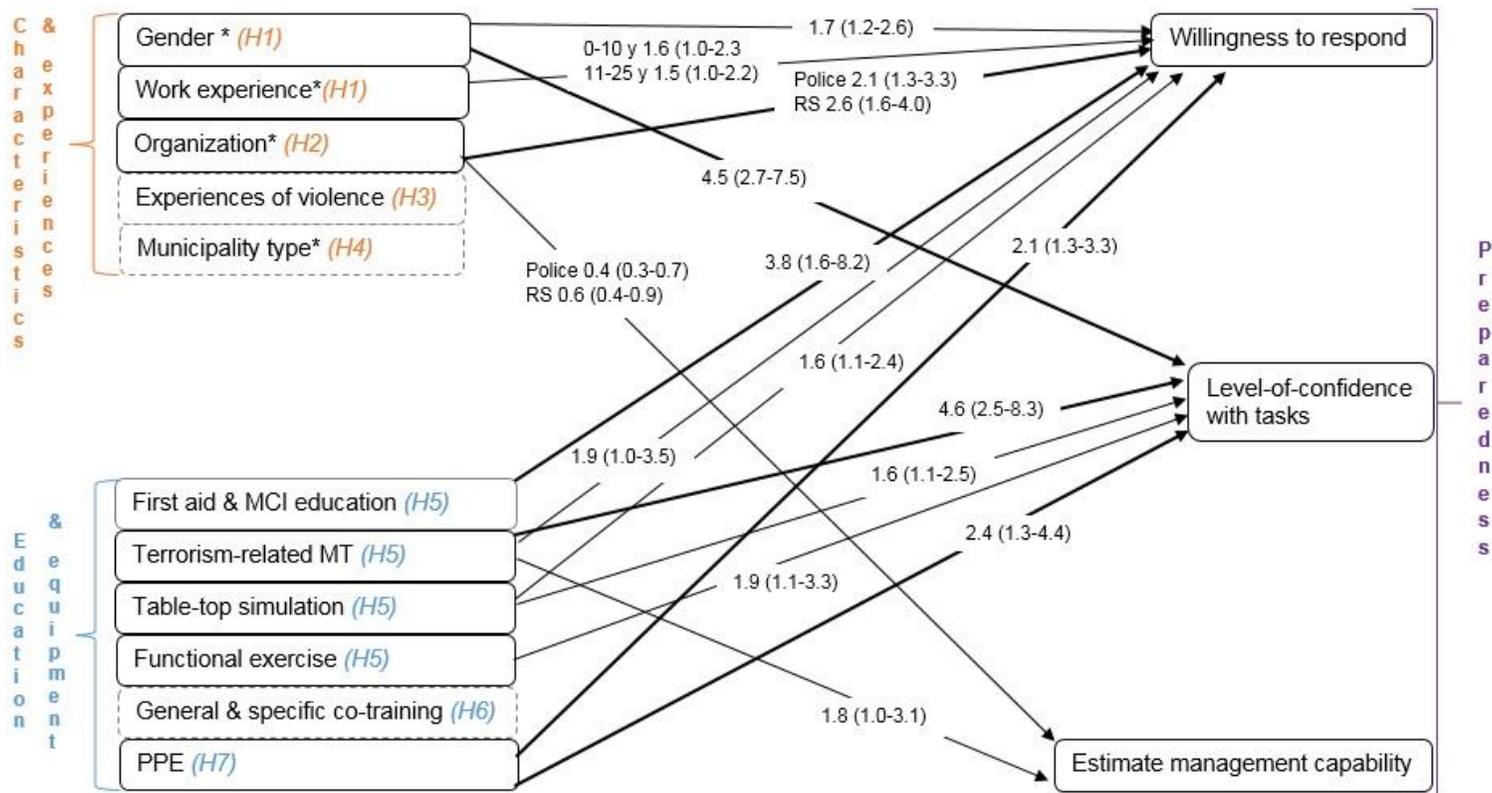


Figure 2. Summarizing figure of adjusted odds ratio and 95% CI within parenthesis for influencing variables on preparedness perceptions within the Swedish emergency organizations. * Reference groups: women, 26-45 years' work experience, EMS, Urban.

“level of confidence with tasks” included male sex, terrorism-related MT, table-top simulations, participation in functional exercises and PPE. Factors positively associated with “estimated management capability” included occupation within the emergency medical services and terrorism-related MT. No effect on preparedness perception could be proven to be connected to experience of violence, municipality type or any of the co-training variables. The study identified education, especially terrorism-related MT and table-top simulations, and PPE as possible interventions that influence perceptions of preparedness among emergency responders. These findings could aid the judgements about investments in preparedness by crisis management planners.

Study V

The last study took another approach to investments in preparedness and mitigation. Since bombings were shown to be the most common type of attack, and full prevention is not considered possible, the starting point was that a functional computational tool of detonations inside a train carriage could contribute to the reduction of the consequences of an explosion in such confined structures. It could also be used to aid estimations of effects as a basis for preparation and need of resources. First though, such a tool would need to be compared to a real-life situation in order to determine if it accurately matched reality. Thus, Study V investigated the effectiveness of modeling detonations inside a train carriage using explicit finite element (FE) techniques against data from the real explosion cases in Madrid in 2004. Results showed that charge size, charge location or door setting did not greatly influence the displacement in the modeled carriage structure; they did however have a significant impact on the risk of eardrum rupture and fatality. The comparison of the simulation and real-life data from the Madrid bombings demonstrates a good agreement between the real and calculated displacements of the carriage. Meanwhile, the risk of death and eardrum rupture is slightly higher in the calculations. Thus, it was hypothesized that including more parameters that influence injuries of blast waves would result in a model that more reliably reproduces the real-life outcomes.

Discussion

Preparedness and response to mass-casualty attacks imply that several, often simultaneous decisions must be made in order to achieve the greatest benefits with limited resources. This in turn denotes a multiple choice balancing act. To counter challenges that delineate from MCAs, proactively or reactively, several aspects must be considered in order to be able to lessen the risk of their occurrence or impact. Effective MCA management entails decisions regarding an array of issues, e.g., investments, inventions, planning, training, security and collaboration. As will be discussed, some of these choices may present themselves as dilemmas, but one can more constructively consider them to represent spectrums with degrees or levels. In order to be prepared to respond to MCAs, difficult questions must be asked, and taken for granted truths may need to be questioned.

Preparedness for mass-casualty attacks - a multiple choice balancing act

So, how has the phenomenon of mass-casualty attacks on public transportation developed over time, and what are the implications for Swedish preparedness? As shown in study **I**, with regard to the geographical patterns of MCAs, only 4% of attacks occurred in Europe. Out of all the cases that transpired in Europe, the most common target was airplanes, accounting for over 40% of cases (**I**). One of these cases was mentioned in the introduction, i.e., the attack of a plane that departed from Stockholm, Sweden on January 26, 1972. Because the plane flew apart over what was then Czechoslovakia, most of the management of the event did not occur in Sweden, and a case of an MCA involving public transportation has not occurred in Sweden since. In terms of preparedness for MCAs, aside from a lack of experience, this implies that Sweden is faced with the well-known preparedness difficulty of planning and preparing for a low-probability high-consequence event. This largely coincides with the Swedish emergency responders' perception of terrorist attacks, as shown in study **III**. The dilemma in the matter regards (1) *investing for extreme event function versus every-day function*. With respect to the public transportation sector, this can be seen as a value conflict (Stern & Sundelius 2002), as these companies must consider how to invest in order to answer the current customers' demands, with consideration to competition, as opposed to making investments and preparations to lessen the risk or consequence of extreme events, which could severely damage the customers' image of the company and considerably decrease use of the company's services. In Sweden, several modes of transportation within the public transportation sector are deregulated and include an ever expanding number of private

actors, contractors and consultants. Thus there is a lack of stability in terms of involved actors, which impacts long-term planning and solid knowledge accumulation. Moreover, there is little regulation of private actors' role in crisis management and they often assume that societal services will manage any large scale crisis resulting from an attack (Strandh 2015). One may infer that many public transportation actors perceive little pressure or incentive to invest for extreme event function. Even within the societal services Örténwall (2005) has also pointed out that difficulties in funding often imply that disaster preparedness is not given top priority, and suggest that central funding is needed to remedy the discrepancy between the central level awareness and priority of crisis management issues and that of the regional and local levels.

Returning to public transport modes targeted in MCAs internationally, the second most common target was categorized as multiple targets, such as the attacks in Madrid in 2004 and London in 2005. These two MCAs were also among the top 10 cases with the most non-fatally injured out of the total 477 cases. The attacks further exemplified the use of “complex tactical approaches” (i.e., occurred during rush hour, bombs were packed with nails and bombs were detonated while at the station/inside tunnel)(I). Thus, the planning of these attacks was quite sophisticated, and there was clear intent to cause major, direct consequences in terms of fatalities and injuries as well as a broader societal impact and disruption to infrastructure. Neither the Madrid nor London cases were among the 10 cases of MCAs with the most fatalities, even though the average number of fatalities per incident and injured per incident in Europe was the second highest among regions. Does this imply that the management of Madrid and London was particularly effective in terms of medical treatment, and if so, what do these cases have in common? What can be learned from previous on-scene responses to mass-casualty attacks? Did the prior experience with terrorism in Spain and the UK, perpetrated by the Irish Republican Army (IRA) and Euskadi Ta Askatasuna (ETA), imply that the personnel of the emergency organizations were particularly effective at lessening the consequences of the attacks? As shown in study II, several challenges were faced during the management of these events, and some less-than-ideal actions were taken. From a disaster medicine perspective, it can however be pointed out that access to needed resources was generally high; the medical level of ambition was not lowered and advanced life support was given in the prehospital setting; availability of medical transportation was considerable; and hospitals were in close proximity to the scenes. On the one hand, this implied that certain lapses may not have had as grievous effects on management as they may have had otherwise. On the other hand, it meant that casualties with traumatic limb amputation were given treatment (and survived), while in other places or in

even more severe incidents, they may have been considered unsalvageable and triaged as expectant⁴. Thus, prior experience may not have been the decisive factor in the management of these MCAs.

The importance of prior experience and planning nevertheless brings us to another dilemma for preparedness; (2) *planning versus well-practiced improvisation*, as highlighted by Czarniawska et al. (2007). It has been argued that emergency management requires both improvisation and preparedness activities; improvisation meaning organizing during an event and preparedness meaning organizing a response prior to an event (Dynes 1994). Moreover, I hold that there is likely an important distinction in use of the word “improvisation” as seen and discouraged in the literature (mainly with a disaster medicine orientation) in study II, as opposed to the meaning of the concept of practiced improvisation (Czarniawska et al. 2007), which is largely based on the broader emergency preparedness field. When some researchers state that “improvisation at the time of the incident did not work” (Lerner et al. 2007:149), they more or less mean a complete diversion from accepted standards of incident management and command where certain defined roles, responsibilities and organizational strategies can be taken for granted. What they claim does not work is un-informed or un-practiced improvisation, where emergency responders are left with doing the best they can, given the circumstances, while there are actually well-tested and functional methods to manage the response capabilities (Nilsson 2012; Rüter et al. 2006), of which they are unaware. The meaning of the word improvisation in one context thus refers to being imaginative in how to solve a problem (ignorance-based), as opposed to being creative in how to apply tools, i.e., which method is most suitable to use to achieve certain mission objectives (resource constraint-based). While planning can bring clarity and dispel some uncertainties, it cannot provide guidance for *how* to handle all eventualities. For emergency responders to be knowledgeable about how to effectively manage MCAs, they likely require both theoretical education and practical exercises.

This takes us to the dilemma of (3) *training generally versus specifically*. If investments in training are made, should they be based on an all-hazards approach or specifically focus on management of terrorist attacks? If training is set to focus on terrorism management, should it cover CBRNE incident

⁴ Providing life-saving, optimal care to those most severely injured (as opposed to prioritizing a large quantity of moderately injured) has been highlighted by Ashkenazi et al. (2008) as the best strategy to impact survival of an incident. Furthermore they held that triage into an expectant category should be based on Advanced Trauma Life Support (ATLS) principles, irrespective of the number of injured. They claimed that this is doable as the number of casualties with moderate or severe injuries after MCAs is not usually overwhelming.

management broadly or concentrate on each type of incident in depth? What level of specificity gives the best effect? How many must be trained in order to have an acceptable level of preparedness? Who should be trained in different geographical regions and who in turn gets to decide that and based on what? I have answered the question of how preparedness for mass-casualty attacks is perceived among Swedish emergency responders as well as shown that their preparedness perceptions were positively influenced by training (especially terrorism-related management training) and access to PPE (IV). Moreover, in the literature study (II), I concluded that certain methods and techniques regarding safety, assessment, triage and treatment differ in the management of unintentional incidents compared to MCAs, which would imply that specific training is required in these aspects to improve the odds of effective response to MCAs. The conducted research (IV), however, also generated many new questions in relation to training that may need to be answered in order to increase Swedish preparedness for MCAs.

Training also constitutes a vital aspect when dealing with the most obvious dilemma for response to MCAs, i.e., (4) *responding safely versus immediately*. As previously mentioned, in relation to previous research, and shown in study II, the scene of an MCA entails many threats to the safety of the responding personnel as well as the casualties. Some of those casualties may very well have critical injuries that require urgent medical attention if their lives are to be saved (Autrey et al. 2014). This creates another value conflict, but one of a predictable kind, which implies that investments in preparedness can provide essential benefits. In relation to this dilemma, one should not underestimate the additional stress on responders by feelings of duty or impulse to aid casualties as well as high expectations from the public to see a rapid societal response. However, as we can conclude that this value conflict is integral to MCAs, we can also pre-determine an array of strategies to manage it. To counter this dilemma, one can observe a progression in recommendations for on-scene response from a more defensive approach, where EMS wait for full-scene safety clearance (Lerner et al. 2007; Perliger & Pedahzur 2006), to a more offensive approach of entering the scene under police escort with the mind frame of “relative safety,” where the entire scene is still not rendered completely safe (Autrey et al. 2014). This transition calls for tighter collaboration between responders from different emergency organizations, where they carry out their missions simultaneously. The need for several simultaneous missions to be carried has also been pointed out in the new Swedish counter-terrorism strategy (Ministry of Justice Sweden 2015). Another approach to enable the effective response to a tactically challenging situation is a more constant integration of the EMS and the police through cross-training, thus amounting to the development of

“tactical emergency medical technicians” or “tactical medics” (Ciccone et al. 2005; McArdle, Rasumoff, & Kolman 1992). This may imply that EMS personnel are given Special Weapon and Tactics (SWAT) training or that law enforcement personnel are provided with Emergency Medical Technician training. Such training may alleviate issues where EMS personnel are not adequately prepared to operate safely with police in tactical situations or law enforcement personnel are incapable or discouraged from providing medical care. It might be a particularly suitable approach in rural or remote regions where the number of staff is limited and distance to the closest medical facility is long (McArdle et al. 1992). While cross-training programs by no means have to be as time consuming as two full degrees, they would still need to be voluntary (Ciccone et al. 2005; McArdle et al. 1992) and would require investment of both time and money.

In relation to initial response capability, the Swedish counter-terrorism strategy states that the basic tactical ability among operative police personnel is essential for efficient management (Ministry of Justice Sweden 2015). With that statement in mind, it was somewhat alarming to find that so few of the operational personnel of the Swedish police indicated that they were confident in their knowledge of tasks that must be carried out in response to a terrorist attack as well as the low overall estimate of the police’s management capability (**III**). Additionally, it was shown how differently the responders from the emergency organizations perceived the probability of different scenarios and how these perceptions appeared to be connected to their respective institutional logic. Using the concepts by Stern and Sundelius (2002), this implies that they likely have a diverging problem perception and framing, inferring that they will interpret and respond differently to the same event. Taking that into consideration brings another dilemma to the forefront, i.e., (5) *collaboration as solution versus source of uncertainty*. Is sought collaboration practically conceivable or an ideal? Given the seeming preoccupation of collaboration in the Swedish crisis management system, together with previous research and findings of study **III**, this particular dilemma appears strikingly obvious but is also likely culturally and politically sensitive. Sweden, however, is not the only place where the government and funding agencies perceive collaboration as the Holy Grail of solutions (Bryson, Crosby, & Middleton Stone 2006). While the suggested increased inter-agency collaboration strategy during response may fit well with the Swedish ideal of collaboration, I hold that it is imperative to dare to question whether it is practically achievable. In relation to the effectiveness of collaboration, as in achievement of desired outcomes, one cannot ignore the issue of leadership. While it has been shown that collaboration networks centralized around one lead agency are more effective than dense, strongly tied networks (Bryson et al. 2006) none of the

emergency organizations in Sweden has the legal right to control the other organizations. During antagonistic incidents the police are expected to initiate and lead the response after deliberation with the other emergency organizations. There is quite a bit of room for uncertainty here between the legal obligations compared to the expectations and wishes of the emergency organizations. With regard to inter-agency collaboration, it is also important to determine at what level this collaboration should occur. However, as it is the emergency organizations do not even have the same labelling or understanding of the strategic, tactical and operational levels in the incident management structure. Again a practical, obvious source of uncertainty appears which opposes effective and functional ideals of collaboration between the emergency organizations. Leadership, communication and collaboration are often trained and exercised as if they were a package deal, but there is room for uncertainty concerning whether effective collaboration among (tactical) on-scene leaders equates to effective collaboration among (operative) responders of different agencies. I pose that if inter-agency collaboration is increased to counter uncertainty issues, it will likely need to be trained by operative personnel with that purpose in mind and not limited to a higher level, senior personnel with a focus on strategic and tactical communication. Testing whether that is correct and whether computer simulations present a feasible option for large-scale inter-agency collaboration training remain interesting questions for future research.

On the subject of simulations, Study V showed that FE modeling techniques could effectively model damage and injuries for explosions and that there was room for improvement of the present model in terms of injuries. A further developed model, incorporating flying debris into the fatal risk calculation, has been created by Valsamos et al. (2015). This means that FE modeling may be used for the improvement of preparedness in the future, perhaps as a part of the Swedish county councils risk and vulnerability analyses. In terms of injury mitigative measures, these can also be evaluated through FE modeling. With regard to inventions, to make changes in the public transportation environment, this however takes us to the next defined preparedness dilemma – (6) *inventing for security versus safety* – although several examples can be found where counter measures actually coincide and simultaneously fulfil several purposes. The “Oklahoma bombing” 1995 case is an illustrative example provided in a study of survivors’ impressions of factors that influenced their risk of injury (Glenshaw, Vernick, Frattaroli, Brown, & Mallonee 2008). Glass, internal structures, building design, prior individual training and lay responder help were identified as perceived injury inducing or mitigating factors, which are features that have been shown to be of similar importance in the research on transport-related unintentional incidents (Doohan & Saveman 2014; Forsberg, Holgersson,

Bodén, & Björnstig 2014; Frykberg 2002; Holgersson, Forsberg, & Saveman 2012; O'Neill et al. 2012). In an overarching manner, these highlight the physical and social environments as important arenas for preparedness efforts (Haddon & Baker 1981), for example, through injury mitigative design and through the immediate response, as such efforts could lessen both fatalities and physical and mental consequences. In terms of inventions aimed to decrease injury and fatalities, there appears to be room for the dual-use of inventions, which ought to be highlighted as a possibility in relation to the transportation sector where these aspects are often separated. One transportation sector that was shown to be susceptible to sabotage was the railway tracks **(I)**, which could thus benefit from primary prevention efforts that could lessen the risk of MCAs as well as theft of essential and valuable elements of the railway infrastructure.

There may very well be some differences in the work conducted to prevent intentional and unintentional incidents, but there appears to be a “research focus bias” on the complete prevention of injury events in transportation sectors such as the railway (Forsberg 2012; Holgersson & Saveman 2011) at the expense of injury mitigative measures that function during an attack and in the aftermath. This may in turn imply that some dual-use opportunities are lost, as comparatively little research and invention are conducted on those phases, and the research that does take place is often separated between safety and security professionals. If one moves on to features that could reduce injuries in the event of an attack or unintentional incident, research and implementation of glass with blast-resistant glazing or other treatment that makes it less likely to injure if shattered has been repeatedly requested (Glenshaw et al. 2008; Holgersson et al. 2012; Thompson, Brown, Mallonee, & Sunshine 2004). Internal structures in vehicles have been shown to cause injuries (Forsberg et al. 2014; Holgersson et al. 2012) as well as have the potential to lessen injuries and fatalities, i.e., through introduction of intersections as injury mitigative measures in railway carriages **(V)**. O'Neill et al. (2012) also showed how the choice of materials and design can be counter measures, which allows for the maintained function of equipment, such as lighting and communication, after a detonation in a railway carriage. This, in turn, could improve the survivability by enabling efficient evacuation and rescue. Other designs and construction possibilities are constituted by the external stability, flexibility and crashworthiness of terminal buildings and transportation vehicles. Finding ways to construct buildings that are stable yet incorporate materials that decrease the effect of blast waves would go a long way toward decreasing fatalities and primary blast injuries. While complete reconstruction or replacement of the transportation infrastructure and vehicles is clearly impossible, some elements can be modified. Moreover, expansion of the

public transportation networks implies that new terminal buildings are built and new vehicles purchased, which provides opportunities to consider the injury mitigative capacity. However, that puts a lot of pressure on the public transportation agencies to give priority toward investing for extreme event function versus every-day function, which brings us back to where we started.

Practical implications

Study of developments and characteristics of MCAs on public transportation have showed e.g. that terminal buildings and railway tracks could be important arenas for future prevention and mitigation measures. The developed FE-model of an explosion in a train carriage can also be used for evaluation of injury mitigation measures in the public transportation environment. Additionally, it can be used as a tool for prediction of injury effects, in risk and vulnerability analyses connected to rail bound traffic, elucidating needs for corresponding capabilities in medical care. The highlighted challenges during on-scene responses previously encountered when managing MCAs can further inform capability requirements in the emergency organizations and the importance of collaborative planning and training. Currently a large majority of responders from all emergency organizations in Sweden perceive a lack of knowledge in main tasks during incident response related to MCAs, highlighting the need to develop their capabilities of rapid and safe response. Training, especially terrorism-related management training, and access to PPE among emergency response personnel, has been shown to increase responders' perceptions of preparedness, which can indicate worthy preparedness investments. Moreover, collaborative response to MCAs may be improved if the training enabled inter-organizational insights on safety culture and knowledge of the other organizations' institutional logics and main tasks during response to antagonistically induced incidents. Based on the findings of this dissertation and previous research, several challenges are indicated in the form of dilemmas that require attention in order to prioritize preparedness efforts for MCAs in Sweden. The results can benefit actors from a variety of fields including public transportation organizations, security agencies, emergency responders and organizations, crisis management planners, engineers and academics.

Further research

Through this research, I have come to find two broad arenas of interest for further investigation: (1) studies for further benefit to the scientific community and (2) studies for further benefit for preparedness and response to emergencies in Sweden.

As far as the international scientific community goes, in relation to preparedness for MCAs on public transportation, three distinct issues have been made clear. The first is of a methodological nature: how can we reliably and effectively collect data regarding issues of preparedness when private actors (e.g., EMS companies) are not subject to the same legislation as the public actors (and can thus deny providing information that would allow for data collection)? The second issue is with regard to the public transportation sector: how can the gap between safety and security professionals be bridged and how can prevention and preparedness for mass-casualty incidents be encouraged and prioritized over day-to-day operations? The third issue has already been mentioned and concerns researching the link between functional tactical leadership and functional operative management during mass-casualty situations.

In terms of research for increased preparedness and response effectivity in Sweden, several issues have already been highlighted that could be of interest to investigate. Additional issues concern the organization of the broader public crisis management system. Especially with regard to the three emergency organizations, one may question whether their division among different departments, governance on different levels and partitions among public, private and NGOs thwarts the efforts to assess readiness, make sound dual-use investments for preparedness and diminish opportunities for familiarity and knowledge sharing among organizations. Finding appropriate opportunities to effectively incorporate NGOs and individual volunteers in response to mass-casualty incidents and increase civilian preparedness among the public constitute other important subjects for future research. Another crucial element to research, in relation to large-scale antagonistic acts in a country where such acts have not occurred, regards promotion of human resilience in the public. In this case, inexperience may be a vulnerability in the population when it comes to susceptibility to terrorists' aims to spread fear. In relation to this, it is also highly relevant to investigate and problematize the role and responsibilities of the mass media as well as the impact of social media on the population. Lastly, as training is of importance for preparedness perceptions, it is a given interest for the future to evaluate the possibilities and practical preparedness outcomes of basic and continued training among the emergency response personnel in Sweden.

Conclusion

An effective response is not only reactive but hinges upon preparedness efforts. Achieving preparedness for MCAs on public transportation is a multiple choice balancing act between ostensible dilemmas regarding investments, disaster plans, training, response strategies, collaboration and inventions.

Acknowledgements

Ulf Björnstig: It is truly thanks to you that this this dissertation was written in the first place. You were the one who encouraged me to pursue a PhD degree and showed complete faith in my ability to see the project through, even though I was neither an engineer nor a doctor. If only more people had your ability to not only see potential in others but also generate competence.

Britt-Inger Saveman: Way before I became a PhD student and you knew what I was made of, you presented me with a big opportunity by allowing me to be a part of the ESS-project. Thank you for your company on real trips to academic conferences abroad as well as along my metaphorical journey as a PhD student.

Dzenan Sahovic: Not everyone would be eager to jump onboard as an assistant supervisor mid-race, but I'm very glad you were. Surely the final papers and dissertation would not be of the same quality without your pointers and questions, which caused me to take things one step further.

Isabelle Doohan: I have had to face quite a few challenges in my life, both as a PhD student and in my private life, but I truly had the best luck when I got to share my office space with you! I cannot put into words how much I appreciate having someone there who always made time to listen and show empathy and genuine interest in my worries and random thoughts. Our discussions on everything from methodological considerations to workout regimes to the “meaning of life” and back again, as well as our leisure activities together, have meant the world to me, and I don't want to consider how lonely this journey would have been without you.

Rebecca Forsberg: You manage to juggle a demanding job with a family life and top the whole thing off by competing (and of course winning) in the national Fitness Five championships. What inspires me most about you is not how good you are at mingling, your enthusiasm about collaborating, your aspiration to improve the workplace or your slight obsession with trains, but it is your dedication to your family. Your children are lucky to have you as their mother.

Veronica Strandh: As a PhD student on a related subject, you have been a role model throughout this process. You set the bar very high for everyone else, as you seem to have managed it all: taught, studied abroad, got published in a top-notch journal, got married and participated in crazy

endurance races. I look forward to seeing what you do next with the conviction that you will be awesome at it. I however admit to hoping that we won't be applying to the same job because then I won't have a snowball's chance in hell of getting it.

Johanna Björnstig: Your work mostly occurs somewhere behind the scenes, and you rarely get the credit you deserve for it! I feel certain that much of the daily KcKM operation depends on you or the whole thing would come to a grinding halt. Whether it's making sure that there are enough office supplies, entering data for analysis or software know-how, you are always there to lend your support. I am grateful for it and I'm sure I'm not the only one.

Jonas Aléx: I know of no other person with your ability to effortlessly and jovially compliment others and raise them up. Though often said in jest, you make others feel that they really are as good as they wished they were, and there are times when that is exactly what one needs to hear to keep struggling on.

Lina Gyllencreutz: We began our projects at about the same time and have both been through the trials and tribulations that come with being a PhD student. I appreciate the aid I received and was able to give during the times we met, and I was certainly glad to watch as you passed your examination, as I hope I will.

Other KcKM and CBRNE center colleagues: There have been times when just grabbing a cup of coffee and talking about something completely different has been an absolutely necessary escape from the difficult tasks that come with doing research. Therefore, I have been very fortunate that you all created an accepting atmosphere and made it possible to engage in such broad subjects of discussion.

Mom: When I was born, someone was very quick to judge and tell you all the things I would never be able to do. You were understandably heartbroken as you thought of all the pleasures your daughter was never going to experience. Yet you at least let me try, and it turns out that this someone was wrong. Not only can I tie my own shoelaces, but I can run obstacle course races! Not only have I ridden horses and skied down slopes, but I have traveled the world! Not only have I learned to read, but I have written my own dissertation! While things have not been easy, I have gotten where I am today, a great deal thanks to you.

Daddy: Not only did you give me the love and support of a parent as I grew up, but you were also my best friend. I am not sure that you quite realize how much it affected me that you gave me your time and interest instead of giving me material stuff. If it seems that your little girl is all grown up and doesn't need you anymore, it is likely because you have shaped me into an intelligent, independent and strong-willed person who does not quit at the first sign of trouble.

Sister Nina: Thank you for putting your gullible sister in the cupboard and stuffing her under the dirty clothes in the laundry basket when playing hide-and-seek. It taught me a thing or two about how people work. It also pushed me to be creative and become smarter, which just means one of these days, when you least expect it, I will pay you back.

Brother Peter: Thank you for the tech support when your somewhat panicked sister couldn't fix basic computer problems. I assume you will be double checking all the numbers in this dissertation, and I wish you the best of luck and enjoyment. Your baby sister still does not know elemental things like the first 10 prime numbers, but I do know a lot of other things, which shows that math is not the solution to every problem.

Cousin Tina: You elucidate the “work hard, play hard” expression. Even though we were born years apart, you are a dear friend and travel buddy, and I am grateful to have you in my life.

To my entire **extended family**, I am very appreciative that you accept that I seemingly fall off the face of the earth every once in a while, yet you still welcome me to come and visit whenever I please.

To **classmates** from my IKK-days and newfound **friends**, especially Karin, Rebecca N and my dance buddies, a huge thanks to you for the workouts, laughter and off-work fun throughout the years.

Lastly, a big thank you goes to **the Swedish National Board of Health and Welfare** for the financial sponsorship of this project.

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