Crime Clusters and Safety in Underground Stations

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Abstract

The objective of this thesis is to explore ways of assessing safety in an urban context and in transport nodes\(^1\). The thesis is composed of articles that aim to determine whether safety levels vary within a city and within a public transportation network, particularly at transit stations. Finally, it offers suggestions to increase safety in these environments. The analysis makes use of Geographical Information Systems (GIS) and statistical techniques and combines several different data sources. Fieldwork supports the data sources by presenting an investigation of the current environment in and around the underground stations in Stockholm. Regression models were used to assess the (strength) relationships between levels of crime and the social and physical environment at underground stations.

Findings show that urban crime in Stockholm municipality is concentrated in stable hotspots, varying as it were by the type of crime, in different places at different times. A majority of these hotspots are located close to underground stations. The environment of underground stations has a significant impact on the crime levels at these transport nodes; for instance, lower opportunities for guardianship were related to higher crime rates, while well-illuminated and open stations showed lower crime rates. An open layout provides better guardianship opportunities, which in turn may decrease crime levels. The surrounding socio-economic composition of neighborhoods and the physical and social environment surrounding the stations affected crime levels similarly. For instance, mixed land uses in the station’s vicinity could be linked to increased crime rates. However, crime levels showed a varying distribution over time and space. Different stations showed different levels of crime at different times of the day; moreover, there was also a correlation to the type of crime: thefts, for instance, were most concentrated at central stations during peak hours, when stations were most crowded.

The results of the study include suggestions for policymakers and organizations dealing with urban safety, planning and public transportation, such as police, transportation companies and municipal planners. The results suggest that crime interventions should take into account the dynamic patterns of crime and adopt a more holistic approach that considers stations as well as their surroundings.

\(^1\) This thesis is part of the project entitled “Safety in Transport Nodes: The Influence of Environmental Attributes on Crime and Perceived Safety”, headed by Associate Professor Vania Ceccato. The research was financed by the Swedish Transport Administration (Trafikverket), Stockholm Public Transport (SL) and Stockholm municipality during 2010 and 2011 and FORMAS Grant 250-2009-479 in 2012.
Acknowledgements

This thesis would not have been possible without the extensive help of my supervisor, Vania Ceccato. The project started out as a research project on crime in the underground system, and has since evolved into my PhD project. This project further developed the analysis and findings of the initial research project. Vania has been very supportive and provided good support and comments that have led to the publication of the majority of the articles included in this thesis. She has also passed along much knowledge about safety and crime from the very beginning. I would also like to thank Mats Wilhelmsson, my co-supervisor, for help and coordination throughout the whole process.

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Over the years I have attended seminars, conferences and lectures that have given rise to new ideas and inspiration, created contacts and thereby improved the thesis work. I am grateful for the possibilities given to me during this work. Special thanks also go out to colleagues at the department of Architecture and the Built Environment (KTH) for providing companionship during the week, and to my family for supporting the work and process.
## Contents

Abstract

Acknowledgements

Contents

List of Tables and Figures

1. **Chapter 1 – Introduction** 6
   1.1 Outline 6
   1.2 Aim and Objectives 8
   1.3 Theoretical Background 9
   1.4 The Study Area 14
   1.5 Data and Methods 15
   1.6 Summary of Articles 21
   1.7 Potential Impact of the Results 28
   1.8 Final Thoughts and Reflections 32

   References 37

2. **Chapter 2 – Articles** 42
   1 Space-time Clusters of Crime in Stockholm, Sweden
   2 Security in Stockholm’s Underground Stations: The Importance of Environmental Attributes
   3 Assessing Guardianship Opportunities at Underground Stations
   4 Space-time Dynamics of Crime in Transport Nodes
   5 Safety in Stockholm’s Underground Stations: An Agenda for Action
List of Tables and Figures

Table 1 – Research questions and links to the topics of the thesis

Table 2 – Articles and their contribution to the research field

Table 3 – Data used in the thesis

Table 4 – Methods and techniques of the thesis

Table 5 – Spatial scale and time frames of the thesis

Figure 1 – Map of Stockholm City. Highlighted in red: municipal border (study area); in black: location of the city center and underground stations; in blue: underground lines

Figure 2 – Examples of (a) litter at an underground station and (b) dark, hidden places at underground stations

Figure 3 – Examples of (a) a light clean underground station and (b) CCTV installed at the entrance of an underground station

Figure 4 – Top ten underground stations in Stockholm with highest rates by type of crime

Figure 5 – Stations located in clusters of violent and property crimes, Stockholm, 2006-2008
Chapter 1- Introduction

This thesis is composed of five articles:


This chapter provides an introduction to the articles and characterizes the main theme of the thesis. It starts by presenting the aim and objectives of the thesis, followed by the basic concepts, data and methods used in the articles. The chapter also offers examples of how urban design and planning can take on the challenges of ensuring safety in transport nodes. In the final sections, a short summary of the articles is presented, followed by conclusions and final considerations.

1.1 Outline

Safety is a basic human need. In the present context, safety is understood in direct relation to risks of crime and victimization. According to Maslow’s hierarchy of needs, after physiological needs such as shelter and food, humans require safety (e.g. ‘security’ and ‘free of fear’) in order to advance in life and satisfaction (Maslow, 1943). In developed and Western countries, the physiological needs of most people are satisfied: they have a home, shelter, access to clean water, warmth and a daily supply of food. However, the second need –
that of safety – is not always fulfilled. Even in relatively safe cities, such as the Scandinavian capitals, a segment of the population declares feeling sometimes, or even often, unsafe (Ceccato, 2013). A recent survey in the capital of Sweden, Stockholm, showed that 15 percent of the population feels unsafe due to the risk of crime in their neighborhood (Stockholm City, 2011). Unsafe feelings represent the perception of crime in a city, which may relate to personal experiences, witnessed events, personal background, vulnerability, gender, and age, but they may also be associated with the urban environment itself. Cities are complex and dynamic places. The urban fabric guides people’s movements around the city by means of the provided infrastructure. Cities are continually dynamic, because activities are performed around the clock and people are mobile, often moving in many directions and with different destinations using different modes of transport. Cities provide the backdrop on which desired safety is created, but they are also a potential site for crimes. The influence of the physical environment on human activities and consequently on crime development and perceived safety is undisputable (e.g., Newman, 1972; Wilson and Kelling, 1982). At so-called ‘transport nodes’, i.e. public places where individuals come together to (des)embark on a transportation en route to other destinations, for example bus stops and underground/train stations; people bundle their paths (Hägerstrand, 1970) and are exposed to different environments with varying risks of crime. Within public transportation, ‘fear of crime’ appears stronger and citizens, women in particular, feel less safe and are even afraid of using public transport. At the Stockholm public transport system 31 per cent of the passengers report feeling unsafe (Stockholm Public Transport, 2013), and nearly 40 percent of the city’s residents felt unsafe when walking between home and public transport. Three percent consciously avoided using public transport because of ‘fear of crime’ (Stockholm City, 2011).

This places a question mark behind current urban planning practices and how levels of safety are addressed in the design of public places, particularly at transport nodes. Moreover, public transportation is used by more than half of the urban population daily (Stockholm Public Transport, 2011). If society’s present aim is to advance towards more sustainable cities and life-styles, then a proper and secure public transportation system is required (Raco, 2007; Saville and Kruger, 2012). Therefore, this research focuses on the analysis of crime as a proxy of safety levels in the city, in particular at transport nodes (embodied by underground stations) and their surroundings. The thesis also demonstrates the importance of establishing links between safety, public environments and urban planning.
This thesis provides a glance into the complex matter of analyzing safety in transportation systems. The articles that compose this thesis concern crime levels at underground stations in Stockholm, Sweden. This cover chapter discusses the possibilities and challenges of carrying out this type of research, from data quality to policy implementation.

### 1.2 Aim and Objectives

The overarching research question posed in this thesis is “why do crimes occur in certain locations in the city, but not in others?” Several research questions developed from this, and these are linked to different topics in the articles (Table 1).

The objective of the thesis is to explore ways to assess safety in an urban context and in transport nodes. The articles aim at assessing whether safety levels vary within a city and within a public transportation network, particularly at transit stations. Finally, the articles offer suggestions for increasing safety in these environments.

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Article</th>
<th>Main Topics</th>
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<tbody>
<tr>
<td>How are crime events distributed over space and time in Stockholm municipality?</td>
<td>1</td>
<td>Space-Time Distribution</td>
</tr>
<tr>
<td>What environmental aspects of transport nodes influence safety levels?</td>
<td>2</td>
<td>Design of Transit Environments</td>
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<tr>
<td>Are opportunities for guardianship related to the design of transport nodes?</td>
<td>3</td>
<td>Guardianship &amp; Design of Transit Environments</td>
</tr>
<tr>
<td>Do safety levels at transport nodes follow our daily activity patterns?</td>
<td>4</td>
<td>Crime Patterns</td>
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<td>How can underground stations be made safer in the case of Stockholm?</td>
<td>5</td>
<td>Crime Prevention</td>
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</tbody>
</table>

Table 1 – Research questions and links to the topics of the thesis.

Each article focuses on a different aspect of urban crime and prevention. The first topic refers to space-time distributions of crime in the City of Stockholm. In the first article, the objective is the identification of crime clusters and their variations by crime type and seasonality. The second article focuses on the design of transit environments, thereby analyzing the variations in levels of crime at the underground stations in relation to their internal environment and surroundings. The third article looks at how opportunities for guardianship, which are important indicators for safety, are related to the design of transit environments. The fourth
article concerns the identification of crime patterns in transit environments in relation to urban activities and transit station design, whilst the fifth article focuses on crime prevention and suggests ways to improve safety at underground stations.

Each of the five articles contributes to different parts of the research area (Table 2). This thesis acknowledges contemporary theories and findings, as well provides new insights for analysis and suggestions for practical and policy implications. The findings of the thesis are of value for other studies, as they can contribute to new thinking and the evaluation of current situations at transport nodes. Results are also of high value for practitioners, policymakers and security organizations because they present detailed information on the distribution of crime events and suggest strategies for targeted interventions.

<table>
<thead>
<tr>
<th>Article 1</th>
<th>Main Research Area</th>
<th>Methods</th>
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<tbody>
<tr>
<td>Urban crime clusters</td>
<td>Crime geography</td>
<td>Spatial cluster analysis</td>
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<tr>
<td>Article 2</td>
<td>Underground station crime levels</td>
<td>Safety in transit environments</td>
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<td>Article 3</td>
<td>Guardianship</td>
<td>Environmental design of transit environments</td>
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<td>Article 4</td>
<td>Crime levels over space and time</td>
<td>Activity patterns &amp; Safety in transit environments</td>
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<tr>
<td>Article 5</td>
<td>Crime prevention</td>
<td>Crime prevention &amp; Urban planning</td>
</tr>
</tbody>
</table>

Table 2 – Articles and their contribution to the research field.

1.3 Theoretical Background

The Geography of Urban Crime

Urban crime may develop on the background of existing city planning in which physical environments, socio-economic settings, accessibility and urban layouts play a role. This implies that crime is subject to a city’s geography and its urban environments. Crime and disorder events are not distributed evenly throughout a city; on the contrary, certain places experience higher crime levels than others. Urban safety has been addressed using different theories within criminology, architecture and urban planning. Some theories focus more on social aspects, while others rely on different environmental aspects to explain variations in
crime. The theories below present a complementing set of explanations on the varying aspects of urban crime.

Firstly, studies suggest that knowledge of a potential victim’s behavior and schedule fosters crime opportunities (Cohen and Felson, 1979). Crime levels vary over space and time because people perform routine activities that present rhythmic patterns. These are guided by time of the day, the season, and the day of the week. Cohen and Felson (1979) argue that these routine schedules provide the anchor points for committing a crime because the possible offender is presented with repetitive patterns and recurrent opportunities. However, this is closely related to the interdependence of space and time. Routine activity theory suggests that for a crime to happen, the motivated offender and a suitable victim need to be at the same place at the same time in the absence of guardians (Cohen and Felson, 1979). A known concentration of people (suitable victims) in a small, accessible location may create an easy crime opportunity for a motivated offender. A transport node could be one such location.

Furthermore, offenders are guided by their willingness to commit a crime. Rational choice theory states that when offenders assess situations, their own personal risks and benefits play a role in the decision of whether or not to commit the offense (Clarke and Felson, 1993). Thus, the environment plays an important role in creating opportunities for crime, as certain features of the environment may contribute to different risks for the possible offender, such as being seen and apprehended (Clarke and Felson, 1993). A crowded or well-guarded location may deter an offender from committing a violent crime because the potential risks are too high. On the other hand, a crowded location may increase the benefits for an offender willing to commit a theft, due to the availability of many targets and the inherent difficulty of surveillance in a crowded location.

Secondly, the influence of the physical environment on opportunities for crime is related to defensible space theory, which defines the layout of a space as the existing (or nonexistent) possibilities for the control and prevention of unwanted activities (Newman, 1972). Different locations can present varying possibilities for surveillance and visibility, which translates into possibilities for direct and indirect social control. As Newman suggests, places with an open layout enhance surveillance and visibility opportunities, and this may deter offenders from committing a crime due to the associated increased risks. Moreover, boundaries between private and public spaces may also influence safety levels. A softer boundary makes both
public and private users responsible for events happening in either place, and it may increase indirect social control (Newman, 1972).

Additionally, certain places may bear evidence of uncivilized social or physical behavior or be visibly deteriorated, littered or insanitary. These environments may be perceived as lacking in control and thus attract criminal activities, as proposed in the broken-window theory (Wilson and Kelling, 1982). Suggested lack of control in an area represents fewer risks for the offender and thereby indirectly increases the opportunities for committing a successful crime.

Thirdly, the urban context also provides a socio-economic background that has a direct effect on variations in the spatial distribution of crime and victimization (e.g., Shaw and McKay, 1942; Wikström, 1990). Social disorganization theory relates crime activity to the social aspects of a neighborhood and the lack of social control that may provide opportunities and trigger offenders to commit a crime (Shaw and McKay, 1942). According to Wikström (1990), local land use influences what kind of activities and type of population can be found in a place. These activities (and the population) vary over time, thereby influencing the place’s vulnerability to crime, as activities directly influence the number of interactions and criminal opportunities (Wikström, 1990).

**Safety and Transport Nodes**

Safety in public transportation has been under analysis since the 1970s; for example, in 1971 Harris published a study of the design and crime rates of the Washington D.C. Metro, Chaiken et al. (1974) examined crime in the New York City subway system, Pearlstein and Wachs (1982) looked into transit crimes and environments of transport nodes in Los Angeles, and Brit (1989) analyzed safety and crime prevention in public transportation in the Netherlands. Recently, this specific area of criminology research has been the subject of increasing interest as more and more researchers devote time to understanding crime and safety levels in relation to transportation.

Transport nodes are argued to concentrate offenders and generate crime (Brantingham and Brantingham, 1995), becoming unsafe places in the absence of good prevention. Although it is not always proven that transport nodes attract the majority of crimes in cities (e.g. LaVigne, 1997; Loukaitou-Sideris et al., 2002), most studies indicate a correlation between transport nodes and concentrations of crime.
Owing to the fact that a great deal of people use public transportation to travel to and from work and various leisure activities, for shopping and outings, etc., transport nodes are places at which large flows of people converge and individuals meet. According to routine activity principles (Cohen and Felson, 1979), offences can only occur at a specific point in time and at a specific place when a motivated offender meets a suitable victim in a place that lacks control. Because of their innate function and their design, public transport nodes provide these occurrences daily; for instance, rush hours provide excellent opportunities for a thief to blend in and go unnoticed while selecting a suitable victim to pickpocket. Transport nodes are public places and therefore have a lower threshold for entry compared to private homes, but they still provide objects and easy targets for an offender. Citizens’ daily routine activities put them at risk of ending up in such a situation when the path of an offender crosses that of a victim.

Besides accommodating convergences between people who may be potential victims or offenders, transport nodes also consist of specific crime-prone features that may increase opportunities for offenders or decrease the safety of the passengers. Smith and Cornish (2006) state that the connection between safety levels and the environment in which a place is embedded is at its most obvious in transport nodes.

The physical environment of public transport nodes includes several features that may contribute to decreased levels of safety or increased feelings of fear of crime. For instance, Harris (1971) showed that within the Washington D.C. subway, lighting, fencing, open design and security cameras contributed to decreased levels of crime. The illumination of transit stations has been found to be of high importance in increasing safety levels at different places in the world and within different types of public transport (e.g., Poyner and Webb, 1993; Pease, 1999; Welsh and Farrington, 2007; Cozens et al., 2003). Cozens et al. (2003) also found that at railway stations in South Wales, UK, visibility aspects were of great importance when assessing safety levels. Loukaitou-Sideris et al. (2002) also indicated that at stations in Los Angeles, better visibility and surveillance opportunities correlated positively with increased levels of safety. Complex layouts with poor visibility, elevated sections, the presence of large stairs and escalators increased the risk for passengers to become victims of crime (Loukaitou-Sideris et al., 2002).

However, the social environment at transport nodes can also impact safety levels at transit stations. The presence of formal guards and possibilities for informal social control at
transport nodes may increase levels of safety. Chaiken et al (1974) found that the presence of police reduced crimes at the New York City subway stations. In the Netherlands, Brit (1989) showed that increased formal surveillance by official guards had a positive effect on crime reduction in public transportation. Informal control has been shown to influence property crime levels, for instance by Reynald and Ellfers (2009). Ceccato and Haning (2004) also argue that the convergence of passengers can have a positive impact on safety levels, as they may act as informal guardians of the place. On the other hand, overcrowding may potentially affect safety levels in a negative manner, as opportunities for surveillance are lost. Studies have shown that at more crowded transport nodes, property crime levels in particular are higher, while at less crowded nodes more violent crimes may occur (Ceccato et al., 2013). This relates both to the (lack of) opportunities for control and surveillance, as well as the presence of opportunities for an offender to commit such crimes at low risks.

Transport nodes are not stand-alone features of the urban space, but are instead often embedded within dynamic surrounding environments consisting of various land uses, social activities and socio-economic status. Social disorganization theory (Shaw and McKay, 1942) provides a background for this reasoning: it states that the lack of formal social organization in some neighborhoods can turn into weak social control which results in a culture of violence and high delinquency rates. Pearlstein and Wachs (1982) concluded that a station located in a deprived neighborhood with low socio-economic status also demonstrated increased levels of crime. Loukaitou-Sideris et al. (2002) also suggested that a neighborhood’s socio-economic status impacts crime levels at public transport nodes. They showed that neighborhoods with a high population density, lower income, lower education, residents with predominantly foreign backgrounds, a younger population and rental housing may be associated with higher levels of crime at the transit station. On the other hand, specific urban features and activities located in vicinity of public transport nodes may attract or create crimes. Certain activities and land uses fundamentally attract offenders, stimulate criminal behavior or concentrate potential offenders (Loukaitou-Sideris, 1999). Block and Block (1995) found, for instance, that a concentration of bars and alcohol outlets close to transport nodes correlated with an increase in crime levels. The presence of large infrastructures such as highways near public transportation stations were also found to be related to increased crime rates (Loukaitou-Sideris et al., 2002). Additionally, the presence of parks, schools, and youth centers in the vicinity of a bus stop showed a positive relationship to crime (Newton and Bowers, 2007). Typical land uses related to increased crime levels are, e.g., commercial and entertainment areas (Kinney et al., 2008).
This thesis considers both internal design and the physical and social aspects of an environment as well as surrounding land uses when analyzing safety levels at transport nodes.

1.4 The Study Area

The city of Stockholm is the capital of Sweden and home to 881,235 inhabitants (Stockholm City, 2013). Stockholm was constructed for the most part on several small islands, covering 216 square meters (including water) and located next to its wide archipelago. The infrastructure connecting the urban areas is very well developed, and there are green areas all the way into the city center. The main mode of public transportation is the underground system, which comprises 100 stations. These share three underground lines (green, red and blue), which transport around 1,800,000 passengers daily. The main transport node is located in the city center; all lines pass through this central station (T-Centralen) (Figure 1). The main city core is the central business district. It is here that most offices, shopping districts and entertainment activities are located. The suburbs of Stockholm vary in nature. Affluent neighborhoods in the north and east are largely made of villa housing. Multiple family housing and low-income groups dominate the south and northeast. Most high-income groups reside in the city center or in low-density suburbs adjacent to the center.

Figure 1 - Map of Stockholm City. Highlighted in red: municipal border (study area); in black: location of the city center and underground stations; in blue: underground lines.
Stockholm is an interesting case study because of the significant seasonal variations, which may play a crucial role in determining crime patterns. Winters in the city are dark and cold, while summer days are light until late in the evening and warm. Activities change accordingly with the seasons, as citizens gather outside in the green parks during the summer and spend more time indoors during the winter. Moreover, a study of Stockholm will contribute new data and results on a Scandinavian capital to existing literature that has hitherto mainly focused on Northern American and British cities. Unlike cities in the United States and United Kingdom, the city planning of Stockholm has largely followed the development of infrastructures as a result of welfare policies from the 20th century. Public transport has been planned as an integrated part of neighborhoods and is fairly well spread out over the city. This may provide new insights on urban crime distributions.

1.5 Data and Methods

Data

Multiple data sources have been used in this thesis in order to give the most comprehensive overview of the case study (Table 3). Nevertheless, the main data sets rely on reports of crime and disorder events, such as official reports to police or reports made by security personnel of the transportation system.

The crime records include coordinates, address, description of the event, address of victim, address of offender, year, day, starting time of event, ending time of event, type of crime, crime code, and more. The database covered four years of recorded crime events, from January 2006 to May 2009. This made it possible to analyze crime distributions and patterns over a longer period of time and include space-time analyses. The data is not without limitations. The records can be faulty due to the reporting or recording method. The victim is not always able to provide exact time frames or locations of the offense when reporting. Moreover, coordinates or addresses can be approximated and arbitrary when reports are being filed.

A common problem with crime records is the positioning of the events, which may provide less consistent results. Geocoding is required in order to analyze crime data from a spatial perspective; moreover, geocoding is the base for space-time analysis. Crime records often include wrongly recorded events, with differing coordinates, which are either filed wrongly or
wrongly transformed. The police crime record database used for the purposes of this thesis required cleaning, for instance. The records were geocoded using Geographic Information System (GIS) software and then put on the map of Stockholm municipality using the local Swedish Coordinate system (RT90). As the records had coordinates attached, the majority could be geocoded automatically, while part of the records had to be geocoded manually. One other problem with crime records is underreporting of crimes. A large percentage of all crime events remain unreported to police or other organizations. This may be related to unwillingness to report, lack of trust in law and police, fear of the offender or of retaliation, lack of knowledge of the system, or of a victim not perceiving the crime as serious, among many other reasons.

<table>
<thead>
<tr>
<th>Article</th>
<th>Police Records</th>
<th>Personnel Reports</th>
<th>Socio-economic Data</th>
<th>Fieldwork Observations</th>
<th>Passenger Flows Data</th>
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<td>Article 1</td>
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<td>Urban crime clusters</td>
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<td>Underground station crime levels</td>
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Table 3 – Data used in the thesis (*bullet size represents the importance of the data set in each article*).

Moreover, crime data includes a certain vagueness of locations; for most offenses it is difficult to pinpoint the exact location and time of the event. Nevertheless, even with very precise data at hand, discussions can arise on the use of exact locations for crime events. Some may argue that crimes with provided coordinates are neither to be taken as fully true from an analytical point of view. As crime is a rather dynamic event process, uncertainty as to exactly where the event took place or the fact that the event took place over a longer route is common, rendering it difficult to state that a crime occurred at a particular spot. Particularly when dealing with offenses such as vandalism and property crimes, the exact timing of the incident can seldom be determined to the hour, let alone to the minute. As an example: the victim of a housebreaking may tell police that it must have happened sometime between 8 a.m., when he left for work, and 4 p.m., when he arrived back home. Unless neighbors noticed
the event, the time frame effectively encompasses half of a day, which leaves little possibility for exact analysis. Another example concerns graffiti; guards patrolling places will only notice the presence of new graffiti upon reaching the location in question. Here too, unless someone had seen and noted the exact time of application (which is very rare), the time frame for the incident will extend from the time of the last visit to the time of discovery. Nevertheless, crime records do sometimes come with such (un)specific time frames for the incidents. This challenges the analysis, as the retrieved event locations and times associated with each event can be contested or imply inaccuracies.

The reports of events at underground stations are linked to the station names and the identified coordinates for each station. Passengers and personnel from the public transportation company report crimes and public disorder events to the central alarm center. As above, the database covered the four-year period from 2006 to 2009.

The data on passenger flows (ridership) at the underground stations was acquired from the Stockholm public transportation company (SL). The data was presented as being collected by the hour during a time frame of one day for each station.

The socio-economic data was gathered from Statistical Sweden and is based on the smallest administrative units (basområde) in Sweden. The data set includes background data on neighborhood and socio-economic statistics, such as population, gender, income, age, housing types, education, unemployment, and ethnic background. The limitation of this type of data is the level of detail. Whereas the crime event data comprises individual events by coordinates, the socio-economic data is linked to the administrative units.

The fieldwork data was collected during visits to the underground stations in 2010. The stations were inspected using a predefined checklist that was set up according to variables that previous studies and theories have suggested as influencing levels of crime, particularly at transport nodes. The variables in the physical as well as in the social environment, were collected through observations by inspecting the design (e.g. corners and hiding places); layout (e.g. overviews, surveillance and visibility opportunities); physical attributes of the environment (e.g. illumination, CCTVs, elevators, stairs) and social attributes (e.g. guards, land uses, activities, pleasantness, crowdedness). Some of the challenges in collecting and analyzing the fieldwork data are discussed in detail in the articles.
In spite of potential problems, data from different sources can provide a comprehensive basis for in-depth analyses, particularly for crime analysis. Recent studies acknowledge the potential of contemporary data and modern sources (e.g. Sampson, 2012). Technological developments have made the analysis of crime data and its distribution a lot easier. Over the past decades, for instance, GIS tools have become a basis for crime analysis in academia as well as ‘working tools’ in the field. Police organizations routinely use GIS to analyze “hotspots” as a basis for deploying their resources in order to deter crime efficiently (Sherman and Weisburd, 1995; Braga et al., 2012). All in all, new technologies enable in-depth analyses that reach to the core of crime distribution and patterns, a condition for safety interventions.

**Methods**

There are a variety of methods and techniques available for urban safety research. Some studies focus on spatial patterns of crime (e.g. Almeida et al., 2003), and others on its temporal patterns (Långström, 2002), or a combination of them, the so-called ‘spatio-temporal’ patterns of crime (Nelson et al., 2001). Other methods were developed to assess the relationship between crime and environment (Perkins et al., 1993), and victim and offender relations (Block, 1981), just to name a few.

Crime records can reveal a great deal about crime distributions. As shown in article 1, crimes are not evenly distributed over space, and possible clusters of crime can be detected when large concentrations of incidents are present in a certain limited space. Concentrations of crime in Stockholm have been identified in article 1 by using spatial scan statistics that calculate hotspots of crime concentrations. Hotspot identification is argued to be the most valuable and important technique in spatial crime analysis (Ratcliffe and McCullagh, 1999). A hotspot is a concentration of crimes within a relatively small area where the number of incidents is higher than expected as compared to the total study area (Canter, 2000). Most studies have focused on spatial clusters of crime exclusively, but recently, with the availability of new software and techniques, more studies have looked into space-time patterns of crime. The novelty of using spatial scan statistics (here, particularly SaTScan) is the ability to directly manage both spatial and temporal data for analysis based on background data. In this thesis, population was used as background data. This results in calculations of crime risk over space and time into which the underlying population can be taken into account. Clusters are calculated according to risk and expected events as compared to the actual number of events. Moreover, when analyzing different time frames, population changes
(during the day and night) can thus be accounted for in the analysis. Other techniques, such as Moran’s I, LISA or GetisOrd, are only able to analyze space-time clusters without accounting for risks and underlying population, and thereby only look at the distribution of the events. Article 1 shows some of the urban space-time clusters in Stockholm, while article 4 presents crime variations and concentrations over space and time in the underground system in Stockholm. Article 4 uses a manual selection of calculated time frames per station and type of crime to analyze differences over time and space.

Data collection was done using observations, which is often part of the analysis of urban crime, particularly when looking at the environments and places in which the crimes occur. In most of the articles in this thesis, observations gathered during the fieldwork of the underground stations’ environments serve as the main source for the analysis (Table 3).

Studies within the field of urban criminology commonly apply ecological analysis in order to assess relationships between crime data and socio-economic and demographical data at aggregated level, such as zones (Haining, 2003; Ackerman and Murray, 2004). In this thesis, ecological analysis is an important framework for articles 1 and 2 by applying mapping techniques (Table 4).

<table>
<thead>
<tr>
<th>Article</th>
<th>Urban crime clusters</th>
<th>Underground station crime levels</th>
<th>Guardianship</th>
<th>Crime levels over space and time</th>
<th>Crime prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster Detection</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>GIS and Mapping</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Space-Time Analysis</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Statistical Modeling</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Assessment of Policy Alternatives</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

Table 4 – Methods and techniques of the thesis (bullet size represents the importance of the techniques in each article).

Most analysis of crime data includes regression analysis in order to identify the strength of relations between crime and environmental aspects and explain the extent of variations between the crime rates and each of the environmental variables (e.g. Krohn, 1976;
Dzemydiene and Rudzkiene, 2002; Andresen, 2006). The results and analyses in the articles of this thesis are based on the use of regression models (Table 4). For the underground stations in Stockholm, a stepwise ordinary least square (OLS) regression model was applied. Because relatively detailed data was available, it was possible to analyze relationships between the environment at individual sections of the stations (platform, transition area, lounge and exits) as well as the overall station confines in relation to the characteristics of the surrounding areas and neighborhoods. OLS techniques were chosen to accommodate the greatly varying conditions of the variables. The variables were checked so as not to violate the OLS assumptions, but it was not known which errors might have been included. Therefore, the OLS technique provided the most stable model for analysis of the relationship between the independent and dependent variables. Article 3 employs a logistic regression technique because the dependent variables are of a dichotomous type. Moreover, a logistic regression technique is able to handle the mixture of different types of available variables in the modeling.

<table>
<thead>
<tr>
<th>Article 1</th>
<th>Urban crime clusters</th>
<th>Spatial Scale</th>
<th>Temporal Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Local administrative unit &amp; municipality</td>
<td>Days &amp; Months</td>
<td></td>
</tr>
<tr>
<td>Article 2</td>
<td>Underground station crime levels</td>
<td>Stations &amp; local administrative unit</td>
<td>Hours, Days, Weeks &amp; Months</td>
</tr>
<tr>
<td>Article 3</td>
<td>Guardianship</td>
<td>Stations &amp; station sections</td>
<td>-</td>
</tr>
<tr>
<td>Article 4</td>
<td>Crime levels over space and time</td>
<td>Stations &amp; surroundings</td>
<td>Hours &amp; Days</td>
</tr>
<tr>
<td>Article 5</td>
<td>Crime prevention</td>
<td>Stations</td>
<td>Hours &amp; Days</td>
</tr>
</tbody>
</table>

Table 5 – Spatial scale and time frames of the thesis.

This thesis provides a detailed analysis of urban crime distributions and possible interventions by looking at different scales, both in space and time (Table 5). The methodology applied includes techniques that cover a variety of scales. Urban crime clusters were assessed by small unit of analysis, local administrative units, in relation to the citywide context in article 1, for instance. The clusters were identified over the period of one year, focusing on months and precise dates of reoccurring hotspots. Following this analysis, the thesis narrows the scale of focus to the underground stations and their surroundings. Crime levels in the underground stations were analyzed by observing the stations’ environments, indoor, exterior and immediate surroundings in relation to the socio-economic aspects of the surrounding context (local administrative units) in article 2. Crime levels may show varying results at different
time windows, and article 4 therefore assesses the crime levels at the underground stations by looking at months and days of the week, up to variations over 24 hours. The variation of crime levels over space and time is further analyzed by looking at selected temporal scales of days and hours, thereby comparing the same temporal scale at different stations. Here, the spatial scale is limited to the stations and their immediate surroundings, making a comparison of more stable urban environments possible; the larger neighborhoods include more dynamic processes and changing environments over time.

The spatial and temporal scales are important when implementing safety interventions. This thesis focuses on crime prevention by suggesting different approaches related to space-time patterns of crime levels at transport nodes. Article 5 focuses on determining whether some specific actions are more effective than others on certain days and at particular times of the day. Moreover, the thesis assesses if different types of stations, e.g. central versus peripheral, require different types of actions in order to increase safety.

1.6 Summary of Articles

Article 1 – ‘Space-Time Clusters of Crime in Stockholm, Sweden’

The first article focuses on crime geography and space-time distributions of crime. The main aim is to identify how crime events are distributed over space and time in Stockholm municipality with the application of spatial cluster detecting and GIS for spatial analysis of the data. GIS was used for mapping and visualizing crime distributions and patterns, while the Kulldorff’s scan test was used for cluster detection. The Kulldorff’s scan test is able to detect clusters of events in both space and time with the possibility to assess concentrations based on an underlying population at risk.

The strong evidence and findings for a Scandinavian city provided here have hitherto been lacking in literature. The article identifies several crime concentrations over days, weeks and seasons. The results indicate that crime is concentrated in the city center, problem suburbs and larger regional centers and around transport nodes. Results of crime rates show that property crimes are most concentrated in the afternoons, while violent crimes are concentrated at night. Likewise, previous studies showed that Stockholm city center is a hotspot of crime (Wikström, 1991; Dolmén, 2002; Ceccato et al., 2002) regardless time of the day and type of crime. However, weekends are more prone to crime, and seasonal variations indicate clear
patterns corresponding to our scheduled activities. During the winter months in particular, crimes are more concentrated around transport nodes; during the summer they are more spread out over the municipality. Spatially, violent crimes concentrate in the city center and around places of entertainment, and also occur in some of the suburbs. These suburbs cope with social problems and are sensitive to crime due to certain underlying socio-economical aspects. In these areas, a lack of social control leads to the suburbs’ indirect consent to criminal activities. No steps are taken to curb the criminal actions of offenders residing there; they may on the contrary even feel encouraged toward criminal behavior (Shaw and McKay, 1942).

As the first article suggests, crime clusters in Stockholm follow a pattern related to the city’s central activities and suburban problems. It is of great importance to notice that crime does not remain stable over time, showing instead different distributions at different times in different places. Crime prevention and police intervention should therefore be focused on the hotspots indicated for each different time span. As an example, there are certain specific places at which crime concentration remains high regardless of the day or time: Välingby center; around Gullmarsplan (a large transition node); the city center; Rinkeby and Hjulsta (for geographical indication see Figure 1). However, during evening hours, on weekends and in the winter months, prevention and intervention actions should focus on the city center and transport nodes.

Article 2 – ‘Security in Stockholm’s Underground Stations: The Importance of Environmental Attributes and Context’

The second article focuses on the safety and design of transit environments. The primary objective is to identify which aspects of the environment in transport nodes influence safety levels by applying statistical modeling of crime rates based on police and security personnel reports. GIS was used for mapping and spatial analysis. A comprehensive fieldwork forms the ground of the modeling by providing a database of the stations’ environmental design aspects acquired by observations.

The current international literature provided strength and value for interpretation of this Scandinavian case study. This article acknowledges the different surrounding environments and uses routine activity principles and urban criminological theories to show the diverse influence of different environments. It was found that these surrounding environments consist of diverse land use patterns which often facilitate several well-known crime attracting
facilities, such as pubs, restaurants, alcohol outlets (Brantingham and Brantingham, 1995). Nevertheless, crime rates varied between stations. The local environment at a station and its relationship to its surroundings as well as the resident population define a large part of the difference in crime levels at different stations. In general, the majority of registered offences comprises events of public disorder (e.g. intoxicated people), followed by fights and vandalism. Some stations report higher levels of violent crimes (fights and violence occur often at Hjulsta and Vällingby, for instance), while others show higher levels of property crimes (thefts are common at T-Centralen). At and around the underground stations theft is most common in the afternoon, vandalism in the evening and violence at night. Although the most events had been reported at the central station and larger stations of Stockholm, the risk of crime (occurrence per thousand passengers per day) was found to be higher at peripheral stations, end-stations, and stations located within hotspots of violence and property crime, as indicated in article 1. These results suggest strong links to findings in the first article, the influence of surroundings and social disorganization theory.

Figure 2 – Examples of (a) litter at an underground station and (b) dark, hidden places at underground stations. Copyright: Author.

Upon further inspection, the environmental attributes at the stations could often explain half of the variance in crime rates between stations. Variables associated with higher crime rates are: low surveillance, in terms of few people being present; low visibility; many corners and hiding places; poor illumination; the presence of litter; and social disturbance (Figure 2). By taking the socio-economic characteristics of the neighborhood into account, it was found that crime rates increase at more peripheral stations, in sparsely populated areas, in physically
Article 1

The first article introduces the study of crime prevention in transit environments and the importance of guardianship opportunities at transport nodes. The article highlights the need for understanding the relationship between environmental attributes and crime levels, particularly at transport nodes. It discusses the significance of guardianship opportunities as a means for crime prevention, emphasizing the role of environmental design in enhancing visibility and surveillance.

The conclusions indicate that there is evidence for the link between environmental attributes and crime levels at transport nodes, an effect of both the stations’ attributes and their surroundings. Additionally, specific stations see different patterns of crime and need a particular intervention approach. No general crime prevention approach should be applied; instead, recognizing the specific needs of different sections of the station will lead to more effective strategies.

The second article focuses on the role of guardianship opportunities in crime prevention. It explores the concept of guardianship as a crucial part of routine activity theory, where any person or object that can supervise or simply watch other people or objects at any given point in time and at any place can force offenders to refrain from committing a crime (Felson and Cohen, 1980).

Findings show that the environment does affect the opportunities for visibility and the capacity to exercise surveillance. Results from the statistical modeling show that half of the variation in guardianship opportunities at stations was explained by environmental factors in general, such as the flow of passengers, the presence of security guards, good sightlines, and tools for surveillance (e.g., mirrors). However, these effects may vary by section of the station. For instance, at platforms and transition areas, the presence of people is most important in providing good opportunities for guardianship, while security guards seem more effective in lounge areas. At platforms and exit areas, guardianship opportunities also improve...
with good sightlines and overviews, while tools for surveillance (like mirrors and CCTV cameras) are more important in the less crowded transition areas. The results from this article did not find a clear link between opportunities for guardianship at the stations and the surrounding environment; this may relate to guardianship being a rather local action or to the perception of different responsibilities that guardians have in different places.

The article suggests improved guardianship opportunities as a means of reducing crime and disorder. It also proposes increasing safety in underground stations by providing the best possible overviews and open sightlines, particularly on platforms, and by installing or replacing tools that facilitate better opportunities for guardianship and providing spaces with noticeable formal supervision, as well as making previously uncomfortable, unsupervised areas attractive as waiting areas for passengers by providing informal guardianship opportunities.

Article 4 – ‘Space-Time Dynamics of Crime in Transport Nodes’

The fourth article deals with safety in transit environments with a focus on activity patterns of individuals and crime patterns. The main objective is to assess whether safety levels at transport nodes correlate with people’s daily activity patterns by applying space-time analysis and statistical modeling based on the police crime records and fieldwork data of the stations’ environmental design aspects.

Drawing on assumptions from time-geography, routine activity principles and defensible space theory, the study investigates daily, weekly, and seasonal variations of crime at underground stations in the Swedish capital, Stockholm. Findings corroborate the conclusions from article 2 that crimes tend to occur more often in the evenings, nights, during holidays and on weekends. There is also evidence of seasonal variations of crime.

This article shows that over time, different environmental attributes have a varying effect on crime levels at different places. It indicates that crime patterns at stations shift over time, following rhythmic cycles that characterize people’s movement through the city, during the week, and even seasonally. Stockholm’s underground stations show a concentration of crime during winter months, during which the system is used intensively due to the cold climate outdoors. The crowdedness at stations in combination with a lack of social control can provide opportunities for crime, and agitation can easily grow while waiting for the train, thereby increasing risks for violence. In the winter, stations with social disturbance and signs
of deterioration demonstrate high levels of crime, whereas in the summer, offenses are concentrated in stations near shops that sell alcohol. During daily peak hours, stations with hiding spots are often targeted by crime, as they facilitate the offender to stay undetected, while during off-peak hours, more crowded stations attract offenders as there are more suitable targets. During holidays, crowded stations and those with shops selling alcohol attract more criminal activities, as opposed to normal weekdays, when offenders are motivated by unusual things as social disturbance and litter in their choice of a site for crime. Furthermore, different crime types are also affected by different attributes over time. During peak hours and holidays, violent crimes increase in crowded environments with social disturbance. Particularly, peak hours in conjunction with dark corners and the presence of cash machines are associated with violence. Vandalism, on the other hand, is concentrated at the less populated stations.

The article indicates that safety in underground stations is not only a function of the internal physical environment, but also of the social interactions that take place at the stations. Moreover, events at the station are a result of the type of surroundings within which these transport nodes are embedded, both in relation to the type of neighborhood (e.g., deprived area) and the station’s position in the city’s context, for instance, as a peripheral transport hub. The article presents an assessment of crime in underground stations that uses aggregated data to provide snapshots of a city’s overall risk over time and space. It shows a methodology for assessing crime over time and space, particularly in areas of convergence such as underground stations. Using hourly crime data and a real-time check-up of environmental attributes in combination with hotspot analysis, provides in-depth results on where and when crime levels change, as well as why. The article concludes by pointing out that the role of the stations’ environment in crime causation varies over time, which is of the utmost importance for safety interventions.

**Article 5 – ‘Safety in Stockholm’s Underground Stations: An Agenda for Action’**

The fifth article deals with policy implementations by looking at crime prevention and urban planning. The main question of how underground stations can be made safer in the case of Stockholm is approached by applying an assessment of policy alternatives for crime prevention at transport nodes.

This article suggests a detailed agenda of interventions in order to create more safe transit environments. The article provides suggestions for the police, local crime prevention councils,
organizations dealing with safety issues, municipalities, county councils, transport organizations, etc., to deal with crime problems at transport nodes.

Based on the findings, interventions should adopt a ‘whole journey approach’, focusing both on the stations and their surroundings. This means that the intervention spans different areas, involves several authorities and requires improved coordination between transportation agencies and other authorities. Environmental design interventions can help eliminate some of the stations’ crime attracting features. Nevertheless they should be complemented with policing and neighborhood watch schemes, general information campaigns and increased usage of security technology.

Figure 3 – Examples of (a) a light clean underground station and (b) CCTV installed at the entrance of an underground station. Copyright: Author.

Suggested actions to improve safety at Stockholm’s underground stations include the identification of those stations in need of intervention. Resources may be wasted if placed in the wrong place at the wrong time. Interventions can take advantage of identified crime hotspots, as presented in article 1, and priority listing of underground stations, as presented in the following chapter. Secondly, it is important to locate and reduce features of the stations that influence visibility negatively, and to improve opportunities for guardianship at the underground station in question as well as surveillance of the surroundings. As is promoted in the crime prevention through environmental design (CPTED) concept, the enhancement of environmental features that deter crime opportunities can have a strong impact (Figure 3). Features such as dark spaces, benches, many exits and escape routes attract offenders (Loukaitou-Sideris et al., 2002; Piza and Kennedy, 2003) while features such as lights, cameras, and signs discourage offenders (Loukaitou-Sideris et al., 2002; Harris, 1971; Webb
and Laycock, 1992; Morgan and Smith, 2006). Thirdly, signs of deterioration and lack of control should be eliminated and the general pleasantness of the stations improved to increase feelings of security. Furthermore, intervention schemes should adapt local initiatives and safety suggestions made by the local community and focus on the needs of individuals. Lastly, the promotion of gender safety and equity principles must be more highly prioritized so that all citizens will have equal access to public transportation.

1.7 Potential Impact of the Results

The articles included in this thesis concern different levels of safety, ranging from the municipal level to sections of underground stations (Table 5). This also has various implications for crime prevention. Certain prevention tools are suitable for both micro and macro levels, while others specifically target the micro scale or offer macro solutions. Moreover, the studies in this thesis have tackled different dynamics behind safety that also relate to the scale levels.

First of all, this thesis presents useful results for the case of Stockholm City in particular. When implementing results from crime analysis, one must always consider the context in which events take place in order to provide a tailored and effective crime prevention agenda. The analysis of violent crimes in Stockholm’s underground stations suggests focusing on the evening/night hours and the city’s suburbs, while different spatial-temporal and social contexts indicate that violent crime may concentrate in the city center and around midday. Safety issues may differ from those in other cities, because there are different mechanisms that might influence crime levels and solutions may therefore work differently than proposed. Nevertheless, the results also provide a good base for other case studies. The improvement of guardianship, as well as surveillance and visibility at stations and the importance of a station’s immediate surroundings can be applied to different cases with adjusted details. Suggested intervention techniques may provide good means for increasing safety in public transportation in other cities. Yet, the timing of these interventions as suggested in this thesis may be subject to variation.

Secondly, as shown in article 5, implementing effective crime prevention calls for the coordination of different strategies and between different organizations. Increasing safety in underground stations may not prove very effective if safety levels in the surroundings are still
low, and this will be reflected in the use of public transportation. An integrated crime prevention approach is required: taking into consideration the transport nodes as well as the way to the stations and neighborhoods in which they are located. Prevention strategies can be more focused on environmental design aspects within the transport nodes, while strategies in the surrounding neighborhoods may emphasize social aspects. For instance, the results presented in this thesis show that the physical environment (e.g. illumination, hiding corners, open layout and security cameras) accounts for most of the variations in crime levels within the stations. On the other hand, the results showed that variations in crime levels in the surroundings are more related to urban functions and social issues in the neighborhood, such as high housing mobility. Remedying the latter will require long-term commitment and structural changes of the social environments in deprived and high-crime areas. Thus, different strategies for increasing safety at and around transport nodes are required and each must focus on different issues. The main strategies will be presented in the following.

Primarily, the results indicate interventions in station environments, thereby referring to environmental design strategies. The environment in underground stations is perceived as rather static and without much possibility for change, except when new stations are being planned. Most underground stations have been in place for a long time and include certain compulsory built features that can neither be removed nor rebuilt. Thus, there is a need for a creative approach to crime prevention that takes basic crime prevention techniques into account, adjusting them to the context of underground stations. For instance, the internal layout and structure of stations will be difficult to change in terms of surveillance and visibility possibilities. However, thinking creatively, walls can be made transparent without damage to the construction’s structural integrity; foundations and pillars would remain, but allow for visibility. High-standard, new technology materials can also provide the necessary bearing strength, but also provide the see-through capacity. On the other hand, new opportunities and great possibilities for implementing safer environments may arise with the expansion of current transport systems. In Stockholm, new plans for the expansion of the underground lines are currently underway; they will augment the underground system with new stations and transport nodes. This provides an excellent opportunity to reap knowledge from the existing situation and design and build the new nodes taking into account the strategies mentioned here in order to provide users with safer transit environments.

The environment of a transport node also includes the surrounding areas and thereby links crime prevention and the creation of safer environments to land use planning strategies.
Taking into account types of land uses and activities in the vicinity of a transport node can facilitate better planning for safer environments by excluding certain elements from the proximity of a station, or alternatively, by increasing control of those places. Urban planning in the neighborhood can help in creating defined safe routes to the transport nodes that are well lit, with good visibility and possibly enjoy high presence of guardians. Such actions contribute to a holistic approach and increase safety for users en route to and in the vicinity of transit stations.

Several suggestions for improved safe transit environments also include *technological and security strategies*. The use of real-time effective CCTV surveillance can be part of these. The advances made in technology also present a myriad of options for implementing crime prevention. By means of social media and mobile phone apps, people can very easily post their comments and report things they see or consider unsafe or uncomfortable. Location and time are thereby directly connected to the message. If used to create a database, this information could be invaluable when addressing crime prevention strategies in a city, because it would reveal precisely where citizens feel insecure or where they report crimes that they otherwise would not report. For many people, submitting a report via apps and social media is both faster and more accessible than going to the police and filing a report; often, people are discouraged by the process and there is a risk that the event will not be reported.

Crime prevention cannot be successfully achieved overnight; it requires long-term effective deployment of several coordinated tools and organizations. There are different *policing strategies* that can help make transit environments safer. Policing can include the deployment of guards and police, but a strategy might also include how they are employed and how crime prevention is being carried out. For instance, policing may be performed on an active basis, where offenders are only searched in the event of serious crimes. In this scenario, policing is in fact too late, and it will not increase safety instantly. Additionally, the location for policing is of major significance for the creation of safer transit environments. In these policing strategies, prioritization is key. Tackling the biggest problems first will help increase overall safety and possible displacement effects will be undermined while safety levels at other locations are maintained. However, the biggest problems are not always the locations with the highest incidence of crime. In the case of Stockholm, the results can be presented in a priority list of actions, ranking the underground stations by high-crime station, crime type, problem, and intervention strategy. This will make it easier for practitioners to take action and make transit environments safer, as it will provide a clear program that indicates the most important
areas of focus and the determined objectives. An example of prioritization might be the stations’ vulnerability to different types of crimes (Figure 4).

<table>
<thead>
<tr>
<th>Violence</th>
<th>Property</th>
<th>Vandalism</th>
<th>Total crime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medborgarplatsen</td>
<td>T-Centralen</td>
<td>Johannelund</td>
<td>Sockenplan</td>
</tr>
<tr>
<td>Hässelby Gård</td>
<td>Fruängen</td>
<td>Axelsberg</td>
<td>Björkhagen</td>
</tr>
<tr>
<td>Sätra</td>
<td>Medborgarplatsen</td>
<td>Skanstull</td>
<td>Ångbyplan</td>
</tr>
<tr>
<td>Rinkeby</td>
<td>Zinkensdamm</td>
<td>Tallkrogen</td>
<td>Medborgarplatsen</td>
</tr>
<tr>
<td>Kärrtorp</td>
<td>Medborgarplatsen</td>
<td>Hagsätra</td>
<td>Akalla</td>
</tr>
<tr>
<td>Axelsberg</td>
<td>Sätra</td>
<td>Akalla</td>
<td>Akalla</td>
</tr>
<tr>
<td>Hjulsta</td>
<td>Globen</td>
<td>Stureby</td>
<td>Hässelby Gård</td>
</tr>
</tbody>
</table>

Figure 4 - Top ten underground stations in Stockholm with highest rates by type of crime (stations in bold appear in more than one crime type). Source: Ceccato et al., (2011).

By using the crime data obtained from the police authorities, crime events were related to the underground stations, which show different patterns when looking at different types of crime. First of all, property and violent crimes follow very different patterns and different stations are affected by each. From this list it is clear that certain stations require more attention in certain areas; for instance, Hässelby Gård and Rinkeby require violent crime prevention strategies. Other stations, such as T-Centralen and Vällingby, require prevention strategies more tailored to property crime reduction. Stations such as Johannelund and Björkhagen require strategies to reduce vandalism. It can also be concluded that certain stations may be especially vulnerable to a certain type of crime, while others see a mix of several crime types, such as Medborgarplatsen and Hagsätra. Additionally, this information provides a basis for effective and specialized crime prevention strategies that focus on the stations in relation to their specific safety issues.

Timing is also crucial for policing strategies. Results reveal that half of all the underground stations with the highest crime rates are also located within Stockholm’s hotspots for violent and property crimes (Ceccato et al., 2011). As analyses in article 1 show, these hotspots also change over time, thereby rendering intervention strategies for stations within the hotspots dependent on the space-time concentrations (Figure 5). Determining methods to tackle the right type of crime at the right station at the right time and using the correct intervention technique should be part of the preparations for policing strategies.
Increasing safety is also a long-term process and it involves social matters that may be founded in neighborhood problems and socio-economic disadvantages. *Education and outreach strategies* may prove effective on a local level by decreasing neighborhood problems and increasing social cohesion. Passengers can also be informed about possible risks of crime and as to how they themselves can contribute to a safer environment or help in the case of an offense. Implementation of safer transport environments requires participation by users, i.e. passengers and citizens, as they are using the system and spending part of their day there. Public participation programs should be activated in order to encourage passengers to become active in crime prevention, giving them security, responsibility and confidence.

### 1.8 Final Thoughts and Reflections

The included five articles have analyzed crime patterns in Stockholm and in the city’s underground stations in order to provide results that can be useful for increasing safety in underground stations. At least two of the articles have presented suggestions for crime prevention. A holistic approach is crucial for increased safety levels and should include urban accessibility and address geography and the stations’ environmental design. Opportunities for
control and guardianship can be improved with the help of technological advancements and educational and outreach programs. By looking at the dynamics of safety in the city of Stockholm and its underground stations, a comprehensive understanding of crime patterns was recovered.

The main method used in this thesis concerns quantitative data assessment. In addition to crime records gathered from different organizations, fieldwork observations have supported the analysis. GIS techniques and statistical analysis have been very helpful for the identification of crime patterns both in space and time. The results of this thesis are unique in that they represent a case not commonly studied, but moreover, show distinctive aspects of public transport nodes – here, underground stations – that influence levels of safety.

One of the most important findings is that guardianship, in terms of surveillance and visibility possibilities, plays an important role in defining safety levels within public transportation. In addition, the identification of specific attributes within the station that are a factor in higher levels of safety or lower levels of crime is an important contribution of this thesis. The aspects of guardianship were further analyzed in the fifth article, which concludes with several suggestions for improving guardianship opportunities and thereby also safety in underground stations. Additionally, the findings presented in the fourth paper are significant for society, as they show the variation in crime levels at underground stations, revealing place and time variations in crime levels. Moreover, the fourth article showed that at different times, different places are influenced by different environmental aspects. Passengers can now assess their own safety in greater detail according to place and time, and the intervention techniques and crime reduction strategies of municipalities or transport operators can be optimized using knowledge of the aspects that influence crime levels and their dynamics over place and time.

Strategies for crime prevention are related to the level of implementation. Article 1 identified clusters of crime at the neighborhood level, and crime prevention should also take the spatial urban layout into account. Authorities involved in neighborhood crime prevention include the municipality, police and local resident organizations. Prevention can be targeted directly at the neighborhood clusters identified in the study at the specific times stated. Priority should be given to property crime clusters from 3 p.m. to 7 p.m., with the most intensive prevention measures made around 5 p.m., while between midnight and 4 a.m., prevention of violent events should be prioritized. Police officers may be deployed at these hours in certain neighborhoods. At the micro level, articles 3 and 5 show that major increases in safety can be
achieved by targeting certain types of crime at specific times (e.g. property crimes during the afternoons) in specific environments in underground stations by deploying more guards or employing visible surveillance tools. The priority listing of stations according to crime type (as shown before in Figure 4), risk of crime, or fear of crime, etc. can also help by providing organizations that strive to improve safety in urban environments with tools for effective implementation.

On the neighborhood level, urban planning can address crime prevention by considering land use planning and functional areas in relation to land uses. As articles 2 and 4 show, underground stations prove to concentrate crime in Stockholm. Public transport nodes can be made safer if planning includes careful consideration of land use planning and public place design; negative spillover effects can be minimized by consciously omitting crime-prone land uses from the dynamic transport environments. For instance, prohibiting bars and places that sell alcohol in close proximity to underground stations will facilitate safer transport nodes. Furthermore, increasing the safety of public spaces around and on the way to transport nodes requires urban planning to include the design of adequate illumination and layouts with unobstructed views and clear sightlines that provide good possibilities for surveillance and visibility from a distance and surrounding buildings. The exterior layout and design in the vicinity of transport nodes are more mutable than the interior designs of stations, as discussed in section seven, but can also have a significant impact on safety levels and perception of safety for passengers. Generally, transport operators and municipal offices have the power to implement safety programs for micro level interventions.

Crime prevention requires an increased recognition of the socio-economic mechanism behind safety issues, which should be addressed by interaction and improvement of citizens’ local situations. Social campaigns increasing cohesion in neighborhoods may have a positive impact on overall safety levels and make public transport safer. This requires the involvement of residents and active campaigning of organizations capable of reaching the local population. Neighborhood-watch schemes and the involvement of local residents in surveillance may increase safety. Interactive reporting, such as previously discussed with regard to social media applications, may also increase safety levels and contribute to social cohesion.

**Challenges**

During the thesis work some limitations were encountered, such as in the quality of data. Crime records included missing data and uncertainty with regard to both time and place. The
Data was checked carefully before and during analysis, but has not been entirely unproblematic. Databases were each collapsed into one year, combining the four years, to create a more robust and reliable dataset. For instance, hotspots identified with the collapsed data indicate a steady and stable hotspot (over the course of four years) and a definite need for intervention.

This thesis is based on crime, rates per thousand passengers or population. These denominators may cause bias. Although it is common to apply crime rates based on a population in criminology, rates require careful interpretation. An underground station may show high crime rates due to a low passenger flow; for instance, a station with 250 crime events and 5000 passengers daily will give a crime rate of 50, while a station with 15 events and 250 passengers a day has a higher crime rate. Yet, it could be suggested that the first station requires more attention and immediate action than the second one.

The fieldwork based on researchers’ observations of the environmental characteristics of the stations also posed a number of challenges. Visiting each station was time-consuming, and observational methods also depend on the observer’s subjective judgments during inspection. The data, however, was mainly coded in yes and no answers, which encourages more objective values. The observers spent enough time at each station to obtain an overall view, as opposed to a fleeting impression.

The hotspot analyses required input decisions from the researcher. For instance, the maximum size and time period for clusters was pre-defined, which impacts results. One method of managing this variability was to try out different sizes and lengths in time and space and select the results that displayed stability across several attempts.

**Future Research**

This thesis has provided an overview of safety dynamics at public transport nodes and will be useful for practitioners working towards a safer transportation environments. However, many questions remain unanswered.

With regard to crime distributions in Stockholm, for instance, the inclusion of more urban aspects not available during the scope of this thesis would be of importance. This would include physical barriers, official land uses, accessibility measures, urban functions, and distance measures, and would thus relate the analysis to the urban fabric and city planning principles. The objective would be an urban planning analysis of how architects can design
the urban environment around the stations to create safer places. Additionally, an investigation of which strategies are actually deployed in different places (and where) would be highly relevant, as would be the investigation into whether high-crime neighborhoods are being provided the attention they need or if most prevention efforts are concentrated in relatively safe neighborhoods and stations. The distribution of crime prevention techniques and strategies should be compared to the distribution of actual safety levels and ‘fear of crime’.

The thesis assessed the underground stations by sections, e.g. platform and exits, but a deeper analysis of where events are taking place would be of great interest; for example, determining the dark corner of the platform in which most crimes are committed or which entrance is safest. Analyzing the routes of offenders and victims can be an interesting topic to study in relation to public transport nodes, and where people actually feel unsafe at transport nodes is also highly relevant.

It may also be of importance to analyze the movements of guards, as well as if and how they concentrate in certain stations. This will contribute to concretely improving guardianship, for instance by increasing formal control at underground stations. As Browning and Jackson (2013) suggest in their paper on active street segments and violent crimes, there is a threshold to be discovered at which (social) activity starts to affect violent crime levels negatively. The examination of the concentration of passengers in certain areas can prove that there may be “hotspots of guardianship” at the stations. The concentration of guardianship should also be analyzed with respect to the effect on ‘unguarded’ spots. Also, relating these ideas to time, with space-time analysis, will improve the usefulness of the findings for crime prevention.

An analysis of social media and the reporting of safety, crime levels, crime events, and fear of crime may provide interesting results. The evolution of technological and online platforms make it possible to create large databases with comments, times, places, and maybe even routes of the posters. Even just looking in distributed media (such as newspapers) can give a hint of perception of safety in urban places (see e.g. Ceccato and Uittenbogaard, 2013).

The combined analysis of both space and time distributions of crime has become more popular in recent years and has been incorporated into several software packages. The enormous increase in interactive multimedia and social platforms augment the possible sources from which researchers can extract data and connect it in both space and time. Today,
mobile phones have integrated GPS location units that are directly linked to the user’s social network. This can make it possible to analyze real-time patterns and track routes.

The new ways of using internet and social media also open up for new perspectives on analysis through these resources. Social media works quickly and precisely. Comments are uploaded within a second, and positions are often attached to the message. This can open up for a whole new type of data source for analyzing how people move and experience crime. Urban crime pattern analysis may see a whole different type of input in the near future that can increase societal involvement and foster more effective crime intervention strategies.

References


Chapter 2 - Articles

1 Space-time Clusters of Crime in Stockholm, Sweden

2 Security in Stockholm’s Underground Stations: The Importance of Environmental Attributes

3 Assessing Guardianship Opportunities at Underground Stations

4 Space-time Dynamics of Crime in Transport Nodes

5 Safety in Stockholm’s Underground Stations: An Agenda for Action