Train Crashes - Consequences for Passengers

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” The train was seen as a terrible beast with its snorting locomotive, rushing through the dark woods. A highly apparent heir to the trolls and giants that had just begun to withdraw”
(1864).

The Swedish railway history
(Kullander, 1994)

“If one refuses to look back, and not dare to look ahead, one has to watch out!”
Tage Danielsson

Contents

ABSTRACT

Background: Globally, and in Sweden, passenger railway transport is steadily increasing. Sweden has been relatively free from severe train crashes in the last decades, but the railway infrastructure is alarmingly worn and overburdened, which may be one reason for an increasing number of reported mishaps. Worldwide, major train crashes/disasters are a frequent cause of mass casualty incidents. Several shortcomings, especially within the crash and post-crash phases cause severe consequences for the passengers.
Aim: To investigate the consequences of train crashes on passengers, focusing on factors of importance in the crash and post-crash phases. The specific aims are: (I) to identify the historical development and magnitude of passenger train disasters globally on various continents and countries, (II, III) to identify injury panorama and injury objects in two train crashes, (IV) to explore survivor´s experiences from a train crash, and (V) to explore their experiences of journalists and media coverage.
Methods: Study I is a register study based on 529 railway disasters worldwide, whereas studies II-V are case studies from the two latest severe train crashes in Sweden (Nosaby and Kimstad). These studies are based on 73 and 21 passengers respectively. Studies I-III is essentially quantitative where descriptive statistics (I, III), multivariate analysis (III), and content analysis (II, III) are used. Studies II and III are also supplemented by semi-structured interviews. Studies IV and V are qualitative and the interviews (n=14, n=30) have been analyzed with qualitative content analysis. Study IV is also supplemented with quantitative data.
Results: The number of railway disasters, fatalities, and non-fatally injured passengers has increased throughout the last hundred years - particularly during the last four decades (1970–2009) when 88% of all disasters occurred (I). Passengers in the first overturned carriage suffered most severe and lethal injuries (III). Internal structures such as tables, chairs, internal walls, as well as luggage, other passengers (II, III), glass (II), and wood pellets (III) induced many of the injuries. Those who traveled facing forward with a table in front of them, in carriages that did not overturn, were more likely to sustain injuries to their abdomen/pelvis than those without a table (III). Passengers who traveled rear facing had higher rates of whiplash injuries. Surviving a train crash was experienced as "living in a mode of existential threat". The long term consequences however were diverse for different persons (IV). All experienced that they had cheated death, but some became "shackled by history", whereas others overcame the "haunting of unforgettable memories." The centrality of others and the importance of reconstructing the turn of events were important when "dealing with the unthinkable". The media coverage were experienced as positive in the recovery process and the journalists were also perceived as helpful (V). By some the journalist's nevertheless were also perceived as harmful or negligible, and the subsequent media coverage as either uncomfortable or insignificant.
Conclusion: Despite extensive crash avoidance systems severe railway crashes still occur. Improved interior safety, as has been implemented in the automobile and aviation industries, would have an important reduction in injuries and facilitate evacuation. Being surrounded by family, friends, fellow passengers and participating in crash investigations, and experiencing descriptive media coverage were some crucial factors when dealing with the traumatic event and should be promoted.

Key words: Accident, crash, disaster, experiences, injuries, injury inducing objects, media coverage, railway, safety

SAMMANFATTNING (summary in Swedish)

Bakgrund: Passagerartrafiken med tåg ökar stadigt både globalt och i Sverige. Sverige har varit relativt förskonad från allvarliga tågkrascher senaste decennierna, men järnvägssystemet är slitet och överbelastat, vilket kan vara en anledning till det ökande antalet rapporterade tillbud. Globalt är allvarliga tågkrascher en frekvent orsak till masskadehändelser. Brister i både krasch och post-krasch faserna leder till allvarliga negativa konsekvenser för passagerare i händelse av en krasch.
Syfte: Att analysera konsekvenserna för passagerare med speciell inriktning på faktorer av betydelse i krasch och post-krasch faserna. Delsyftena är: (i) att identifiera den historiska omfattningen och utvecklingen av tågkatastrofer i olika världsdelar och länder, (ii) att identifiera skadepanorama och skadebringande objekt från två svenska tågkrascher, (iii) utforska överlevandes erfarenheter av en tågkrasch, och (iv) att utforska deras erfarenheter av journalister och media.
Metod: Studie I är en registerstudie baserad på 529 tågkatastrofer i hela världen. Studie II-V är fallstudier från de två senaste allvarliga tågkrascherna i Sverige (Nosaby och Kimstad). Dessa studier baseras på 73 respektive 21 passagerare. Studie I-III är i huvudsak kvantitativa, där beskrivande statistik (I, III), multivariat data analys (III) och innehållsanalys (II, III) använts. Studie II och III har även kompletterats med semi-strukturerade intervjuer. Studie IV och V utgår från intervjuer (n=14, n=30) och har analyserats med kvalitativ innehållsanalys. Studie IV har även ett inslag av kvantitativa data.
Resultat: Antalet tågkatastrofer, dödsfall och skadade passagerare har ökat under det senaste seklet och särskilt under de senaste fyra decennierna (1970-2009) när 88% av alla tåg katastrofer inträffat (I). Vid kraschen i Nosaby ådrog sig de åkande i den första vagnen, som välte, de allvarligaste och mest dödliga skadorna (III). Inre strukturer såsom bord, stolar, innerväggar, bagage, passagerare (II, III), glas (II), och träpellets (III) var angivna skadefaktorer. De som reste framåtvända med ett bord framför sig, drabbades av signifikant fler bukskador än de som inte hade ett bord framför sig. De som åkte bakåtvända hade högre andel whiplashskador (III). En tågkrasch upplevdes som ett existentiellt hot men långtidskonsekvenserna var i många avseenden olika (IV). Samtliga upplevde att de "lurat döden" men några lyckades inte gå vidare i livet medan andra övervann de oförglömliga minnena. Betydelsen av andra, samt att rekonstruera händelsen, visade sig vara viktiga faktorer vid bearbetningen av den otänkbara händelsen. Media upplevdes av vissa som ett sätt att hantera det som hänt och journalister på skadeplats kunde uppfattas som behjälpliga (V). Dock kunde de även ha negativt inflytande, och innehållet i media kunde uppfattas som obekvämt. De fanns även de som inte brydde sig om journalisterna på skadeplats och innehållet i media var obetydligt.
Konklusion: Trots omfattande åtgärder för att förebygga tågkrascher inträffar fortfarande katastrofala krascher runt om i världen. Förbättrad inre säkerhet, så som i vägfordon och flygplan, skulle ha en betydande potential att minska skadorna och underlätta vid evakuering. Att vara omgiven av närstående eller andra passagerare, samt att medverka i utredningar och ta del av faktabaserad media kan för vissa vara viktiga faktorer vid bearbetning av händelsen och bör därför främjas.

Nyckelord: Olycka, krasch, katastrof, upplevelser, skador, media, järnväg, säkerhet, tåg, skadebringande objekt

ABBREVIATIONS AND EXPLANATIONS

Injury event, crash, or incident	These terms are used interchangeably throughout the thesis
Passengers	This term is used for people on the train, including train crew members
Train/ rail	These terms are used interchangeably throughout the thesis
ATC	Automatic Train Control
ERTMS	European Rail Traffic Management System
AIS	Abbreviated Injury Scale
MAIS	Maximum Abbreviated Injury Scale
TGV	Train Grande Vitesse (high speed train)
PTSD	Posttraumatic Stress Disorder
km/h	Kilometers per hour
mph	Miles per hour
CRED	Centre for Research on the Epidemiology of Disasters
EM-DAT	Emergency Events Database
PCA	Principal Component Analysis
PLS-DA	Partial Least Square Discriminant Analysis
MSB	Swedish Civil Contingencies Agency
EU	European Commission
SPAD	Signal Passed At Danger

LIST OF PUBLICATIONS

This thesis is based on the following studies that will be referred by their Roman numerals in the text:

I Forsberg, R. & Björnstig, U. (2011). One Hundred Years of Railway Disasters and Recent Trends. *Prehospital and Disaster Medicine*, 26(5): 367-373.

II Holgersson, A., Forsberg, R. & Saveman, B-I. (2012). Inre säkerheten i tåg eftersatt- Fallstudie efter tågkraschen i Kimstad. [Internal safety in train is neglected – a case study of the train crash in Kimstad]. *Läkartidningen*, 109(1-2): 24-26.

III Forsberg, R., Holgersson, A., Bodén, I. & Björnstig, U. A study of a mass casualty train crash focused on the cause of injuries using multivariate data analysis (submitted).

IV Forsberg, R. & Saveman, B-I. (2011). Survivors' experiences from a train crash. *International Studies on Qualitative Health and Wellbeing*, 6: 8401.

V Englund, L., Forsberg, R. & Saveman, B-I. Survivors' Experiences of Media Coverage after Traumatic injury events (submitted).

INTRODUCTION

In late 2006, a collaboration project was initiated between the National Board of Health and Welfare´s Centre for Research and Development - Disaster Medicine, in Umeå, and the Swedish Civil Contingencies Agency (MSB) with the aim of developing prehospital care for passengers at major train crashes. The train sector proved to be complex and fragmented with several actors involved and different responsibilities appeared to fall between the cracks. Several knowledge gaps and lack of safety measure implementation were also found within the crash and post-crash phases. Clarity crystallized when comparing how the automobile and aviation industries deal with similar safety issues.

Indeed, traveling by train is relatively safe; however, much more can be done to reduce the consequences for passengers, both physically and psychologically. The focus of the thesis, thus, investigates possible mitigation measures that would reduce these harmful consequences in future crashes.

BACKGROUND

The history of train travel

Railway has a long history with passenger railway traffic. It has its roots in England where the first passenger railway line was opened in 1825 (Kirby, 2002). Industrialism and technological breakthroughs accelerated the impact of the railway by, for example, enabling the transportation of heavy goods over long distances in a faster and more economical way. Technological developments have had a tremendous impact on the railway, and three different methods of powering can be identified throughout history. Steam was the first and most common method until the 1950s. Thereafter, the diesel engine became popular but since the 1970s, more countries nonetheless have electrified their railways (Kullander, 1994; Ohlin, 1997). The most recent development encompasses a new method consisting of magnetic levitation as propulsion. This so called Maglev train (se Figure 1) is currently available to a limited extent in Japan, China, and Germany, and this type of train will most likely continue to operate in the future as technology is further developed (Railway Technical Research Institute, 2012).

Figure 1. The commercial speed of the Maglev train in Shanghai, China is 430km/h (267mph). *Photo:* Hervé Aubert, International Union of Railways.

The development has also led to a continuous rise in train speeds. The first steam trains reached approximately 50 km/h (31 mph) and since then speeds have constantly increased (Kullander, 1994). When the electrified high-speed Train Grande Vitesse (TGV) was introduced in France in 1979 it averaged 213 km/h (132 mph). Later, the TGV reached 574.8 kilometers per hour

(357.2 mph). Yet, the Maglev train, propelled by magnetic force, has the highest recorded speed after reaching an impressive 581 km/h (361mph) in 2003 (Railway Gazette International, 2007). The increased speed even enables the railway traffic to compete with domestic aviation.

Based on the profound development of trains as well as environmental considerations, many countries are investing in high-speed lines. In fact, one of the main transport infrastructure initiatives in Europe during the late 1990s was increased development of high-speed trains (De Rus & Nombela, 2007), and the development has continued. A parallel process has been a continual deregulation of the railway sector in EU member states, meaning changes in the regulatory structure and a gradual privatization of the former state monopolies. Today cross-border rail traffic in Europe is mainly hampered by differing technical standards and services; and a lack of effective coordination between countries. Thus, the European commission has stated that a major argument for reforms and for a deregulation process is the establishment of a more common European railway transportation market (Alexandersson & Hultén, 2008). However, it is important to remember that the railway sector differs from, for example, road and air transportation in that regard, and that various historical and political reasons have influenced differing technical specifications of rail transportation from country to country. Accordingly, a process for creating cross-country operability is developing, the European Rail Traffic Management System (ERTMS). This system aims to create a European standard of railway infrastructure and will improve the overall safety (Midya et al., 2008). Yet, such a process will take time.

In Sweden, there is a long history of state-owned railway since the Parliament decided on a general nationalization of private railway tracks in 1939. Gradually, the sector nevertheless has transformed. For instance, cars and buses became more common in the 1960s; resulting in the closure of nearly half of the railway tracks. However, a growing awareness of environmental issues has later contributed to a renewed interest in train travel by Swedes. Moreover, the introduction of the train set X2000 in 1990, reaching a maximum speed of 200 km/h (124 mph), contributed to an immediate upsurge in passenger traffic (Kullander, 1994; Ohlin, 1997). According to Alexandersson & Hultén (2008) the transportation volume increased more than 40% between 1990 and 2003, and it has continued to increase since (Trafikanalys, 2012).

The Swedish deregulation process started in 1988 when the railway sector was nearly synonymous with Swedish State Railways (SJ); yet, in 1988 the monopoly was broken and a new authority responsible for the train infrastructure, the Swedish Rail Administration was formed (Alexandersson

& Hultén, 2008). The Swedish State Railways has since been divided into several specialized companies, some state-owned, some privatized: SJ (passenger), Green Cargo (freight), Euromaint (technical maintenance of rail carriages), Train Tech Engineering (engineering and technical services), Unigrid (IT business), Jernhusen (properties) and Trafficare (cleaning and switching). Thereafter, the competition “for the tracks” has continued and now public procurement by competitive tendering dominates the passenger rail market (Alexandersson & Hultén, 2008). As a result, one can conclude that many actors with different areas of responsibility characterize the Swedish railway sector. Accordingly, the railway sector is highly fragmented and it is challenging to get an overview of the many actors involved. The consequences of such a development are not yet fully known, but today the railway infrastructure is alarmingly worn and overburdened (Swedish Transport Administration, 2011a), which may be one reason for an increasing number of reported mishaps during the last years (Swedish Accident Investigation Authority, 2011abc). As recent as February 2012, a passenger train collided with a truck at a level crossing in Åkersberga Sweden, but fortunately only four people were injured (Carpo, 2012). However, it is an indication that it is not a question of if a severe train crash will occur, but rather when it will happen again. It further raises the questions of what factors are important for passenger safety and recovery after train crashes.

Haddon´s matrix as analytical framework

In this thesis I use Haddon´s Matrix (Haddon, 1980; Haddon & Baker, 1981), originally created for road traffic trauma (Table 1) to determine influencing factors on the passengers in the railway sector. Thus, it has been the basis for the entirety thesis. It provides a compelling framework for understanding the origins of the negative consequences for the passenger’s and for identifying multiple countermeasures to address those problems in the context of the railway.

Haddon identified several factors that contribute to injury events and injuries: (i) human, (ii) vehicle/equipment, (iii) physical environment, and (iv) socioeconomic environment. These factors contribute in three phases: (i) pre-event, (ii) event, and (iii) post-event (Haddon, 1972; Haddon, 1980).

Table 1. Haddon’s matrix.

	Human	Vehicle/equipment	Physical environment	Socioeconomic environment
Pre-crash				
Crash				
Post-crash				

The upcoming literature review has been designed according to Haddon´s structure to determine influencing factors on the passengers in train crashes. The pre-crash phase includes factors that influence the probability of an injury event taking place. The crash phase is about factors that affect the amount of crash energy reaching passengers. The post-crash phase deals with mitigation of incurred injuries; for example, using the best possible rescue procedures and rehabilitation care. Human factors deal with individuals and their characteristics, both for drivers and passengers in the carriages. Vehicle and equipment factors deal with train construction, crashworthiness, interior design, and equipment. Physical environment includes the environment surrounding the train, such as weather conditions, level crossings etc. Socio-economic environment is the category in which society in general affects the railway structure through, e.g., national laws.

Through the use of the Haddon matrix, casual or associated factors that contribute to the problem can be pinpointed. However, not all casual factors are key determinants. Interpreting a casual pathway requires the controllable factors be identified to provide a basis for injury preventive interactions.

Ten strategies for reducing human losses

Mitigation of injuries can then be based on Haddon’s (1970, 1995) ten injury mitigation strategies. The strategy aims at reducing energy from reaching humans at levels that exceed the injury threshold, to strengthen the human body, and to reduce acute and long term consequences (emergency/acute care and rehabilitation) when an injury does occur
(Table 2). The discussion in this thesis is, therefore, structured according to reasonable preventive measures based on the thinking represented by Haddon´s ten injury prevention strategies in their logical sequence.

Table 2. Haddon´s ten injury reducing strategies in their logical sequence.

Haddon´s ten injury preventing strategies
1. Prevent the marshalling of the form of energy in the first place
2. Reduce the amount of energy marshalled
3. Prevent the release of energy
4. Modify the rate of spatial distribution of release of the energy from its source
5. Separate, in space or time, the energy being released from the susceptible structure
6. Separation by "barrier"
7. Modify appropriately contact surfaces (softening)
8. Strengthen the human resistance
9. Prevent aggravation of occurred injury event – emergency care
10. Restoration and rehabilitation of those injured

Train crashes understood through Haddon´s matrix

Pre- Crash

The *Human factor* has proved to be the direct cause of several train crashes. Many studies have been carried out within this factor and contain aspects of the human factor through investigations of crash causes and user-friendly instruments and tools. The term is often used to denote the human tendency to misunderstand, make miscalculations, and mistakes.

The 1999 crash in Ladbroke Grove, Great Britain is one example where the human factor was the direct cause when there was a failure to stop at red signal; so called Signal Passed At Danger (SPAD) (Lawton & Ward, 2005). Kecklund et al. (2001) have also pointed out problems between the interaction by the driver and Automatic Train Control (ATC). Stress, low motivation combined with lack of information, and dilapidated automatic monitoring technology are some contributing factors. Fatigue problems (Chang & Ju, 2008; Dorrian et al., 2011; Kecklund et al., 2001) and inattentiveness (Edkins & Pollock, 1997) are other causes for human faults. Speed limit violation by the drivers, as in Amagasaki, Japan, in 2005, caused a train to derail in a curve killing 107 passengers and injuring another 549 (Nagata et al., 2006).

Miscalculations or infringements by car drivers at level crossings are another common cause for crashes (Evans, 2011). Edkins and Pollock (1997) also found that inadequate maintenance can cause severe consequences. Lawson and Ward (2005), nevertheless, warn against putting too much blame on human error and thereby miss other important factors. The human factor must, therefore, be seen in context.

Train crashes caused by carriage and equipment failure must be avoided by for example timely inspections and maintenance, and are included in the *vehicle/equipment* factor. The 1998 train crash in Eschede, Germany (Figure 2) occurred when the Intercity Express (ICE) traveling at 200 km/h collided with a bridge (Oestern et al. 2000) after wheel failure. The train crash in Skotterud, Norway, 2010 (Thurfjell, 2010) is another example. Non user-friendly instruments, tools and inadequate equipment designs (e.g., driver safety systems) inside the train are other causes for train crashes because the risk for human mistakes is increased (Edkins & Pollock, 1997).

Physical environment factors can also be reasons for crashes. In the early days, trains sometimes collided with cows, but it did not create any severe injury events. Bridge collapses were other hazards (Shaw, 1978). Improved materials and performance of railway tracks have reduced the number of crashes caused by, e.g., the weather or climate, which cause heat distortions of tracks, ice formations, problems induced by snow (Shaw, 1978; Semmens, 1994; Kichenside, 1997).

Figure 2. The German high-speed train derails at 125 miles/hour (200 km/h), resulting in 101 deaths and 103 injured. *Photo:* IngoWagner/DPA/Scanpix

However, the rail disaster with the highest death count in history occurred in Sri Lanka, 2004, and was caused by the tsunami following an Indian Ocean earthquake. More than 1,700 people died when the wave swept in and overturned the carriages (Steele, 2004).

Existing level-crossings have been improved (c.f. Millegran et al., 2009; Yan, 2010) and the construction of new ones has been minimized. Despite this, the number of European level crossing crashes between 1990 and 2009 remained the same in relation to the number of passenger kilometers traveled (Evans, 2011). This makes level crossing crashes a high priority issue. For example, in 1999 a passenger train collided with a tractor-semitrailer at a grade crossing in Bourbonnais, Illinois. U.S. The locomotive and 11 of the 14 Amtrak cars derailed. The accident resulted in 11 deaths and 122 people being transported to local hospitals (National Transportation Safety Board, 2002). Davey et al., (2008) suggest that the crossings design and location should be reviewed as they are often unsuitable for large vehicles. Reliable safety systems also need to be in place to reduce human mistakes, and have been improved immensely over the years. Broadly, modern signaling has taken the place of flag or hand signals (Kichenside, 1997); this means that information about, e.g., clearance and the maximum permitted speed are now specified in the driver's cab. If drivers fail to react to a signal the train automatically brakes.

Within the *socioeconomic environment,* surroundings are put into a larger context. Train crashes are seldom tied to a single casual factor, but could be the result of systematic failure (Lawton & Ward, 2005). Among several important developments in this area is the introduction of a standard time. When trains began to run across time zones according to a schedule, several crashes were caused because of the lack of a common time (Shaw, 1978). Numerous improvements have then been developed for traffic control over the years, but the latest is the implementation of the European Rail Traffic Management System (ERTMS). This will make rail transport safer and more competitive, and guarantees a common standard that enables trains to cross national borders (Midya et al., 2008).

Unfavorable company policies regarding e.g. work schedules may cause fatigue, stress and low motivation (Kecklund et al., 2001), may contribute to crashes. Chang and Ju (2008) showed, that long shifts and too high working pressure was part of this problem. Improved railway safety requires good working conditions for all employees according to Dorrian et al. (2011). Edkins and Pollock (1997) show many human failures can be symptoms of latent defects within the organization. Organizational impact has been linked to numerous incidents, which demonstrates that, for example, improved resource management and organizational climate is a critical part for safety improvements (Baysari et al., 2008; Sanne, 2008, Santos-Reyes & Beard, 2006).

There is also a wider causal perspective; questioning the impact on railway safety through privatization. Nevertheless, there is no evidence that the 1994 privatization in Great Britain (Evans, 2007) or in Japan in 1987 (Evans, 2010), have increased the risk for train crashes. Elvik (2006) even found that deregulation was associated with improved rail safety. However, more research is needed on the effect of privatization and safety.

Crash

Human factors in the crash phase refer to passenger movements in a crash and their injuries. In a crash, energy will be transferred to the body by the deceleration of the train. Modern trains run at increasingly high speeds, increasing the kinetic energy that must be handled. Passengers sustain injuries by intrusion when the carriage bodies break down and when passengers are thrown as projectiles inside the carriages or hit by flying objects like luggage.

Vehicle/equipment factors refer to train carriage crashworthiness and interior design. The improvements in train construction and crashworthiness have been remarkable over the years. During the 19th century the carriages were made of wood and simply disintegrated when the train decelerated in a crash. A crash in France in 1933 demonstrated this reality. In thick fog, a locomotive struck a slow moving wooden passenger express from behind and crashed through the carriages entire length; killing 230 and injuring 300 people (Kichenside, 1997), in phenomenon called "telescoping." Crashes during this time were further complicated by fire (Shaw, 1978). New stable metal train carriages were introduced and by the 1950s they had mostly replaced wooden carriages worldwide. The change accordingly minimized the telescoping problem but created another dangerous phenomenon, "overriding," casting a shadow over railroad crash safety for decades. As an example, three morning trains collided in Clapham, England in 1988. One train carriage overrode the other and crashed down on the passengers below, which cost 35 passenger their lives and injured nearly 70 (Semmens, 1994). Deformation zones on train carriages were encouraged and crash zones have been investigated as possible answers to the "overriding" problem. Corrugated metal plates, which hooked the carriages together in the event of a crash, were fitted to the end of each rail carriage. These designs decreased the risk of vertical movement that could develop into overriding. The train crash in Germany in 1998 (Figure 2), on the other hand, highlighted another dangerous crash phenomenon called "jack-knifing" or "lateral buckling". Upon impact, the train carriages derailed and collided into each other's sides. The weak side walls collapsed inwards

(Oestern et al., 2000). One approach to counter this phenomenon was to make the couplings between carriages stronger and more stable to prevent carriages from buckling either sideways or vertically.

Changes in the design of the train exterior, to provide passenger protection, continue to evolve; as seen in numerous articles in engineering (e.g., Kirk et al., 1999; Tyrell & Perlman, 2003, Gao & Tian, 2007; Scholes & Lewis, 1993; Xue et al., 2005). Both simulated and experimental crash tests are commonly used to evaluate the design change effectiveness. Simons and Kirkpatrick (1999), for example, used a finite element model to estimate the probability of surviving a crash by showing the number of expected deaths. Omino et al. (2002) also estimated passenger movement patterns during a crash to find injury prevention countermeasures using computer simulations. Crash zones (Tyrell & Perlman, 2003) and structural modifications (Gao & Tian, 2007) have improved the crash-worthiness of train carriages, however, they cannot withstand the high energies produced in today's high-speed train crashes. The front carriages often take the brunt of the impact. Thus, sitting in the front carriages proves to be most dangerous; causing the most severe and fatal injuries (Shackelford et al., 2011; Hambeck & Pueschel, 1981). A 1999 head-on collision in India is one example where there were more than 800 people injured and 256 fatalities; most of them were in the two first carriages (Prabhakar & Sharma, 2002).

Relatively little research has been conducted concerning internal carriage design. Rail carriage seats are not equipped with seat belts; thus, passengers are thrown against various structures and into each other, sustaining injuries in case of a crash (Braden, 1974; Braden, 1975; Fothergill et al., 1992). Passengers can even be thrown through the train windows landing beneath the carriage (Fothergill et al., 1992). Seats coming loose in a crash (Eriksson et al., 1984ab) or seat structure (Fothergill et al., 1992) also cause injuries. Ilkjær and Lind (2001) also found that passengers received injuries from tables. Unlike airplanes, train carriages do not have sealable luggage hatches allowing luggage to fly around like missiles causing injuries (Braden, 1974; Eriksson et al., 1984ab; Fothergill et al., 1992; Cugnoni et al., 1994; Ilkjær & Lind 2001). More research is, therefore, needed to investigate modern carriage interior design and its injury inducing effect.

The *Physical environment* such as bridges or steep embankments can further aggravate the crash. In 2007, a passenger train derailed in Cumbria, Great Britain. All nine carriages derailed; eight of them subsequently fell down the steep embankment and five turned onto their sides injuring more than 80 passengers (Rail Accident Investigation Branch, 2009). In 2011 serious faults in a signaling system and poor management caused a fatal collision on

China’s high-speed network; killing 39 and injuring nearly 200 people. The initial impact of another train colliding into it from behind was aggravated when four of six carriages fell from a bridge (Railway Gazette International, 2012). Formal demands and regulations fit within the *Socioeconomic environment* factor and are of importance in the crash phase. For instance, if there is no seat belt law in trains, or formal demands on how luggage should be safely stored; it will be reflected on the interior construction. The consequences of this can be read in the vehicle and equipment factor section.

Post- Crash

The *Human* factors also play an important role in the post-crash phase. Evacuation knowledge and well prepared train crew are factors that can affect the outcome. Further, if passengers have not been provided with appropriate safety critical information they cannot be expected to know how to handle the situation when it arises. Besides the physical injuries and perhaps irrespective of their severity, train crashes affect the whole person (psychological, social, and existential). There are many studies focusing on, for example, psychological and psychiatric effects such as posttraumatic stress disorder (PTSD) among people who have been involved in serious disasters (Berg Johannesson et al., 2011; Rosser et al., 1991; Wang et al., 2005). Survivor’s reactions are considered severe immediately after the event, but many people find pathways to recovery (Bonanno, 2004). However, there are survivors who experience trauma affects from 5 years after event to lifelong (Hull et al., 2002; Lazaratou et al., 2008; Lundin & Jansson, 2007). There are a few studies focusing on psychological or psychiatric perspectives from train crashes. According to these studies passengers still suffer from psychological problems (Raphael, 1977; Hagström, 1995) after approximately 18 months (Arozenius, 1977; Boman, 1979; Selly et al., 1997), and up to more than 10 years (Lundin, 1991). To take advantage of narrated experiences from these survivors are not found despite that these stories can reveal other aspects of existential, psychosocial character that cannot be revealed in surveys. Narrated experiences have nevertheless been done in studies of the Asian Tsunami (Roxberg et al., 2010; Råholm et al., 2008; The National Board of Health and Welfare, 2008). One’s own strength, help from family and friends (the National Board of Health and Welfare, 2008), and visiting the event site (Heir & Weisaeth, 2006) were described as helpful for dealing with the situation. More deeply, existential effects and a struggle between life and death were also described (Råholm et al., 2008). Even if these effects, to some degree, can be transferred to train crashes it seems reasonable to assume that surviving a train crash is different from a large-scale severe disaster like the Asian Tsunami. Learning more about personal experiences from train crashes gives, not only knowledge about if they recovered or not, but also about how they perceived the rescue process as well as give insight into possible preventive strategies.

At the scene of the event, besides passengers and rescue personnel, there are also bystanders and journalists. First on site, bystanders have been seen as helpful in the rescue effort in transport casualties (Nagata et al., 2006). Journalist's staffs (photographers and reporters) have yet been described as intrusive, insensitive, and sensational; thus adding to the survivors' grief (Coté & Simpson, 2006; Haravouri et al., 2011; Kay et al., 2010) and causing a secondary victimization (Campbell & Raja, 1999). Survivors might wish that media staff would help in the rescue, but instead they are professional eyewitnesses causing a dilemma (Englund, 2008; Englund et al., 2012). Also, rescue personnel become negatively stressed by the presence of the media (Lundälv & Volden, 2004). There is tension between the journalists' need for information and the privacy of the survivors; making the encounter between the involved parties a mostly negative experience for survivors (Doohan & Saveman, personal communication; Roxberg et al., 2010). Rescue personnel are in a position to help the victims, including protecting them from being exposed in ways that increase their suffering. When considering human factors, there are many actors at a train crash scene who play various roles that might improve or deteriorate the rescue effort and survivors' experiences in the post-crash phase.

The *Vehicle/equipment* factors involve clear and effective evacuation routes, and Weyman et al., (2005) have shown that there were serious shortcomings in functionality, including emergency exits and evacuation equipment at the rail crash at Ladbroke Grove. Displaced luggage also increased the difficulties for evacuation. Further, the design did not facilitate access through windows in overturned carriages; and the doors, which were now located upwards, were impossible for a lone individual to open (Braden, 1974). Braden stated that the interior design and the lack of roof hatches were factors hampering evacuation. Additionally, the internal doors can jam and obstruct evacuation and can further be aggravated by narrow stairways, trapping survivors in upper compartments in double-decker carriages (Weyman et al., 2005). The need to ease evacuation routes through intelligent design in railway applications is obvious.

In the Clapham rail disaster in 1988 the *Physical environment* made it difficult to evacuate and transport the injured from the steep embankment to the road (Stevens & Partridge, 1990). Further, railway crashes might happen far from roads as was the case when two trains collided head-on due to a signal malfunction in Japan, 1991, The rural setting of the crash hampered rescue efforts. Forty-two passengers died and 614 were injured (Ukai et al., 1995). In 2005, a passenger train collided with a truck in Israel. The collision resulted in a multiple-scene mass-casualty incident in an area characterized by difficult access and a relatively long distance from trauma centers. The crash resulted in 289 injured passengers and seven fatalities (Assa et al., 2009).

The *Socioeconomical environment* comprises, e.g., guidelines, competence, resources, and disaster plans. If rescue personnel are not prepared and trained for a train crash, this will most likely affect the outcome. Robinson (1975) showed the need for rapid evacuation of casualties as those who have died from traumatic asphyxia and crush syndrome might have survived if they had been rescued more quickly. In a 2008 train crash in Los Angeles, two of the fatalities were passengers trapped under debris. They most likely they died from asphyxia due to the prolonged extrication time (Shackelford et al., 2011). In the Amagasaki, Japan train crash, it proved to be a success that the personnel were trained in confined-space medical techniques. Without this training, the two trapped with crush syndrome would probably have died. It took 22 hours until the last passengers were extricated because the rescue teams were forced to work with small hand held tools due to fire risk caused by a gasoline leak. This risk precluded the use of metal cutters and heavy machines (Nagata, 2006). In a collision in Hamburg, 11 persons were caught in the front part of the first carriage and the use of extensive cutting torch work rendered the rescue very difficult. It could further not be properly started until the carriages had been securely stabilized. All eleven died despite that these injuries would not necessarily have proved fatal (Hambeck & Pueschel, 1981). The Clapham rail disaster in 1988 highlighted the problem of gaining access to the carriages. The site was divided into three sections and ladders were needed to clamber from one carriage to another (Stevens & Partridge, 1990). Despite indicators that we need to pre-plan, exercise, and have efficient extrication and evacuation equipment there are incredibly few improvements implemented. Further research and development concerning tactic, technique and equipment is needed.

RATIONALE FOR THE THESIS

Train crashes causing severe consequences for passengers are not a problem of the past; rather they continue to be highly relevant today, in Sweden as well as abroad. The magnitude of the problem and the trends require illumination. Preventing train crashes in the first place must surely be the first priority and the most effective prevention strategy to achieve a safe railway environment. This idea is also reflected in research as much of previous research has been conducted with a pre-crash focus.

However, we cannot only concentrate research on the pre-crash phase because train crashes continue to occur and will continue to occur. Therefore, we also need to carry out research within the crash and post-crash phases to find important consequence reducing factors. The literature review showed that passengers suffer from both physical and psychological injuries in a train crash. Injuries that probably could be prevented and psychological consequences that may be reduced if survivors' experiences were shared; yet, this is a neglected area. Therefore, it is important that more research is carried out on how to reduce the physical and psychological consequences resulting from a train crash experience. This thesis contributes in this direction by combining research on both physical and psychological consequences of two train crashes; addressing factors of importance for the passengers in the crash and post-crash phases. In Table 3, factors of importance are shown as well as the factors studied in this thesis.

This thesis argues that an increased awareness and knowledge of factors central to the crash and post-crash phases are of utmost importance. It serves as a basis for a much-needed preventive work to reduce passenger consequences when train crashes occur. Hence, we need to understand how train crashes affect passengers to identify and to further present possible opportunities for consequence reducing measures for future train crashes.

Table 3. Factors of importance in injury events with trains (modified for the thesis). (The thesis focus areas are marked grey).

	Human factors	Vehicle	Physical environment	Socioeconomic environment
Pre-crash	- Age - Sex - Education - Experience - Intoxication - Fatigue - Inattentiveness	- Carriage	- Railway track - Signal system - Level crossings - Bridges - Weather	- Company policies (safety rules) - Speed limit - Traffic control - Seatbelt law - Exercise, training, education, and disaster plans
Crash	- How the body moves in a crash - Injuries	- Crashworthiness - The interior design and supply	- External objects (e.g., trees, tunnels, bridges, embankments)	- Formal demands of the trains crashworthiness and interior safety construction (e.g., luggage space)
Post-crash	- Evacuation knowledge - Passenger experiences - Bystanders	- Clear and effective evacuation routes	- Geographical location - Weather/climate - Access routes	- Treatment and evacuation guidelines - Competence and training of EMS and fire brigade personnel - Resources for major incidents (emergency vehicles, hospitals, personnel, equipment) - Disaster plans and organization

Overall aim

The overall aim is to investigate the development and magnitude of major railway crashes and the physical and physiological consequences of train crashes on passengers with a focus on crash and post-crash phases.

Specific aims

I: to identify the magnitude and development of passenger rail crashes over the years in various continents and countries

II: to identify injuries and injury objects at the train crash in Kimstad, Sweden 2010

III: to identify the injury object and injury panorama and to determine injury inducing variables

IV: to explore survivors’ experiences from a train crash in Nosaby, Sweden 2004.

V: to explore survivors’ experiences of interacting with journalists, media coverage and personal media exposure following two Swedish train crashes

METHODS

The research process and design

This section describes the research process of this thesis and each study is illustrated in Table 4. Initially a holistic approach (Morton et al., 2012) was assumed and the methodological assumptions that guided the process were pragmatic (Morgan, 2007). Thus, train crashes first were described according to their context in a global perspective. Hence, the first paper **(I)** identified if major train crashes were still reckoned a problem. Indeed they are, and gave motive to further investigate the physical (**II**, **III**) consequences on the passengers in crashes. I decided to study train crashes in a Swedish context, both for practical and useful reasons. When collecting data for study **II**, **III** I came to understand that the passengers had significantly greater and more problems than physical injuries alone. This prompted the combining of qualitative and quantitative methods, and interviews were performed with a focus on survivor experiences (**IV**, **V**) both during and after a crash.

Table 4. An overview of studies I-V

Study	Content	Design	Data collection	Disasters/ participants	Analysis
I	Trends of railway disasters	Retrospective epidemiological study	Register data	529 train disasters	Descriptive statistics
II	Injury panorama and injury objects	Retrospective case study	Medical records Semi- structured interviews (n=16)	21 passengers - 1fatal - 18 non-fatal injuries - 2 no injuries	Quantitative content analysis
III	Injury panorama and injury objects	Retrospective case study	Police records Printed press Semi- structured interviews (n=13)	73 passengers - 2 fatal - 71 non-fatal injuries	Descriptive statistics Multivariate analysis Quantitative content analysis
IV	Experiences from a train crash	Retrospective case study	Narrative and semi- structured interviews (n=14) Police records Instruments	14 passengers	Qualitative content analysis
V	Experiences of media coverage	Retrospective case study	Semi- structured interviews (n=30)	30 passengers	Qualitative content analysis

Settings

The studies in this thesis are based on worldwide data from train disasters (**I**) and the two latest severe Swedish train crashes. One is the crash in Nosaby, 2004 (**III**, **IV**, **V**) where a truck, fully loaded with wood pellets became stuck between the gates at a level crossing. An oncoming three-carriage passenger train smashed straight into the side of the truck at 121 km/h (75 mph). The impact disintegrated the front of the first carriage allowing wood pellets from the truck to pour in. The first carriage hit a tree, disengaged from the others, rotated 180°, and overturned. The second carriage partly derailed and plowed into the ground alongside of the track, but remained on the railway embankment (Figure 3) (Swedish Accident Investigation Authority, 2006).

Figure 3. Photo from the crash site in Nosaby, 2004. *Photo*: Swedish Transport Administration

The other crash occurred in Kimstad, 2010 (**II**, **V**), where a six-carriage passenger high-speed train crashed into an excavator shovel working on the adjacent track (Figure 4). At the collision the front shovel cut up the whole side of the locomotive and then the excavator spun around and hit the other carriages several times (Swedish Accident Investigation Board, 2012).

Figure 4. Photo from the crash site in Kimstad, 2010. The first three carriages are seen. *Photo:* The Swedish Accident Investigation Authority

Sampling and participants

The inclusion criteria in study **I** were railway disasters from 1910 through 2009 with 10 or more fatalities and/or 100 or more people reported non-fatally injured (n= 529). Additional data from the register (2010-2011) are also presented in the results section. Study **II**, is based on all 21 passengers who came in contact with medical care from the train crash in Kimstad. The population sample in study **III** is based on all 73 known fatally and non-fatally injured passengers from the train crash in Nosaby (se Figure 5). In study **IV**, police authorities

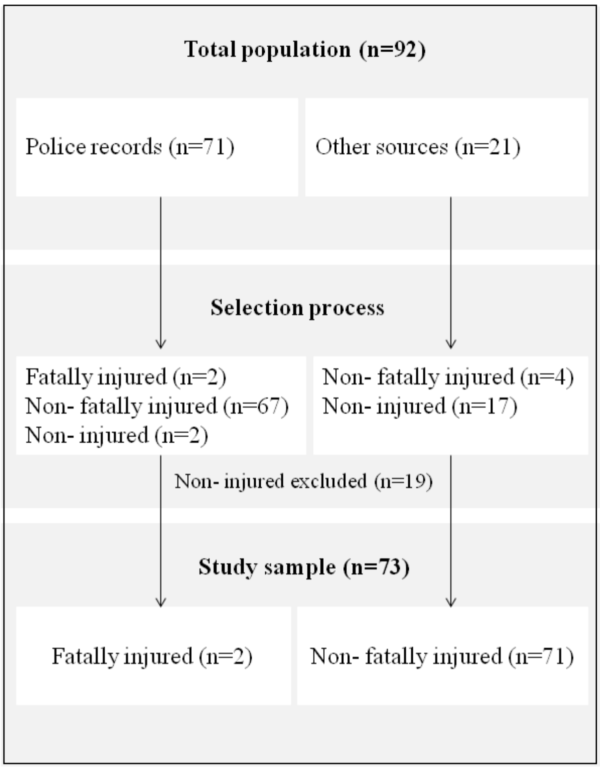

Figure 5. Flow chart of participation in study III.

provided available records of the Nosaby train crash. Sixty-five of these passengers were asked to participate in interviews as three were deceased (two in the crash and one later on) and three could not be located. Out of these, 14 participants were recruited (**IV**). Study **V**, is based on all 16 adult passengers who sought medical care (four children excluded) from the train crash in Kimstad, and those 14 passengers who were recruited from the Nosaby train crash (see study **IV**). Thus, 30 survivors were interviewed.

Data collection

Register data

Data on railway disasters was made available from the Centre for Research on the Epidemiology of Disasters (CRED), which maintains the Emergency Events Database (EM-DAT), a worldwide database on disasters. Disasters included in study (**I**) were selected on two of CRED's criteria defining a disaster: 10 or more reported fatalities and/or; ≥100 or more people reported affected. Within the criterion "affected," a further sample specification was made to include only events resulting in ≥100 non-fatally injured victims. Thus, eight disasters are excluded where people had required immediate assistance during a period of emergency or had been evacuated, thus affected, but not injured. A total of 529 railway crashes were included, of these, six were subway disasters and one was a Maglev disaster. With the additional data for 2010/2011 another 20 disasters were analyzed.

Police and medical records

In study **II** data on passenger injuries were retrieved from medical records accessed through the Swedish Accident Investigation Authority. Data regarding passengers' injuries (**III**) were collected from official police records including, e.g., medical charts, autopsy records, and own statements. Data on gender and age was also obtained from these sources. We also located four passengers with minor injuries through printed press (**III**).

Interviews

Narrative interviews (Riessman, 2008) were performed with passengers from the train crashes in Nosaby (n=14) (**IV**) and Kimstad (n=16). (Parts of the interviews from Kimstad will be analyzed and described elsewhere). An interview guide including a few semi-structured questions was constructed according to pre-crash, crash, and post-crash phases (Haddon & Baker, 1981). The interviews began with the question, "Please, tell me about where you were going?", followed by "What happened during and after the crash?" Participants told their stories without restraint. At times, the narratives were supported with follow-up questions such as, “What do you mean?”, and “What did you experience then?” This was done to clarify the content of the interviews (Mischler, 1986). If not mentioned spontaneously, questions from the interview guide such as “Do you know the reason for the injury origin?”, “Can you point out your position in the carriage?” (**II**, **III**), and “What is your experience of interacting with journalists at the crash site?” (**V**) were asked. The interviews were performed face-to-face (n=13) at a location agreed to by the participants and by telephone (n=17), lasting 20 to 80 minutes (average 40 minutes). The interviews were recorded (except for one, from which notes were taken) and transcribed verbatim.

Questionnaire

As background data, participants in study **IV** also filled in two validated self-evaluation scales; PTSD Check List-Civilian Version (PCL-C) for estimation of posttraumatic stress reactions (Blanchard et al., 1996; Weathers et al., 1993) with 17 questions, and the General Health Questionnaire-12 (GHQ 12) (Goldberg et al., 1997) including 12 questions to evaluate participants’ general health.

Data analyses

Statistics

Descriptive statistics were used to analyze frequencies and proportions in studies **I** and **III**. Further, multivariate data analysis methods, such as Principal component analysis (PCA) (Wold et al., 1987) and Partial least square discriminant analysis (PLS-DA) (Wold et al., 2001) were used to determining correlations between injuries and inducing variables in study **III**. *PCA and PLS-DA* were performed with EVINCE 2.2.5 (UmBio AB, Umeå, Sweden). Matlab R2008b (The MathWorks, Natic, MA, USA) and Microsoft Excel (Microsoft, Seattle, WA, USA) were used for editing the matrices, calculations, and evaluation of statistical differences in score plots from PLS-DA and PCA models with unpaired NOPAPROD (Nyström et al., 2009; Bodén et al., 2011) where $\alpha = 0.05$. *P*-values < 0.05 were considered statistically significant.

Quantitative Content analysis

Quantitative content analysis (Krippendorff, 2012) has been used to organize and summarize injuries and injury objects in the Kimstad train crash (**II)**. The method has also been used to, e.g., categorize injury objects recalled by the passengers in study **III**.

Qualitative content analysis

In studies **IV** and **V** the interview texts were analyzed using a qualitative content analysis (Graneheim & Lundman, 2004). In study **IV** the narrated text itself generated ideas for subthemes and themes and in study **V** we only analyzed text related to media and the semi-structured questions thus generated ideas for the categorization. Repeated readings led to divisions of meaning units that were condensed while preserving the core content. The condensed text was then abstracted and given codes. The codes were next sorted into preliminary subcategories (**V**) and subthemes (**IV**) and after content comparison within and across them combined into subthemes and subcategories. In the next step, themes (**IV**) or main categories (**V**) were formulated based on the text as a whole, the content of the subcategories and subthemes, and the interpretation of the underlying meanings (**IV**).

Methodological considerations

All methods have limitations and without careful consideration, wrong choices can distort the data or fail to describe the purpose of the study (Sandelowski, 1993; Sandelowski, 2000). Below, I therefore will discuss methodological choices in the studies.

Combination of quantitative and qualitative methods

The combination of quantitative and qualitative designs in the thesis has enriched the studies as the methods complement each other. Important information that is not revealed in quantitative studies emerges in the studies with a qualitative design and vice versa (Sandelowski, 2000; Pope & Mays, 1995). By combining these two designs a broader and deeper understanding on the passengers' consequences and provided answers to various questions. The ability to bring various strengths within the different methods together in the same research project became an enormous benefit (cf. Morgan, 2007).

Register data

The EM-DAT has a standardized approach with a clear selection criterion for inclusion of unintentionally caused railway disasters in the database (≥10 killed and/or ≥100 non-fatally injured). Unreliable numbers of reported fatalities and non-fatally injured means that disasters may not be included in the database. This was probably more common in the past because information systems have improved over the last decades. Therefore, the number of missed disasters in recent times was most likely higher in the past. Those train disasters that are caused by explosions of chemical spill are further categorized in another category in the database. Train incidents were occasionally caused by boiler explosions in the past which means that those events are not presented in the data. Another limitation in the selection procedure is that it is difficult in some cases, to ascertain whether a disaster was intentionally caused or not. Thus, some cases might be included that should not be.

Quantitative content analysis
In order to describe the data in study **II** and some of the data in study **III** a quantitative content analysis was used. This method was considered suitable, as we wanted to quantify frequencies of injuries and injury objects. This method yet needed to be supplemented with a statistic analyzes method to find correlations between injuries and inducing object in study **III**.

Interviews and Qualitative content analysis
The participants memory of the traumatic events can be questioned when a large amount of time has elapsed (4 years) between the crash and interview in study **IV** and **V**. The nature of memory of traumatic events can be discussed. Some researchers state that traumatic memories are fixed or unforgettable (Terr, 1990; Conway et al., 1994), while others have found memories to be flexible and subject to substantial alteration (Southwick et al., 1997). The participants' stories from the Nosaby train crash were detailed and emotion filled; thus, I assume their memories from the event are also detailed and valid. Furthermore, in this context, whether their experience has changed or not, is less important. The relevance is their perceived experience and their reflections of what happened. In terms of qualitative research, the number of respondents is not crucial, but rather the quality of the interviews text achieving the purpose (Polit & Beck, 2011); ergo, the samples of 14 (**IV**) and 30 (**V**) participants can be seen as fully sufficient.

Using interviews as a data collection method is satisfactory when the desire is to explore people's experiences (Graneheim & Lundman, 2004). However, one should not ignore that the interface between the interviewer and the interviewee leaves an opportunity for co-creation (Kvale & Brinkmann, 2009; Mishler, 1986). Nevertheless, this is not necessarily negative as it is possible to curb preconceptions and instead influence to get a more detailed story. The pre-understanding has nevertheless increased during the process because the studies are built on each other; therefore they also might have influenced the interpretations. The goal has, thus, been to keep close to the text (Kvale &

Brinkmann, 2009; Mishler, 1986). However, it is important to be aware of one's own preconceptions during the interview and in the analysis process. During the interview I attempted to remain open-minded about the participants' experiences, i.e., hold my pre-understanding in check. Having several researchers analyzing the text further minimized the pre-understanding to obscure the analyze process. This also resulted in that the most likely interpretation emerged. It has been ensured that that the coding, categories, and themes were in line with the meaning units and with the text as a whole. The procedure was repeated to refine and validate the chosen structure (Graneheim & Lundman, 2004). The internal logic and consistency are also verified by quotations from the text (Polit & Hungler, 2004). The aforementioned steps increase the credibility and transferability of the findings (c.f. Dzurec & Abraham, 1993; Polit & Beck, 2011). Several interpretations of narrated texts are nevertheless possible and can be valid, even if different (Krippendorff, 2012).

Finally, it is assumed that the findings in study (**IV**) are transferable to similar contexts where people's lives are threatened, but especially relevant to those involved in a train crash. The results in study **V** are eminently transferable to other contexts where victims experience journalists and media coverage, but in the end, it is only the reader that can determine if the results are transferable to other contexts (Polit & Beck, 2011).

Statistics

It is difficult to use traditional statistics when seeking significant correlations between an injury and its causes because of dependency on multiple variables. Using multivariate data analysis methods simultaneously considers several variables for each passenger. Thus, it is possible to find more accurate correlations between the type of injury, location of injury, and the circumstance that caused the injury.

These methods, nevertheless, traditionally are not used in these types of data sets and therefore chemo metric methods may need to adapt better because, e.g., using only the most severe injuries on each body part when constructing the matrices a few injuries automatically were excluded, not given weight to the PCA and PLS-DA models. Despite this, results from multivariate analysis serve as indications of the injury inducing variables in the crash. Thus, the study is not a precise representation and more studies of similar nature, preferably on a larger dataset, are required to confirm the conclusions.

Ethical considerations

The studies in this thesis are performed in accordance with the principles outlined in the Declaration of Helsinki (World Medical Association, 2008). Study **IV** was approved by the Regional Ethics Committee at Umeå University (Dnr 09-143 Ö). Information about study **IV** was provided to the passengers by letter with a request to participate. If the passengers chose to participate, informed consent was given by phone or e-mail. Information about study **V** was given when these passengers were contacted on behalf of The Swedish Accident Investigation Authority. Informed consent was, thereby, given by phone. Participants (**IV**, **V**) were informed that participation was voluntary and of their right to withdraw at any time without explanation. Face to face interviews were conducted at a location agreed upon by the participants, and were recorded after obtaining permission. Because powerful emotions can arise when recounting their experiences psychiatric help was available if needed. However, no one chose to make use of the resource. Even though powerful emotions came up during the interviews, it was perceived more rewarding than demanding to recount their stories (c.f. Eilegård et al., 2011).

RESULTS

Global trends – major crashes

The number of railway disasters, people killed, and non-fatally injured has increased throughout the last hundred years — particularly during the last four decades (1970–2009), when 88% of all disasters occurred. Most railway disasters (74%), during 1970–2009, occurred in Asia and Africa. On those continents there is an increasing trend in the number of fatally injured passengers, whereas Europe and the Americas have experienced a decreasing trend; as shown in Figure 6.

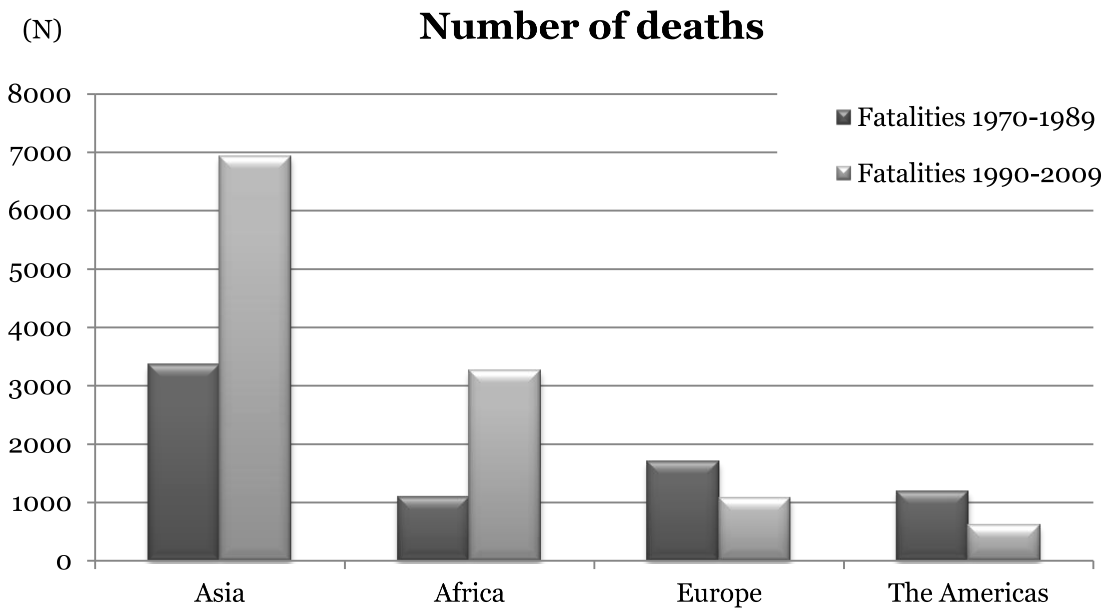

Figure 6. The number of fatalities in railway disasters on different continents between 1970–1989 and 1990–2009, respectively. The Americas include North, Central, and South America.

Since the publication of paper (**I**) there have been 20 disasters globally during 2010-2011, compared with 15 during the two preceding years (2008–2009); indicating that the problem persists and might be increasing. Of the 20 incidents, 9 were in Asia, 4 in Europe, 4 in Africa, and 3 in South America.

The number of fatalities per railway disaster has decreased steadily throughout the years. From 1910-1949 there were 135 passengers killed per railway disaster; 84 during 1950-1969; and 41 from 1970-2009. Nevertheless, the average number of non-fatally injured per disaster has increased during the aforementioned periods, and has been 48, 89, and 92, respectively. From 1910-1949, the number of non-fatally injured was only 0.4 times the number of deaths, but since the 1970s, the number of non-fatally injured has averaged 2.2 times the number of deaths (Figure 7). The variation in total number of fatally and non-fatally injured per disaster has shown a slight decreasing trend; 184, 173, and 133, respectively, for the three periods above. During the last four decades (1970- 2009) the number of fatalities per crash has remained relatively stable, while the number of non-fatally injured shows an increasing curve.

Disasters on different continents and countries- On the Asian continent, India reported the most railway disasters (104 of 233; 45%), followed by Pakistan (24; 10%). On the African continent, the most disasters were reported equally from South Africa (12 of 79; 15%) and Egypt (12 of 79; 15%). In Europe, Russia reported the most railway disasters (17 of 95; 18%) followed by the United Kingdom (13 of 95; 14%). In South and Central America, Mexico reported more than half of all disasters (17 of 33; 52%) followed by Cuba (7 of 33; 21%). In North America, 21 (91%) of the 23 disasters occurred in the United States.

The fatality rate per disaster differs within the continents. South Africa and Egypt had the highest number of reported railway disasters (n=12 each) in Africa, but South Africa had a notably lower rate of average number of fatalities per disaster (n=17) compared with Egypt (n=65), and Angola (n=300). In Asia, Japan had 33 killed per disaster, close to the average for Asia.

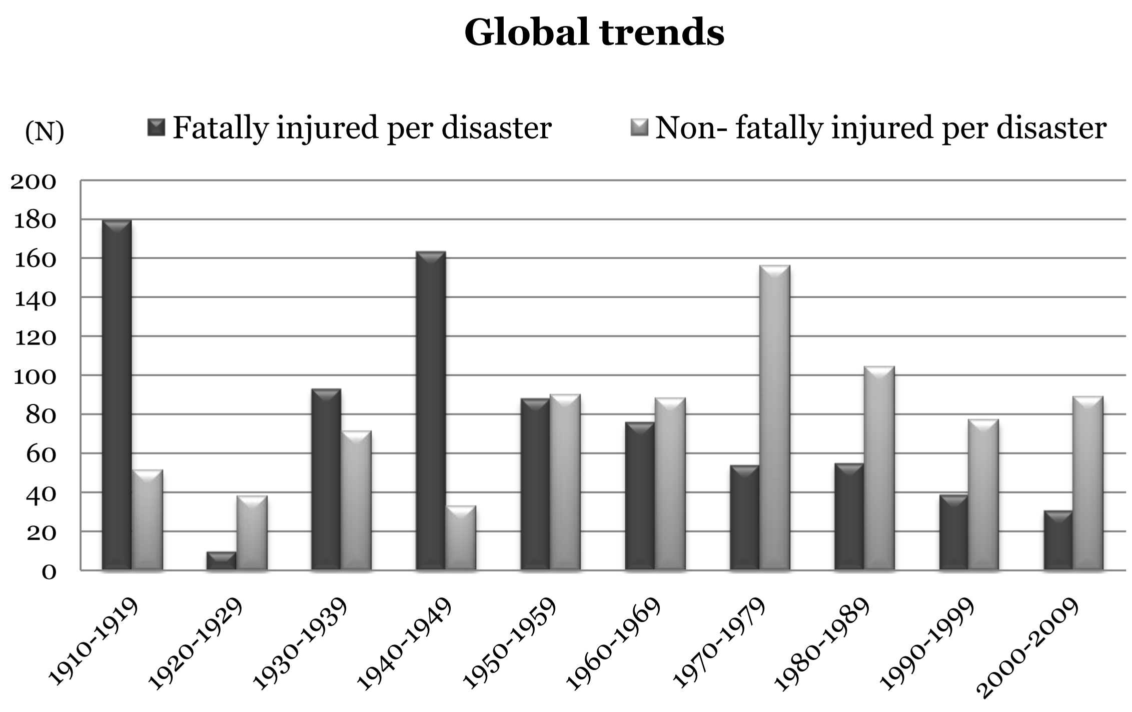

Figure 7. The trend on fatally and non-fatally injured.

Crashes in Sweden

Crash phase

Several factors inside the carriages caused injuries (**II**, **III**). Impact against seats and tables were common as well as against other interior structures: walls, shelves and glass/windows. Many of these objects came loose turning into projectiles hitting the passengers. Passengers flew around colliding with other passengers and interior structures (**III**) and some were squeezed under different structures (**III)**. Luggage falling on passengers was also reported as injury inducing objects (**II, III**).

The trunk (chest, abdomen/pelvis) was a frequent injury location constituting 33% of the injuries in the Nosaby crash (**III**) and 30% in the Kimstad crash (**II**), (Figure 8). However, head and neck injuries were also common (Figure 8), with an especially high rate in the Kimstad crash (**II**), (49% of the injuries), compared to 30% in study **III**. As many as 40% (**III**) and 24% (**II**) of the passengers sustained neck sprains; some were severe enough to cause long-term disabilities.

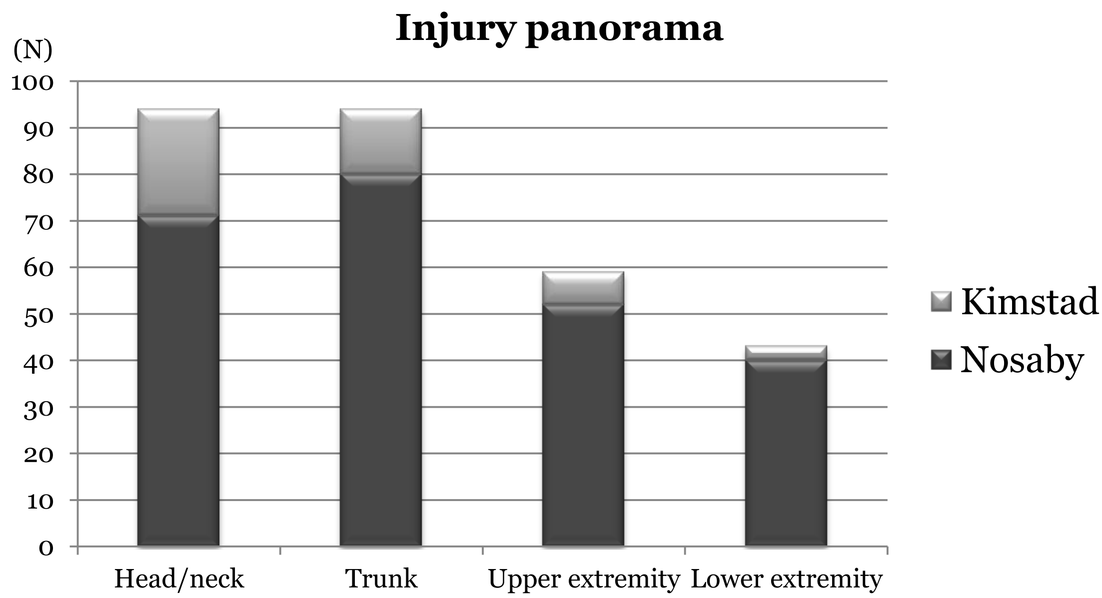

Figure 8. Injury location in the Nosaby and Kimstad train crash

In the Kimstad crash (**II**) 21 passengers sought medical care. One suffered critical head injuries (MAIS 5) and was pronounced dead after two days of neurosurgical intensive care. One had severe trunk injuries (MAIS 4), while six passengers had moderate (MAIS 2) injuries such as concussion, fractures, etc. Eleven people had minor injuries (MAIS 1). Two passengers were admitted for observation; one with initial headache and one pregnant woman without an injury diagnosed. Of the passengers onboard the train, 229 were uninjured or had so minor injuries that they were not medically treated.

Interior structures such as tables, seats and internal walls were related to the most severe injuries, luggage to moderate and minor injuries, and glass to minor injuries such as lacerations. However, the frequency was the opposite with lacerations as most common (**II**). In the Nosaby crash, two persons sustained fatal injuries, one from traumatic asphyxiation/suffocation caused by chest compression plus severe internal bleeding, and the other by maximal injuries - "traumatic dismemberment." In total, 73 were injured in the Nosaby crash; one each with maximal, critical, and severe injuries (all in the first overturned carriage). Four had serious, 12 moderate, and 54 had minor injuries (**III**). One was suffocated by wood pellets from the truck the train had collided with, but was saved by fellow passengers. However, she sustained permanent anoxia induced damage to the brain.

In the Nosaby crash passengers in the overturned first carriage, suffered the most severe and lethal injuries (**III**) and in the Kimstad crash those passengers on the left side in the carriage hardest hit by the excavator, sustained the most severe injuries (**II**).

By using multivariate data analysis methods as Principal component analysis (PCA) (Wold et al., 1987) and Partial least square discriminant analysis (PLS-DA) it was possible to study injury inducing factors in the Nosaby crash (**III**). Having a table in front of a passenger significantly ($p<0.05$) influenced injury type and injury location. Those who traveled faced forward with a table in front of them in carriages two and three (not overturned) were more likely to sustain injuries to their abdomen/pelvis than those who traveled rear facing or those without a table. Neck sprains were significantly ($p<0.05$) more prominent for those who traveled rear facing. In carriage one (overturned) the passengers received injuries to their lower extremity, head, neck, and chest independent of facing direction; probably because they tumbled around and were impacted from several sides when the carriage overturned violently.

From interviews with the passengers from the Nosaby and Kimstad crashes (**II-IV**), additional and common comments of the crash sequence are presented in Figure 9 illustrating the crash and post-crash phase.

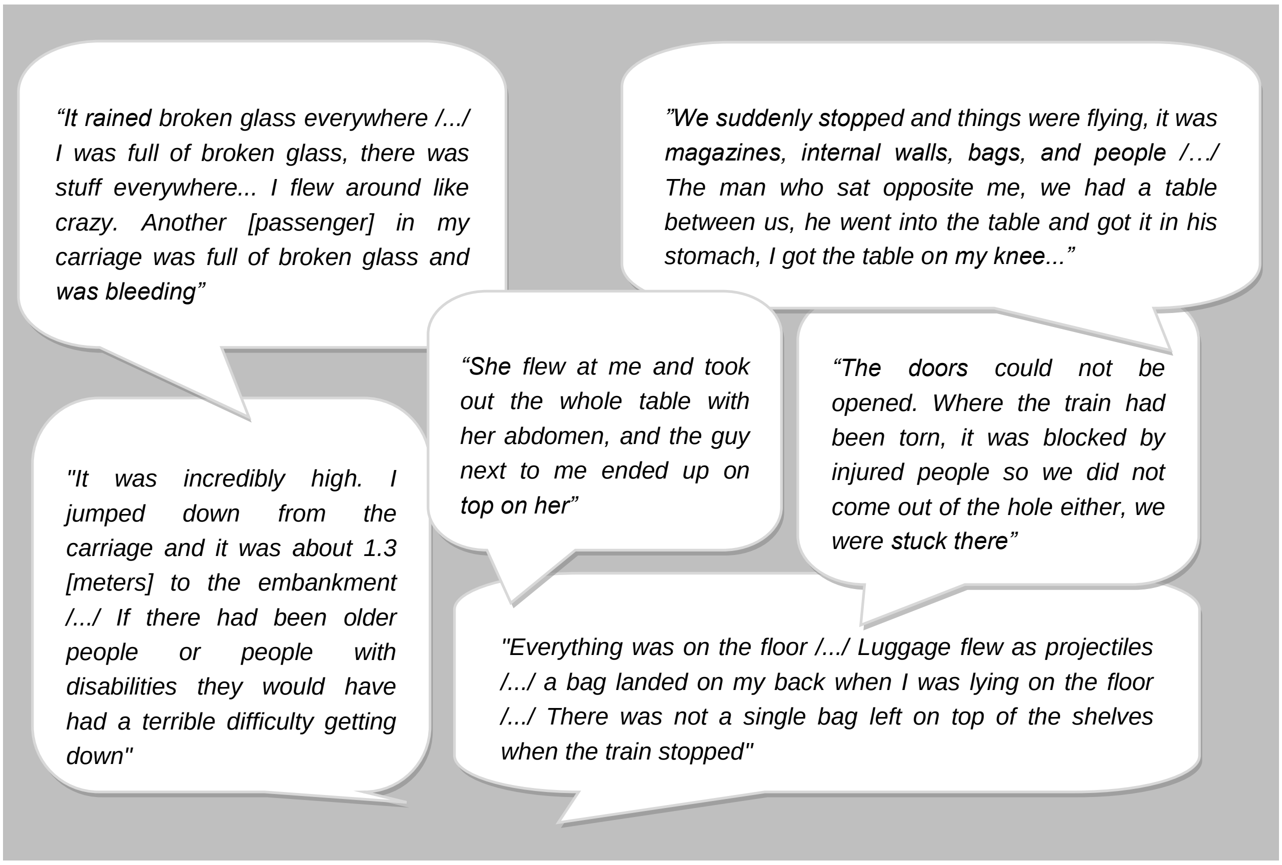

Figure 9. Citations from the Nosaby and Kimstad train crashes.

Post-crash phase

Rescue

Passengers stated that loose and detached objects such as seats, tables, interior/debris, and luggage as well as unsecured passengers were piled up (**II**, **III**). These items and wood pellets in the first carriage in the Nosaby train crash, made entrance for rescue personnel and evacuation of the injured difficult. Passengers also reported becoming trapped by some of these objects delaying evacuation. In the overturned carriage (**III**) it was exceptionally difficult to get out. It was further difficult to get out from the carriages still on the track due to the high height from the carriage down to the embankment (**II**). Additionally, the available rescue equipment was not suitable for the situation, which hampered evacuation.

Experiences

Passengers who survived the Nosaby train crash exhibited notably more experiences than only physical injuries sustained during the crash. Surviving a train crash had various consequences for the passengers (**IV**). Three themes were identified: Living in the mode of existential threat, Dealing with the unthinkable, and Having cheated death. Living in the mode of existential threat was described as abruptly being thrown from normalcy and control to chaos and loss of control. They found themselves in a surreal situation, not knowing if they would survive. Living through this unimaginable chaos, fear, and uncertainty overwhelmed the passengers. They were hurtled into, e.g., interior structures and into each other, like being in a tumble dryer or riding a chaotic roller coaster. It was like waking up in a movie. They described that they were facing death and that they were fearful of further threats to life. Both silence and hysteric screams were heard. Their lives flashed in front of their eyes escalating a deep anxiety and fear of dying.

For some passengers, dealing with the unthinkable in this situation began just a few minutes after the crash, but for others it took longer. One way to regain control was to collect their belongings; some described an obsessive search for personal things and was found to be both surprising and sickening. Another strategy for regaining control was to help fellow passengers. This was done by, for example, remaining close together, talking calmly, and helping them out of the carriage. Focusing on others allowed them to maintain their own composure. Performing a task kept them from falling apart emotionally. They did not only help others, they also expressed a need to be with others: fellow passengers, family, and friends. A strong need for closeness was prominent for their well-being and security. Being together was central and even described as lifesaving. Some described a strong need to recount their stories from the event to someone close or who had the same experience, sometimes over and over again.

Another way of dealing with the unthinkable was to try to reconstruct the turn of events. Visiting the site and viewing the crashed train created different perspectives essential to putting the "pieces of the puzzle" together. Following news reports was helpful as was joining group meetings where investigators explained and illustrated the event. Thereby they gained more insight into their own stories. The experiences of group meetings were mixed; some found it helpful, others thought nothing was added, whereas others found it overwhelming.

Having cheated death by surviving a major trauma event, most of the survivors were tremendously grateful. Some remained stuck and afflicted by the past, whereas others described a richer, fuller life. Those passengers shackled by history are on the edge all the time, afraid of train travel, and suffer from nightmares. Several years later they described their condition as exhausting. As time passed some of them began to overcome the haunting of unforgettable memories. They came to terms with their experiences and moved forward with life. Memories could still be triggered, but different strategies to deal with them were mentioned: interacting with family and friends, psychotherapy, and refusing to become a victim. All expressed gratitude and happiness for receiving a second chance at life, and they described the importance of family, friends, and small things in life. Last, some were glad for opportunities to meet many nice people they otherwise would never have met.

Survivors also described their interactions with journalists, experiences of the media coverage, and personal exposure in various ways (**V**). They were categorized into three groups; those who had negative, neutral, or positive experiences. The negative experiences when interacting with journalists could be perceived as harmful, and they felt violated as they were helpless and vulnerable in front of the journalists. They could not judge the significance of being exposed and felt unprepared for cameras. The confrontation violated their dignity. Passengers also described the interaction with photographers and reporters as demanding, burdensome, and others were provoked by the presence of the journalists, as they were not helpful. They were seen as passive witnesses, nonchalant, rude, and disrespectful. The crash experience was considered private. The passengers who had a more neutral approach to the interaction with journalists described it as negligible; some were unaware of the media presence as they were injured, lying down, or busy helping others. Others noticed the journalists but did not care; they expected the media presence and considered it normal in this situation. They were uninterested in the media coverage and cared little when, for example, they were misquoted in newspaper. The survivors who saw the interaction with journalists as helpful could describe feeling acknowledged. The journalists became necessary listeners to stories in the midst of the chaos. They also felt supported, as the journalists were experienced as genuinely wanting to help. They read, listened to, and watched all the news they could find. They saw this as a way of interpreting the traumatic event. They were grateful for the media coverage and photos of themselves, and it helped them recover. It was seen as healing.

DISCUSSION

As is often the case within the transport sector, a multi-factorial strategy would have the best potential to reduce losses. The results from the phases studied (crash and post-crash), which in many respects are neglected within the railway sector, may contribute partly in the work to minimize the consequences caused by railway crashes. The logical sequence of injury mitigation strategies by Haddon (1970) (see Table 2) is a suitable framework for analyses and discussion of data from the presented studies.

The ***first and the second*** strategies are not realistic today as they would require the reduction or suspension of train travel, and decreasing train speeds. Society would not accept this as train travel provides other benefits, e.g., it is environmentally friendly and its enormous passenger capacity reduces vehicle congestion in big cities and other densely populated areas. Passenger kilometers and speeds are on the increase (International Union of Railways, 2011), and probably will continue to increase, especially with the expected global development of high speed rail systems in the coming years. In the next 15 years, the new high-speed network is projected to be four times the length of the existing network (International Union of Railways, 2010).

The safety measures and systems introduced, especially during the last three to four decades, have not reduced the number of railway disasters (**I**), as has been the case in aviation in which the death toll has been reduced to one fifth (Björnstig & Forsberg, 2010). Factors related to this lack of disaster reduction may also be more passenger-kilometers traveled, more passengers inside each train carriage, and increased speeds. Comparison of risks based on passenger-kilometers traveled in different continents and countries was difficult to calculate because only International Union of Railways (UIC) members are represented in the passenger-kilometers statistics. Therefore, the few data references on the number of kilometers traveled used in this thesis should be considered rough.

Low safety standards in many countries, such as those in Asia and Africa are probably factors resulting in high fatality rates per disaster, and higher ratio of deaths to injuries. In high-income countries, as in Europe, the ratio of deaths to injuries has a more favorable development.

In this thesis (**I**) only major crashes with ≥10 killed and/ or ≥100 non-fatally injured were included. Thus, these crashes only represent the "tip of the iceberg," as noted by Kumar et al. (2012). For this reason, the present study does not aspire to give a complete picture of all railway crashes in the world.

The ***third*** strategy; “to prevent the release of energy,” is mainly focused on fail-safe systems. For example, ATC systems have been developed and refined during the last decades for the railway industry (Evans & Verlander, 1996; Khoudour et al., 2009). This may have contributed to limiting the adverse effect of higher speeds and increased traffic, especially in high-income countries (**I**).

The ***fourth*** strategy; “modifying the release of energy arising in a crash,” has been addressed in, for example, better crashworthiness in trains, where the risk of telescoping, overriding, and jack knifing (Shaw, 1978; Semmens, 1994; Kichenside, 1997) has been mostly reduced (**I**). However, these mechanisms may not be sufficiently reduced as, for example; the disastrous 2012 train crash in Buenos Aires may indicate (Sjöholm, 2012). A commuter train hit a stop block at a speed of less than 30 km/h – killing about 50 passengers and injuring 700 – the second carriage seems to have telescoped into the first. In the Nosaby crash (**III**), the travelers in the first carriage had the most extreme crash kinematics, and suffered the most severe and lethal injuries; a phenomenon also seen in other train crashes (Weyman, et al., 2005; Nagata et al., 2006; Shackelford et al., 2011). Change in the design of the train's exterior continues through simulated and experimental crash tests to evaluate the efficiency of design changes (cf. Kirk et al., 1999; Tyrell & Perlman, 2003; Kirkpatrick et al., 2001). One method to make the carriages safer has been shown by Gao and Tian (2007) who tested crash zones on either end of all train carriages. These crash zones could redistribute the compressing force from the front of the train to designated compression zones in each carriage.

The ***fifth*** strategy, “separate in space or time,” is applicable to crashes as those in Nosaby (**III**) and Kimstad (**II**). Despite improvements of existing level crossings between road and rail traffic and further a reduction of them, they still are a relatively common cause for crashes (Evans, 2011). Level crossings are still a major challenge (Davey et al., 2008; Khoudour et al., 2009; Millegran et al., 2009; Yan et al., 2010), of which the Nosaby crash is a typical example (**III**). This crossing had level crossing gates, but despite these the crash occurred, indicating that human factors (cf. Baysari el al., 2008; Edkins & Pollock, 1997; Cahn & Ju, 2008) are the reasons for crashes when they, for example, override the automatic system. Naturally, level crossings should be minimized, or eliminated, when new tracks are built. This is especially important on high-speed tracks as research shows that it is difficult to eliminate these crashes despite solutions of different safety systems (Saccomanno et al., 2007; Khoudour et al., 2009; Yan et al., 2010) or through education programs geared toward, e.g., motorists (Savage, 2006; Davey et al., 2008). Furthermore, as in the Kimstad crash (**II**), it is remarkable that construction and maintenance work proceeds on railway tracks adjacent to those in use by high-speed trains.

The ***sixth and seventh*** strategies, “separation by barrier” and “modifying appropriate contact surfaces (softening),” would be wise to introduce more extensively in train carriages, as has been implemented in other modes of transportation such as road traffic and aviation. The present studies **II** and **III** indicate that passenger injuries are caused by loose objects like luggage and other passengers and by interior structures, e.g., seats, interior walls, and glass shards (cf. Fothergill et al., 1992; Cugnoni et al., 1994; Madsen, 1998; Ilkjær & Lind, 2001; Eckstein and Heightman, 2009). In the Mundelstrup, Denmark crash, passengers sustained trunk injuries more often if they were seated at a table. They also found that neck rests reduced the risk for neck sprains. They draw the conclusion that tables that detach would reduce trunk injuries (Ilkajær & Lind, 2001). On the other hand, the tables should be deformable and firmly attached to compartmentalize passengers so they are not thrown around in the carriages (Parent el al. 2004). Omino et al. (2008) further showed that seat design was important for injury outcome. The injuries may be reduced if seats, tables, and other objects were better attached and were outfitted with softening surfaces. Further, sealable luggage hatches would prevent luggage from becoming projectiles and/or reducing the risk of trapping passengers. Improved interior safety would probably have great potential to reduce morbidity and mortality in future crashes and merits further investigation.

The passengers in the first, overturned carriage in the Nosaby crash (**III**) suffered the most severe and lethal injuries when they were tossed around. Higher lethality and injury risk has also been observed in other cases in which carriages have overturned (Braden, 1974). Interestingly, passengers seated backward without a table, in carriage one, were significantly less injured than the others (**III**). In this crash, passengers tumbled and fell several meters from one side onto objects and passengers on the other side; experience survivors liken to being in a tumble-dryer (**IV**) (c.f. Fothergill et al., 1992). These risks could be mitigated by compartmentalization inside the carriage, with impact friendly surfaces catching the passengers, seat belts, and/or by traveling rear faced.

There were a number of whiplash injuries in both the Kimstad (**II**) and Nosaby crashes (**III**); some of them giving long-term consequences. In the Nosaby crash, the rate was significantly higher for those traveling rear faced, given they traveled in a carriage that did not overturn. The seatbacks visually gave an impression of taking care of the head, but the seat backs elasticity might need to be evaluated. Perhaps they have elasticity similar to some seat backs in cars from the early 1990s, which were especially prone to cause whiplash injuries (cf. Krafft, 1998). Additionally, lacerative broken glass caused many injuries (**II**), and is a reason why anti-lacerative glass may be discussed as a less injurious alternative. Maybe the car industry's handling of interior safety can give ideas for injury mitigation measures in trains.

The ***eighth*** strategy, "strengthen the human resistance" is not studied – but in the light of the political will that public transport systems should be for all, including children and elderly, the above strategies will be even more important.

The ***ninth*** and ***tenth*** strategies denote the reduction of consequences after a crash has occurred, i.e., in the post-crash phase. It can, for example, relate to the rescue and acute care. At the Kimstad crash (**II**), well planned and trained disaster response provided an efficient rescue operation, at first supported and organized by initiative train crew and passengers onboard, while waiting for the rescue personnel. Physicians in the most demolished carriage started immediate resuscitation on the most severely injured (who died two days later from head injuries). Command and control as well as cooperation between ambulance and rescue service followed the well trained disaster plan for the area (Swedish Accident Investigation Authority, 2012).

The Nosaby crash showed the negative effects of too slow handling and extrication of the injured (**III**); also demonstrated by others (Hambeck & Pueschel, 1981; Robinson, 1975), who found that a number of victims might have survived if they had been extricated more quickly. In the Nosaby crash (**III**), the rescuers did not understand the crash scenario; had they, lives may have been saved and injuries lessened. The rescue started in the first carriages that the rescue personnel came to, i.e., not the train's first, overturned, most demolished carriage; where the probability of finding severely injured passengers was highest. Consequently, it took time before they reached the passenger who died from traumatic asphyxiation caused by compression of the chest, and the passenger choking on pellets, who was dragged from the pellet pile by a fellow passenger. It took over eight hours until the fire brigade could ensure that no passengers were wedged down under the carriages, fortunately no one was (Swedish Accident Investigation Authority, 2006). The reason was lack of training in this kind of scenario and the absence of suitable rescue equipment, also emphasized by several other authors (Nagata et al., 2006; Weyman et al., 2005). Exiting the overturned carriage was particularly complicated (**III**), also shown by Weyman et al. (2005). The debris pile of loosened internal structures, luggage, and glass made it further difficult to evacuate the injured, as did the height difference between the carriages and ground. Installation of evacuation equipment such as rescue ladders (cf. aviation) and easily understood emergency evacuation route information may facilitate evacuation.

“Reading the crash” is a skill that obviously needs to be practiced by rescue personnel during training (cf. **III**). Train crashes need to be accounted for in disaster planning and training because railway crashes put rescuers in complicated situations, with many new challenges. Cryer et al. (2010) studied two train crashes and found that revisions of pre-plans made the rescue more efficient and thus improved the quality of care. Assa et al. (2009) also found that the use of evacuation with aircraft in areas of inaccessible terrain minimized the rescue time and reduced the fatality rate. It was further helpful for transporting rescue personnel to the crash site.

The rehabilitation of the affected is very important. Psychological consequences can be reduced if the society understands what the passengers have experienced and how the traumatic events have affected them, and then the caring can be adapted according to their needs. The experiences from surviving a train crash were described as living in a mode of existential threat, losing control, being in unimaginable chaos, and facing death **(IV)**. The experience of being close to death was also revealed in a survey of PTSD after another train crash (Hagström, 1995). Survivors from the Asian Tsunami described similar experiences as from the train crash; fear of losing control and the struggle between life and death (Råholm et al., 2008). When trying to restore control, passengers from the present train crash study described helping others as an important focus for them (**IV**). Similar findings are described by others; from a train crash (Arozenius, 1977) and from the Asian Tsunami (Rehnsfeldt & Eriksson, 2004). Helping others could be a pathway to resilience (Bonnano, 2004). Assisting others or receiving some kind of help, reveals the centrality of others. This is also seen in other studies (Berg Johannesson et al., 2006; Bowels, 1991; Rehnsfeldt & Eriksson, 2004). To be seen and validated by another person is one step to recovery (Råholm et al., 2008). Another way to recover and regain meaning was to narrate their stories, as also described in other studies (Raphael, 1977; Roxberg et al., 2010). To have someone willing to listen, a family member, a fellow passenger, or a journalist (cf. **V**) confirms that social support is crucial to survivors’ recovery (Bonnano et al., 2007; Roxberg et al., 2010). The importance of others and the interdependence among people, emerged as very important and especially family, friends, and fellow passengers who played a very important role in recovery. This needs to be taken into account when medical personnel arrive at the scene of a traumatic event and afterwards as a complement to psychological support from, for example, a crises team. Not all passengers found psychological support to be important, and they could even feel insignificant compared to other survivors’ experiences. Even if formalized support has proven crucial (Bowels, 1991; Lundin, 1991) the need for it has to be individually assessed.

Being able to reconstruct the turn of events by visiting the crash site and listening to, for example, the Swedish Accident Investigation Authority explaining and illustrating what happened was another avenue for recovery and piecing the puzzle together. The positive effect from increased understanding has also shown important from other traumatic events (Heir & Weisaeth, 2006; Michel et al., 2009; Roxberg et al., 2009).

Experiences of being close to death were perceived as receiving a second chance in life. However, it was experienced in different ways; some could go on with their lives quite easily while others had difficulties moving forward. This result might not be surprising as not suffering long-lasting consequences is also confirmed by others (Linley & Joseph, 2004, Norris et al., 2004, North et al., 2004). Being shackled by history and finding it difficult to go constructively on with life is also described in other train crash studies (Arozenius, 1974; Bowels 1991; Hagström 1995; Sing & Raphael 1981) and from other traumatic events (Berg Johannesson et al., 2006; Bonnano et al., 2006).

The phase of being close to death is a situation Jasper (1970) called an existential limit situation, which is the transition from one phase to another. In study **IV** the interaction with others was helpful to understand what had happened and find new meaning in life, i.e., helped in the transition. This is also what Frankl (1963) claimed was a way to extract meaning out of suffering. The importance of facilitating a positive transition phase and minimizing health risks is something rescue personnel need to be aware of. Also, the importance of fellow passengers, family, friends and the positive effects of media (c.f. **V**) and that these aspects can constitute a part in the transition to recovery. It is also important to consider the psychological effects for those with less serious physical injuries, a group, which seems to be overlooked and thereby may receive insufficient help.

Another experience revealed by interviewing the survivors was their interactions with journalists at the scene and the following media coverage, including personal exposure (**V**). A broad spectrum of experiences was described, from very negative to very positive and the experiences could change over time. A surprising result was those who cared little about the media presence and media coverage; they found it expected and normal. Earlier studies have found both positive and negative experiences of interacting with journalists (Kay et al., 2010), but no one has mentioned those with a neutral attitude towards journalists. There were also passengers who described the collaboration with journalists as harmful and that the already overwhelming stress was increased. Descriptions of journalists behaving unprofessionally and insensitively confronting survivors and relatives are also described by others (Doohan & Saveman, personal communication; Hodkinson & Stewart 1998). Media presence at a trauma event can add to the burden of grief among survivors (Jemphrey & Berrington, 2000; Swedish Government Official Reports, 1999). Media coverage and personal exposure was experienced as uncomfortable, re-traumatizing, and evoking irritation (c.f. Råholm et al., 2008). Despite that critical voices are often heard, there were also many positive examples described. At the site they had someone to talk to, who listened, and who was helpful. The journalists' significance could also increase during the recovery process; some who were negative at the beginning could later see the media coverage as a helpful part of recovery and putting the pieces together.

Journalistic presence and media coverage is a natural part of a traumatic event but it is important that reporters and photographers keep a respectful distance, which is described as important for a person who endures a stressful experience (Morse, 2001), like a train crash. The media ethics and individual journalists' way of interpreting the situation at the scene can be more or less problem solving, compassionate, personal, or professional (Englund, 2008), which of course influences the survivors' experience. Nonetheless, by increasing the informative and descriptive media coverage more affected probably would experience positive effects of the media since this seems to help in the recovery process. This would perhaps also in the end result in a more positive attitude to interacting with journalists on the injury site. It develops to a win-win situation.

The rescue personnel, such as the ambulance crew may be the only ones who can speak for the injured and in some cases be gatekeepers between media and the injured persons (Englund et al., 2012). This may be as important as taking care of the physical injuries, the role of, for example, nurses is to provide total comfort, hence also handle psychological needs.

Final remarks

Based on the findings in this thesis, important preventive work within the crash and the post-crash phases seems to be neglected. This is alarming because the physical and physiological consequences on the passengers are far-reaching. Hence, several measures need to be undertaken to improve safety in the crash phase and further enhance the post-crash phase care.

I have, nevertheless, understood during these years that the process of implementing injury preventive interventions in this fragmentized sector is complicated; thus, one more strategy needs to be added to Haddon's ten strategies. The ***eleventh*** strategy needs to embrace implementation, which brings us back to the Haddon matrix and the need for one more dimension.

One more dimension

Returning to Haddon's matrix, his research has been informative for this thesis in the regard that it has contributed to identifying weaknesses and helping to find alternative interventions. Nevertheless, this matrix has been developed further by researchers such as Runyan (1998) and Fowler (2009), adding one more dimension, which highlights and guides the decision making process in choosing and implementing injury preventive interventions. Fowler's Revised Intervention Decision Matrix includes eight elements as criteria for selecting an intervention. 1), Effectiveness 2), Feasibility 3), Cost feasibility 4), Sustainability 5), Political will 6), Social will 7), Potential for unintended risks 8), Potential for unintended benefits. These all come into question after establishing that the intervention is ethically acceptable, which is a prerequisite. These additions to Haddon's model are very constructive after identifying the problem to ease reflection on pros and cons of various intervention options.

Several of these criteria are relevant for discussion on how to improve railway safety. One example could be safe luggage storage, either through building hatches in new trains (like in airplanes) or adding nets over open shelves on older trains. This could have large benefits in terms of injury reduction on trains (even when they do not crash) and most of the above mentioned criteria would be met.

This issue is one of the most important ones, no matter what intervention is suggested, it is severely impeded by the fragmentation of the railway sector. I claim that this fragmentation is further exacerbated by the ongoing deregulation and privatization of the sector. A big-picture perspective is essential for a safe integrated railway system. Otherwise, unintended small errors may interact and the integration of the system could mean larger errors later on (c.f. Perrow 2006); something that may be more likely caused by the multitude of actors involved. Moreover, because of the obscurity between actors they are probably inclined to deny responsibility for errors or avoid taking the initiative to implement interventions. We have to adapt and find new strategies to how the sector is structured today to meet the safety needs; otherwise interventions in injury prevention will consequently continue to be compromised.

In Sweden, it will, therefore, be my future mission to transfer the results from this thesis through a systematic dissemination process, by use of e.g., translational science (Mitchell et al., 2010) to those involved in the railway sector, and supplementary, establish lines of communication between them. Santos-Reyes and Beard (2006) highlighted from the Ladbrock Grove crash problems with communication channels in the fragmentized train sector. By involving all the actors in the railway sector, through regular meetings where system weaknesses and alternative interventions are discussed, the Swedish railway can be made safer.

PRACTICAL IMPLICATIONS

- Train crashes are inevitable; thus, the train sector needs to consider internal safety standards, as in aviation and automobile sectors. For example, interior should be designed with soft surfaces, windows ought to be in an anti-lacerative material and sealable luggage racks are essential. Further, passengers must remain in their seats in the crash.
- Train crashes can occur wherever train tracks exist, including areas with few and limited resources. Further, crashes can occur in inaccessible areas or in extreme cold areas. All communities that could become involved in a train crash should, therefore, pre-plan and practice on a regular basis to overcome the special rescue and evacuation complications.
- To be together with “others,” such as family, friends, other passengers, or be informed of investigation results helps the recovery process and should be promoted and facilitated.
- Media staff should not be excluded from incident sites as they prove to be an important part of many survivors’ processing and recovery, if the media cover informative and descriptive facts. Yet, it is important to limit and delimit areas for the media to enter– and when.

FUTURE RESEARCH

It is desirable to examine the number of disasters in different continents and countries in relation to the number of passenger kilometers traveled to gain a more accurate understanding of the problem. Further, it would be of great value to explore not only the disasters, but also the train crashes (not classified as disasters) that cause considerable consequences for passengers. The train disasters (≥10 fatal and/or ≥100 non-fatal injured) only represent the “tip of the iceberg” rather than a complete picture.

To our knowledge, multivariate data analysis has not been used previously when seeking injury-inducing variables in a train crash. Thus, more studies of a similar nature are required to confirm the conclusions of this study.

More technical and innovative research is recommended concerning injury reducing design solutions in train carriages. Soft surfaces, reversible chairs, and the use of safety belts are some examples requiring further investigation. Additionally, anti-lacerative windows ought to be considered. Deformation zones are placed at the end of the carriages where passengers stand; a solution to this also needs to be reviewed.

A larger study population would make it possible to investigate and discover how other factors such as, severity of injury, age, gender, or the degree of social support influence passengers' experiences of a crash and the media coverage as these variables have not been considered in the present study.

Despite extensive crash avoidance, railway crashes and disasters occur all over the world and more passengers survive train crashes today than in previous years. These types of complex incidents are, moreover, difficult and time consuming to handle indicating that innovative solutions would facilitate and accelerate the evacuation phase.

The list could be long for possible and important research areas (see Table 3 in the rationale section). Of special interest, in addition to the aforementioned, is to study the socioeconomic environment, as some shortcomings concerning company policies and safety rules exist within the train sector. Furthermore, no seatbelt law for train travel exists. No formal demands on, e.g., how train interiors should be constructed (except for fire), exist and there is a lack of luggage stowage requirements. Why does it look this way, and what is it that distinguishes the rail sector from the aviation and automotive industries in terms of safety? This should be explored further.

CONCLUSIONS

Despite extensive crash avoidance systems train crashes are not a problem of the past; rather, they continue to be highly relevant today, in Sweden as well as abroad. The trunk and head/neck was most frequently injured body part. Interior structures, such as tables, seats, internal walls, and glass affected the injury panorama in the studied crashes, as did luggage and unbelted passengers. These factors also hampered evacuation because they were piled up in the carriages. Being surrounded by family, friends, fellow passengers, descriptive and informative media, and participating in crash investigations were some crucial factors when dealing with the life altering traumatic event.

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"My interest is in the future because I am going to spend the rest of my life there"
Charles Franklin Kettering