Crime Clusters and Safety in Underground Stations

Adriaan Cornelis Uittenbogaard

KTH Royal Institute of Technology

School of Architecture and the Built Environment

Department of Real Estate and Construction / CEFIN

Doctoral Thesis

Akademisk avhandling

Stockholm 2014

TRITA / KTH / CEFIN-DT-09

ISSN 1654-9376

ISBN 978-91-87111-95-2

www.kth.se

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.

I am also thankful to Ulla Wittrock (from Stockholm County Police), Stefan Liljevall (Stockholm Statistics), Mats Pergel (SL), Peter Assor (Veolia), Niklas Roth and Ludvig Elgström (Stockholm Municipality) for providing the data for analysis on which this thesis is based.

My thanks go to the Swedish Transport Administration (Trafikverket), Stockholm Public Transport (SL) and Stockholm Municipality during 2010-2011 and to the FORMAS Grant 250-2009-479 in 2012, which have partly made it financially possible to complete this work.

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

List of Tables and Figures

Chapter 1- Introduction

This thesis is composed of five articles:

Article 1 – Uittenbogaard, A.C. and Ceccato, V. (2012). ‘Space-Time Clusters of Crime in Stockholm, Sweden’. *Review of European Studies*, Vol. 4 (5), p.148–156.

Article 2 – Ceccato, V., Uittenbogaard, A.C. and Bamzar, R. (2013). ‘Security in Stockholm’s Underground Stations: The Importance of Environmental Attributes and Context’. *Security Journal*, Vol. 26, p.33–59.

Article 3 – Uittenbogaard, A.C. (forthcoming). ‘Assessing Guardianship Opportunities at Underground Stations’. *Security Journal*. Accepted, 2013.

Article 4 – Ceccato, V. and Uittenbogaard, A.C. (2014). ‘Space-time Dynamics of Crime in Transport Nodes’. *Annals of the Association of American Geographers*, Vol. 104(1), p.131-150.

Article 5 – Uittenbogaard, A.C. and Ceccato, V. (2013). ‘Safety in Stockholm’s Underground Stations: An Agenda for Action’. *European Journal on Criminal Policy and Research*, published online October 2013.

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.

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

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.

	Main Research Area	**Methods**
Article 1 Urban crime clusters	Crime geography	Spatial cluster analysis
Article 2 Underground station crime levels	Safety in transit environments	Comprehensive fieldwork/ secondary data & Modeling
Article 3 Guardianship	Environmental design of transit environments	Comprehensive fieldwork/ secondary data & Modeling
Article 4 Crime levels over space and time	Activity patterns & Safety in transit environments	Space-time analysis & Modeling
Article 5 Crime prevention	Crime prevention & Urban planning	Policy implementation

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.

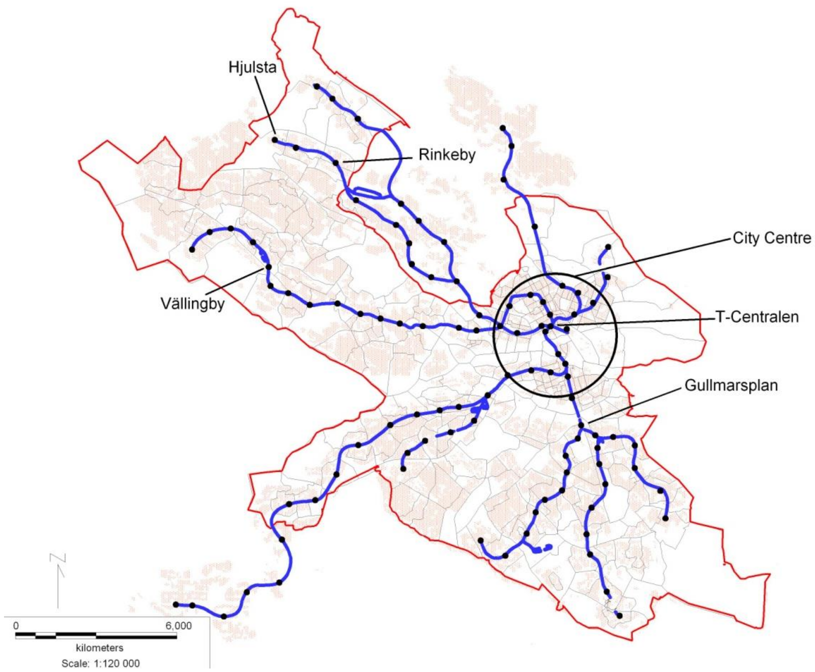


Figure 1 - Map of Stockholm City. Highlighted in red: municipal border (study area); in black: location of the city center and underground stations; in blue: underground lines.

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.

	Police Records	**Personnel Reports**	**Socio-economic Data**	**Fieldwork Observations**	**Passenger Flows Data**
Article 1 Urban crime clusters	◯		○		
Article 2 Underground station crime levels	○	○	◦	◯	◦
Article 3 Guardianship				◯	◦
Article 4 Crime levels over space and time	◯			○	◦
Article 5 Crime prevention	◯	◦		○	

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).

	Cluster Detection	**GIS and Mapping**	**Space-Time Analysis**	**Statistical Modeling**	**Assessment of Policy Alternatives**
Article 1 Urban crime clusters	◯	○	◯		
Article 2 Underground station crime levels		○		◯	
Article 3 Guardianship				◯	
Article 4 Crime levels over space and time			◯	○	◦
Article 5 Crime prevention					◯

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.

	Spatial Scale	**Temporal Scale**
Article 1 Urban crime clusters	Local administrative unit & municipality	Days & Months
Article 2 Underground station crime levels	Stations & local administrative unit	Hours, Days, Weeks & Months
Article 3 Guardianship	Stations & station sections	-
Article 4 Crime levels over space and time	Stations & surroundings	Hours & Days
Article 5 Crime prevention	Stations	Hours & Days

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: Vällingby 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 deteriorated neighborhoods, and in areas with more cash machines but fewer police stations in the vicinity. However, the significance of these variables can vary by crime type.

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. Adding to that, specific stations see different patterns of crime and need a particular intervention approach. No general crime prevention approach should be applied; instead, particular stations should be specifically targeted at particular times, using a 'whole journey approach' that also encompasses the surroundings.

Article 3 – 'Assessing Guardianship Opportunities at Underground Stations'

The third article focuses on the environmental design of transit environments and the opportunities for guardianship as a means for crime prevention. The main objective is to determine whether guardianship opportunities are related to the physical and social environment of a transport node by applying statistical modeling based on the fieldwork data of the stations' environmental design aspects, land use and socio-economic data.

Available literature is rich with evidence of how crime is influenced by guardianship. However, little is known about how the social and physical environment affects guardianship opportunities, particularly at transport nodes. Guardianship can relate to people's capacity to affect crime simply by the force of their presence, to exercise surveillance or to intervene if something happens. Guardianship was originally defined as a crucial part of routine activity theory, and it includes any person or object that is able to supervise or simply watch other people or objects at any given point in time and at any place which may force offenders to refrain from committing a crime (Felson and Cohen, 1980). In this article, guardianship constitutes two dependent variables, indicated by visibility and surveillance.

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.

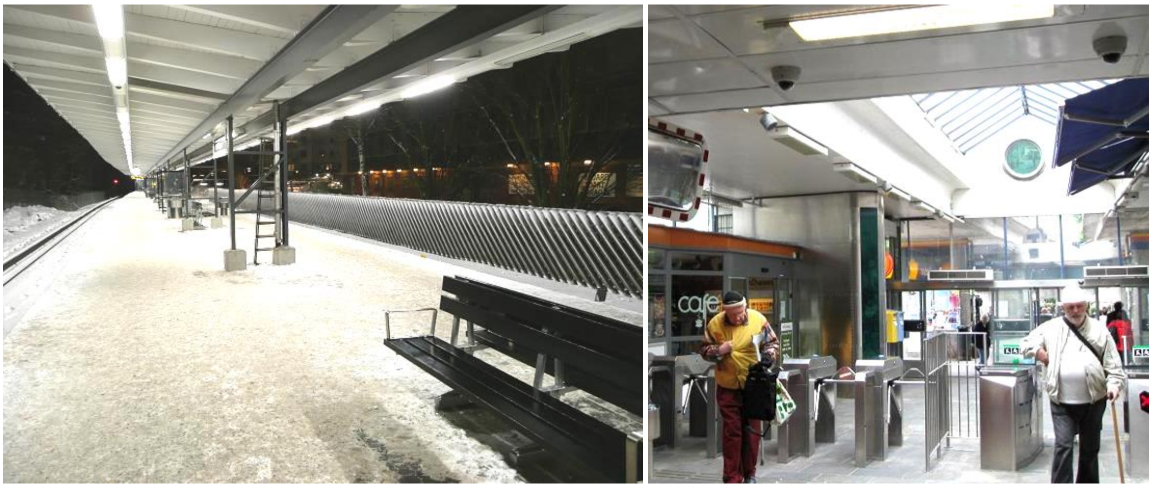


Figure 3 – Examples of (a) a light clean underground station and (b) CCTV installed at the entrance of an underground station. Copyright: Author.

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).

Violence	**Property**	**Vandalism**	***Total crime***
Medborgarplatsen	T-Centralen	Johannelund	*Sockenplan*
Hagsätra	Vällingby	Björkhagen	*Johannelund*
Sätra	**Medborgarplatsen**	**Sockenplan**	*Ängbyplan*
Hässelby Gård	Skanstull	Hammarbyhöjden	*Axelsberg*
Fruängen	**Kärrtorp**	**Axelsberg**	*Björkhagen*
Rinkeby	**Sockenplan**	Ängbyplan	*Kärrtorp*
Rågsved	Zinkensdamm	Tallkrogen	*Medborgarplatsen*
Kärrtorp	**Sätra**	Enskede Gård	*Sätra*
Axelsberg	**Hagsätra**	Akalla	*Akalla*
Hjulsta	Globen	Stureby	*Hässelby Gård*

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.

Violent crimes	Property crimes
Primary Cluster	**Primary Cluster**
20 – 26 December	*14 – 20 Aug*
T-Centralen	T-Centralen
Gamla Stan	Gamla Stan
Kungsträdgården	Kungsträdgården
Östermalmstorg	Hötorget
Hötorget	Rådmansgatan
Secondary Clusters	**Secondary Clusters**
16 Jan – Rinkeby	*6 – 12 Feb* – Hagsätra
1 Feb - Farsta	*7 – 13 May* – Telefonplan, Midsommarkransen
28 May – 2 Apr – Skärholmen	*8 – 14 May* – Vällingby
4 – 10 Aug – Vällingby	*2 – 8 Oct* – Johannelund, Hässelby Gård
29 Aug – Tensta, Hjulsta	*4 – 10 Oct* – Skärholmen
	17 – 20 Oct – Stora Mossen, Alvik
	7 – 13 Nov – Kista
	23 Nov – Råcksta, Vällingby

Figure 5 - Stations located in clusters of violent and property crimes, Stockholm, 2006-2008. *Source: Ceccato et al., (2011).*

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

Ackerman, W. and Murray, A. (2004). 'Assessing Spatial Patterns of Crime in Lima, Ohio'. *Cities*; 21(5), p.423–437.

Almeida, E., Haddad, E. and Hewings, G. (2003). 'The Spatial Pattern of Crime in Minas Gerais: An Exploratory Analysis'. *Economia Aplicada*; 9(1), 2005.

Andresen, M.A. (2006). 'Crime Measures and the Spatial Analysis of Criminal Activity'. *British Journal of Criminology*; 46(2), p. 258-285.

Block, R. (1981). 'Victim-Offender Dynamics in Violent Crime'. *The Journal of Criminal Law and Criminology*; 72(2), p.743-761.

Block, R. and Block, C. (1995). 'Space, Place, and Crime: Hot-spot areas and Hot Places of Liquor-Related Crime', in J. Ech and D. Weisburd (Eds.), *Crime and Place*. Monsey, NY: Criminal Justice Press.

Braga, A.A., Papachristos, A.V., Hureau, D.M. (2012). 'Police Programs to Prevent Crime in Hot Spot Areas'. *No. 7 of Crime Prevention Research Review*. Washington, D.C.: U.S. Department of Justice, Office of Community Oriented Policing Services.

Brantingham, P.J. and Brantingham, P.L. (1995). 'Criminality of Place: Crime Generators and Crime Attractors'. *European Journal on Criminal Policy and Research*; 3(3), p.1-26.

Brit, J. (1989). 'Crime Prevention that Works: The Care of Public Transport in the Netherlands'. *British Journal of Criminology*; 29(1), p.47-56.

Browning, C.R. and Jackson, A.L. (2013). ‘The Social Ecology of Public Space: Active Streets and Violent Crime in Urban Neighborhoods.’ *Criminology*; 51, p.1009-1043.

Canter, D. (2000). ‘Using a Geographic Information System for Tactical Crime Analysis’, in V. Goldsmith, P. McGuire, J. Mollenkopf and T. Ross (Eds). *Analyzing Crime Patterns: Frontiers of Practice*. Sage Publications, Thousand Oaks, US.

Ceccato, V. (2013). *Moving Safely: Crime and Perceived Safety in Stockholm's Subway Stations.* Lanham, MD, USA: Lexington Books.

Ceccato, V. and Haining R. (2004). ‘Crime in Border Regions: The Scandinavian Case of Öresund, 1998 – 2001’. *Annals of the Association of American Geographers;* 94(4), p.807-826.

Ceccato, V. and Uittenbogaard, A.C. (2013). ‘Environmental and Wildlife crime (EWC) in Sweden’. *International Journal of Rural Crime*. (In press).

Ceccato, V., Haining, R. and Signoretta, P. (2002). ‘Exploring offence statistics in Stockholm City using spatial analysis tools’. *Annals of the Association of American Geographers*; 92(1), p.29-51.

Ceccato, V., Uittenbogaard, A.C. and Bamzar, R. (2011). ‘*Safety in Stockholm’s Underground Stations: The Importance of Environmental Attributes and Context.*’ Preliminary Report. Department of Urban Planning and Environment. Royal Institute of Technology (KTH), Stockholm, Sweden.

Ceccato, V., Uittenbogaard, A.C. and Bamzar, R. (2013). ‘Security in Stockholm’s Underground Stations: The Importance of Environmental Attributes and Context’. *Security Journal*; 26, p.33-59.

Chaiken, J.M., Lawless, M.W. and Stevenson, K.A. (1974). *Impact of Police on Crime: Robberies on the New York City Subway System*. New York: R-1424-NYC, The New York City Rand Institute.

Clarke, R. and Felson, M. (1993). ‘Routine Activity and Rational Choice.’ *Advances in Criminological Theory*; 5. New Brunswick, NJ: Transaction Books.

Cohen, L. and Felson, M. (1979). ‘Social Change and Crime Rate Trends: A Routine Activity Approach.’ *American Sociological Review*; 44, p.588-605.

Cozens, P., Saville, G. and Hillier, D. (2003). ‘Crime Prevention through Environmental Design (CPTED): A Review and Modern Bibliography.’ *Property Management*; 23(5), p.328-56.

Dolmén, L. (2002). Brottslighetens *Geografi: En analys av brottsligheten I Stockholms län.* (The Geography of crime: an analysis of crime in Stockholm County). Avhandlingsserie Nr 6. Institute of Criminology, Stockholm University.

Dzemydiene, D. and Rudzkiene, V. (2002). 'Multiple Regression Analysis in Crime Pattern Warehouse for Decision Support'. In: A. Hameurlain, R. Cicchetti, R. Traunmüller (Eds.). *Database and Expert Systems Applications. Lecture Notes in Computer Science Volume 2453*, p.249-258. Springer, Berlin/Heidelberg.

Felson, M. and L.E. Cohen. (1980). 'Human Ecology and Crime: A Routine Activity Approach.' *Human Ecology*; 8(4), p.389−405.

Haining, R. (2003). *Spatial Data Analysis: Theory and Practice*. Cambridge, UK: Cambridge University Press.

Harris, O. (1971). *A Methodology for Developing Security Design Criteria for Subways*. Washington DC. Urban Mass Transit Administration, Report No.: UMTA-URT-5 (70)-71-4.

Hägerstrand, T. (1970). 'What about People in Regional Science?' *Papers of the Regional Science Association*; 24, p.7-21.

Kinney, J.B., Brantingham, P.L., Wuschke, K., Kirk, M.G. and Brantingham, P.J. (2008). 'Crime Attractors, Generators and Detractors: Land Use and Urban Crime Opportunities.' *Built Environments*; 34(1), p.62-74.

Krohn, M.D. (1976). 'Inequality, Unemployment and Crime: A Cross-National Analysis.' *The Sociological Quarterly*; 17(3), p.303–313.

LaVigne, N.G. (1997). *Visibility and Vigilance: Metro's Situational Approach to Preventing Subway Crime*. National Institute of Justice-Research in Brief. U.S. Department of Justice, https://ncjrs.gov/txtfiles/166372.txt, accessed 12 October 2013.

Loukaitou-Sideris, A. (1999). 'Hot Spots of Bus Stop Crime: The Importance of Environmental Attributes.' *Journal of the American Planning Association*; 65(4), p. 395 – 411.

Loukaitou-Sideris, A., Ligget, R. and Iseki, H. (2002). 'The Geography of Transit Crime. Documentation and Evaluation of Crime Incidence on and around the Green Line Stations in Los Angeles.' *Journal of Planning Education and Research*; 22(2), p.135-151.

Långström, N. (2002). 'Long-term Follow-up of Criminal Recidivism in Young Sex Offenders: Temporal Patterns and Risk Factors.' *Psychology, Crime & Law*; 8(1), p.41-58.

Maslow, A. H. (1943). 'Conflict, Frustration, and the Theory of Threat.' *Psychological Review*; 50, p.370-396.

Morgan, M. and Smith, M.J. (2006). ‘Vandalism and Graffiti.’ In M. Smith and D. Cornish, D. (eds) *Secure and Tranquil Travel – Preventing Crime and Disorder on Public Transport.* UCL Jill Dando Institute of Crime Science, University of London, London.

Nelson, A., Bromley, R. and Thomas, C. (2001). ‘Identifying Micro-Spatial and Temporal Patterns of Violent Crime and Disorder in the British City Centre.’ *Applied Geography*; 21, p.249–274.

Newman, O. (1972). *Defensible Space: Crime Prevention through Urban Design*. New York, NY: Macmillan.

Newton, A. and Bowers, K. (2007). ‘The Geography of Bus Shelter Damage: The Influence of Crime, Neighborhood Characteristics and Land-Use.’ *Internet Journal of Criminology*, http://www.internetjournalofcriminology.com.

Pearlstein, A. and Wachs, M. (1982). ‘Crime in Public Transit Systems: An Environmental Design Perspective.’ *Transportation;* 11(3), p.277-297.

Pease, K . (1999). *A Review of Street Lighting Evaluation: Crime Reduction Effects*. Huddersfield, UK: University of Huddersfield Press.

Perkins, D., Abraham, A., Richard, R. and Taylor, B. (1993). ‘The Physical Environment of Street Crime.’ *Journal of Environmental Psychology*; 13, p.29-49.

Piza, E. and Kennedy, D. (2003). *Transit Stops, Robbery, and Routine Activities: Examining Street Robbery in Newark, NJ Subway Environment.* [http://proceedings.esri.com/library/userconf/proc04/docs/pap1303.pdf]

Poyner, B. and Webb, B. (1993). ‘What Works in Crime Prevention: An Overview of Evaluations.’ In: R.V. Clarke (ed.) *Crime Prevention Studies*, Vol. 1. Monsey, NY: Criminal Justice Press.

Raco, M. (2007). ‘Securing Sustainable Communities Citizenship, Safety and Sustainability in the New Urban Planning.’ *European Urban and Regional Studies*; 14(4), p.305-320.

Ratcliffe, J. and McCullagh, M. (1999). ‘Chasing ghosts? Police Perception of High Crime Areas.’ *British Journal of Criminology*; 41(2), p.330-341.

Reynald, D.M. and Elffers, H. (2009). ‘The Future of Newman’s Defensible Space Theory.’ *European Journal of Criminology*; 6(1), p. 25-46.

Sampson, R.J. (2012). Great American City: Chicago and the Enduring Neighborhood Effect. Chicago, IL: University of Chicago Press.

Saville, G. and Kruger, T. (2012). 'Designing Cities to Minimize Crime.' *Sustainable Cities: Building Cities for the Future*. Rio+20 Conference 2012. Accessed via www.sustainablecities2012.com/read

Shaw, C.R., and McKay, H. D. (1942). *Juvenile Delinquency in Urban Areas*. Chicago, IL: University of Chicago Press.

Sherman, L.W. and Weisburd, D. (1995). 'General Deterrent Effects of Police Patrol in Crime "Hot Spots": A Randomized, Controlled trial.' *Justice Quarterly*, 12(4), p. 625-648.

Smith, M.J. and Cornish, D.B. (2006). *Secure and Tranquil Travel – Preventing Crime and Disorder on Public Transport.* UCL Jill Dando Institute of Crime Science, University of London, London.

Stockholm City- Stockholm Stad (2011). *Trygg i Stockholm? 2011: En stadsövergripande trygghetsmätning* (Safe in Stockholm, 2011: A City-wide Safety Survey).

Stockholm City – Stockholm Stad (2013). *Statistik, fakta och kartor* (Statistics, Facts and Maps). Accessed via: http://www.stockholm.se/OmStockholm/Fakta-och-kartor/.

Stockholm Public Transport - SL (2011). Database on Crime Reports 2008-2011. Unpublished.

Stockholm Public Transport - SL (2013). *Upplevd kvalitet i SL-trafiken: Våren 2013* (Experienced Quality of Stockholm Public Transport: Spring 2013). Trafikförvaltningen, Stockholms Länslandsting.

Webb, B. and Laylock, G. (1992). *Reducing Crime on the London Underground: An Evaluation of Three Pilot Projects.* Crime Prevention Unit Paper No. 30. London: Home Office Police Department.

Welsh, B.C. and Farrington, D. (2007). *Improved Street Lighting and Crime Prevention, Stockholm, Sweden*. Swedish Council for Crime Prevention, http://www.bra.se/extra/faq/?module_instance=2&action_question_show.435.0.=1, accessed 10 October 2012.

Wikström, P-O. (1990). *Crime and Measures Against Crime in the City*, Allmänna förlaget, Stockholm, Sweden.

Wikström, P-O. (1991). *Urban Crime, Criminals, and Victims: The Swedish Experience in an Anglo-American Comparative Perspective*. Stockholm: Springer Verlag.

Wilson, J. and Kelling, G. (1982). 'The Police and Neighborhood Safety: Broken Windows.' *Atlantic*; 127, p.29-38.

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

Review of European Studies; Vol. 4, No. 5; 2012
ISSN 1918-7173 E-ISSN 1918-7181
Published by Canadian Center of Science and Education

Space-time Clusters of Crime in Stockholm, Sweden

Adriaan Uittenbogaard[1] & Vania Ceccato[1]

[1] CEFIN - School of Architecture and the Built Environment, Royal Institute of Technology, Sweden

Correspondence: Adriaan Uittenbogaard, CEFIN - School of Architecture and the Built Environment, Royal Institute of Technology, Drottning Kristinas väg 30, 10044 Stockholm, Sweden. Tel: 46-8-790-8732. E-mail: acui@kth.se

Received: August 28, 2012 Accepted: October 17, 2012 Online Published: November 26, 2012

doi:10.5539/res.v4n5p148 URL: http://dx.doi.org/10.5539/res.v4n5p148

Abstract

The aim of the study is to detect geographical clustering of offences over time using Kulldorff's scan test (SaTScan version 9.01; Kulldorff, 2010) and police recorded data over Stockholm city, the capital of Sweden. This technique has a rigorous inference theory for identifying statistically significant clusters. The space–time scan statistics are used in a single retrospective analysis using data from 1st January 2006 to 31st December 2009. A four years' dataset is collapsed into 'one year'. All space-time dimensions of the data are kept except 'year'. Clusters over the hours of the day, weekday and weekend and by seasons were tested. Total population but also day-time and night-time populations were used as reference. Findings show clear distinct patterns of concentration for violence (assault and threat) and property crimes (theft, robbery and burglary) over time and space. Whilst property crimes tend to happen more often in the afternoons in the center and regional commercial centers in the southern and western parts of Stockholm, violence takes place more often in the night, and is heavily concentrated in large parts of the city center. Weekends are more targeted than weekdays for both offences. Regardless of day of the week, the main urban core of the city contains the most likely cluster that extends to commercial and socially disorganized areas in the west and south Stockholm. Whilst property crime levels do not show significant differences over the seasons, violent crimes levels do (winter and summer). The most likely clusters tend to be fairly constant in space over time. The article ends with implications of the results for both research and practice.

Keywords: spatial concentration, space-time cluster, poisson discrete model, violent and property offences

1. Introduction

Quetelet (1842) in his seminal work suggested that the greatest number of crimes against a person is committed during summer and the fewest during winter. Since then, researchers have found new empirical evidence on how crime levels vary over time and space (for a review see Cohn, 1990; Cohn & Rotton, 2003; Ceccato 2005). Some relate these temporal differences to the influence of weather on behavior (Anderson et al., 2000) whilst others associate them to variations in people's routine activity (Cohen & Felson, 1979). Routine activity theory suggests that an individual's activities and daily habits are rhythmic and consist of patterns that are constantly repeated, moreover most crimes depend on the interrelation of space and time: the offenders' motivation, presence of suitable targets (victims) and absence of responsible guardians (Cohen & Felson, 1979). This is the basis of the explanation of the mechanisms behind seasonal (summer–winter) and weekly (weekend–weekday) variations of crime over time and space.

The advance of new technologies for data storage and analysis such as Geographical Information System (GIS) has led to systems for visualising and analysing the growing amounts of geocoded data, including for crime. Cluster techniques, such as Kulldorff's scan test, can be used for detection of variations of crime over space and time. As suggested by Ceccato (2008), "these techniques are making geographical analysis of crime data more in-depth and interactive than they were in the past and therefore space can now be addressed more dynamically, both in time and space. Spatial analysis of crime data often uses information on the unique location of individual crimes (x, y co-ordinates) or aggregated data (combining individual point data into larger areal units, such as a city's statistical units)". The use of Kulldorff's scan test to detect hotspots of violent and property crimes in Stockholm, Sweden, is assessed.

The Kulldorff's scan test has been chosen because it uses input data based on single events and is a software able to detect statistically significant clusters of point data (such as crime records). The events are assumed to be randomly distributed over space and time (Kulldorff, 2010). Kulldorff's SaTScan has several modelling options available for cluster detection; it is possible to search for only spatial, temporal or space-time clusters. The scan test can be applied to both continuous and discrete data, where the latter data may be aggregated to local area levels, instead of individual point data, and the center point of the polygon will be used as location reference (Kulldorff, 2010). This aggregated method makes the analysis faster as fewer individual points need to be 'scanned', yet not less trustworthy if one is satisfied with using larger area data. The discrete models can be based upon the underlying assumptions of either Poisson, Bernoulli, space-time permutation, multinomial, ordinal, exponential, normal or spatial variation in temporal trends model distributions. The choice of model relies on the input data, as for instance the Poisson model requires the existence of a concerned population at risk while the Bernoulli model involves the use of both cases and controls data for the cluster analysis (Kulldorff, 2010). In order to detect clusters over space and time, the space–time scan statistic is defined by a cylindrical window with a circular geographic base and with height corresponding to time. This cylindrical window is moved in space and time, so that, for each possible geographical location and size, it also visits each possible time period. An infinite number of overlapping cylinders of different size and shape are obtained, jointly covering the entire study region, where each cylinder reflects a possible cluster. This procedure is used to ensure data robustness (there is a higher power to pick clusters up with the collapsed data than one year dataset) (Kulldorff, 2010).

The objective of this study is to assess geographical clustering of offences over time using a Poisson discrete model and police recorded data over Stockholm city, Sweden. This will be achieved by detecting the concentration for violent and property offences in three moments in time: hours of the day, weekend and seasonally. For cluster detection during the day, two different reference populations are tested: day-time and night-time population and results are compared.

The structure of the article is the following. First, we present the area of study and the data used in section 2. The review of literature on space-time clusters followed by a set of hypotheses is presented in section 3. In section 4 the use of the methods is motivated. Section 5 puts forward the results while in section 6 findings are discussed. Conclusions and implications for future research and practice are presented in section 7.

2. The Study Area and Data

The study area is the municipality of Stockholm. Stockholm, as the capital city of Sweden, constitutes an interesting study area because the differences in seasonal weather variation are significant. Winters are cold and dark while summers provide warm and long, light days. These variations may affect crime levels and concentrations in space, which can potentially be picked up by space-time cluster techniques. Moreover, analyzing spatial clusters in Stockholm will provide an insight of the distribution of crime in a typical Scandinavian city, planned and built according to rather organized urban planning disciplines following the main infrastructures (e.g. underground and roads). So far, most previous research on cluster of crime has focused on cases in North America.

The data used is within the borders of the municipality, which covers an area of 216 km^2 and a total population of 790 642 (2007). The city is divided into 408 small units of analysis (*basomrade*), with an average population of 1937.85 and standard deviation of 1833.11. Crime data is extracted from official records of the Stockholm Police over four years: 2006 to 2009. For the police crime data only the years from 2006 to 2009 were at our disposal but the numbers are robust enough to work with and represent the most recent crime trends we can get hold off. Of all the selected records 6.3 per cent was eliminated as those either lacked coordinates, dates, were outside the study area or were registered before the recorded year. The records included all registered crimes of which five categories were selected: assault, threat, theft, burglary and robbery. For this study, assault and threat were combined as "violent crimes" and theft, burglary and robbery as "property crimes". Violent crimes includes all in- and outdoor violent related reports, of both attempts and completed crimes, e.g.: threat against duty officer, violence against women, rape, murder, limiting rights of freedom, harassment, insult, abuse. Property crimes covers thefts, burglaries and robberies from both persons and buildings, for instance: pick pocketing, theft of vehicle, theft from home or shop, theft of purse or phone, burglary in apartment, burglary in garage, burglary with break-in, robbery with weapon, robbery of shop, robbery of vehicle, robbery of person. The selected records comprehend 349 492 cases. The four years were collapsed into one year in order to create a more robust dataset. The records contained information on the offence, place (x, y coordinates) and time (by minute). Besides the crime records, demographic data of Stockholm municipality was used to run the cluster detection for seasonal variations. Total population for each small unit of analysis as well as night-time and day-time population was available. Night-time population shows a high correlation with total population whilst day-time population reflects people's movement patterns in the city. Table 1 indicates that more offences happen during weekends than weekdays. This finding makes a case for us to check if there is any variation in crime levels in space, which will be examined further in the paper.

Table 1. Average statistics of two types of crime in Stockholm, 2006-2009

	Total 4 years	Average a year	Average an hour	Average weekdays		Average weekends	
				One day	One hour	One day	One hour
Violent	75 117	18 779.25	1.84	43.51	1.81	61.99	2.58
Property	274 375	68 593.75	6.98	180.95	7.54	196.96	8.21

3. Space-time Clusters: Theory and Hypotheses

"Until recently, the role of space (and space-time) was not explicitly acknowledged in the methodology used in crime geography studies, but it is central in a number of respects" (Anselin et al., 2000). An important reason is that knowing where and when crime happens is fundamental for police intervention (Ratcliffe, 2010). Both Ratcliffe (2010) and Anselin et al. (2000) emphasize the importance of spatial techniques to detect and analyze space-time in crime data. More recently, Nakayo and Yano (2010) suggest the need to visualize both crime patterns in space and time to get a grip on the movement of clusters over time and space instead of focusing on all individual clusters. The study on crime clusters in Kyoto showed that the use of both kernel density based analyses and space-time scan statistics analyses are complementary to each other. Johnson et al. (2007) used Monte-Carlo simulations and Knox's ratio results to identify space-time clusters of burglary. Their cross-national findings showed that burglaries tend to be clustered in space but more important in time as well; clusters decayed as time elapsed. Johnson and Bowers (2004) use Knox's ratios but in combination with the Mantel technique to identify burglary clusters in space and time. The result of a two step analysis, firstly for spatial clustering of 'close pairs' and secondly space-time clustering, is that clusters of burglary appear more stable in time and movement in space occurs only in the vicinity in different time periods. Kulldorff's scan test has successfully been applied in the literature for both cities in the North and South hemisphere. LeBeau's study (2000) used the Kulldorff's scan test for a risk based assessment using space-time cluster of crime in the USA. Ceccato (2005) focused on space-time clustering (Poisson discrete model) of homicides in Sao Paulo (Brazil) and showed indications of a seasonal pattern which changes spatially according to months of the year. Other studies focusing on seasonal patterns of crime also found that crime levels vary over the year, but often different types of offences show different patterns (e.g. Anderson et al. 2000; Bromley & Nelson, 2002; Cohn, 1990; Cohn & Rotton, 2003; Farell & Pease, 1994). Nonetheless, these studies do show varying results and are inconclusive on seasonal effects (e.g., whether summers are more criminogenic than winters). Those studies which are concerned with the geography of these clusters, often present indications that crime patterns follow people's routine activity, places where people converge (Cohen & Felson, 1979; Sherman et al., 1989; Brangtingham & Brantingham, 1993) and/or neighborhoods that show signs of poor social control and social disorganization (Shaw & MacKay, 1942).

Taken together, the existing literature on Kulldorff's scan test is encouraging with regards the detection of space-time cluster of crime. Moreover, the suggested link between activity patterns and crime hotspots is a motivation to look closely at the behavior of crime over different periods of time and over space. For the purpose of this study, the recent strand of research is used as a background to hypothesize that the Kulldorff's scan tests provide robust results for the case of Stockholm. The analysis makes use of four years' crime data over Stockholm city to test the following hypotheses:

1) Both violent and property crimes show daily, weekly and seasonal variations over time and space.

2) Crime opportunities tend to be concentrated where people converge (city center, commercial areas, and central stations) but also in areas with signs of poor social control and social disorganization.

3) Hotspots of crime are sensitive to the population basis used in the test. Night-time population tends to shrink hotspots where people live (periphery of the city) whilst day-time population affects the size of hotspots in the opposite direction.

4. Method

Crime data sets were selected by using time windows representing peak and low hours of crime during the day.

By inspecting histograms, the highest and lowest crime rates were extracted. For instance, for property crimes the peak hour was 17:00, represented by the events happening from 17:00 to 18:00. This was done manually for total crimes, property and violent crimes, by day and month. As the database included an aggregated set of four years, each hour had enough events to be used in the analysis. Before cluster analysis, A-nova tests (with Scheffe test) were used to test whether there was significant difference in crime rates over time.

The study was based on models assuming a Poisson distribution of the number of cases at each location, under the null hypothesis that the expected number of cases in each area is proportional to the population in that area (Kulldorff, 2010). As the Kulldorff's scan test uses space-time statistics from the user's input, input data was created separately for each different run. In order to have an effective but comprehensive data input, all crime records were linked to their respective small unit areas (*basomrad*), as defined in the Stockholm population database, using GIS (population basis). This implied that the scans were not based on the exact coordinates of each separate crime record but on the coordinates of the centroide of each polygon (reflecting population basis) of the small unit areas. For cluster detection during the day, two different reference populations were tested: day-time and night-time population. Originally, Stockholm municipality consists of 408 small unit areas, but a few of these units have low population counts (less than 50 inhabitants). To improve the population basis for running the scan tests, about 40 units were aggregated to the neighboring polygons using GIS; so that none showed a population count lower than 50. The space-time scans were executed within different time frames defined by the user. In this study, the maximum temporal cluster size window was set to seven days (if applicable) so that the crime clusters were identified at a maximum length of a week. For spatial scan limits, two ranges were used: one being maximum 50 per cent of the population at risk and the other a maximum of 10 per cent of the population.

5. Identifying Space-time Clusters of Violent and Property Crime in Stockholm

This study explores when and where crime happens in Stockholm and therefore investigates three different moments in time. The analysis is divided into three parts; crime during the day, between weekdays and weekends and whether there are any seasonal variations. For all three moments the clustering of crime has been assessed using the Kulldorff's space-time cluster test based on a discrete Poisson model.

5.1 Clusters during the Day

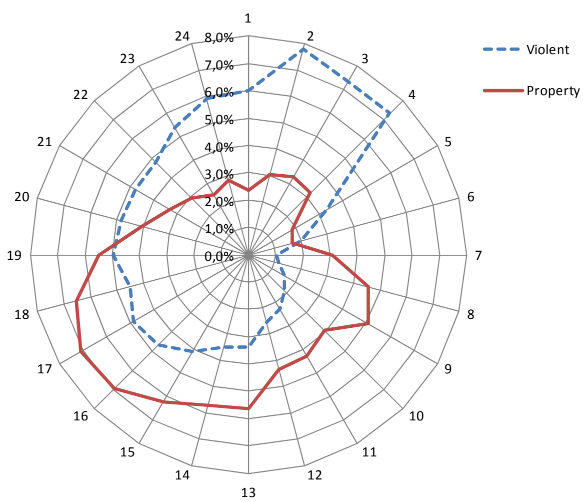


Figure 1. Percentage of violent and property crimes by hour of the day in Stockholm, 2006-2009

Source: Stockholm Police Database, 2006-2009.

During the day people are on the move and execute different patterns related to their destinations and activities. This also relates to the opportunities for different kinds of offences. The two types of crime show two different patterns over the day; property crimes happen more during day-times and violent crimes are more committed during night-times. There is a peak for property crimes at 17:00 and at 02:00 for violent crimes (Figure 1).

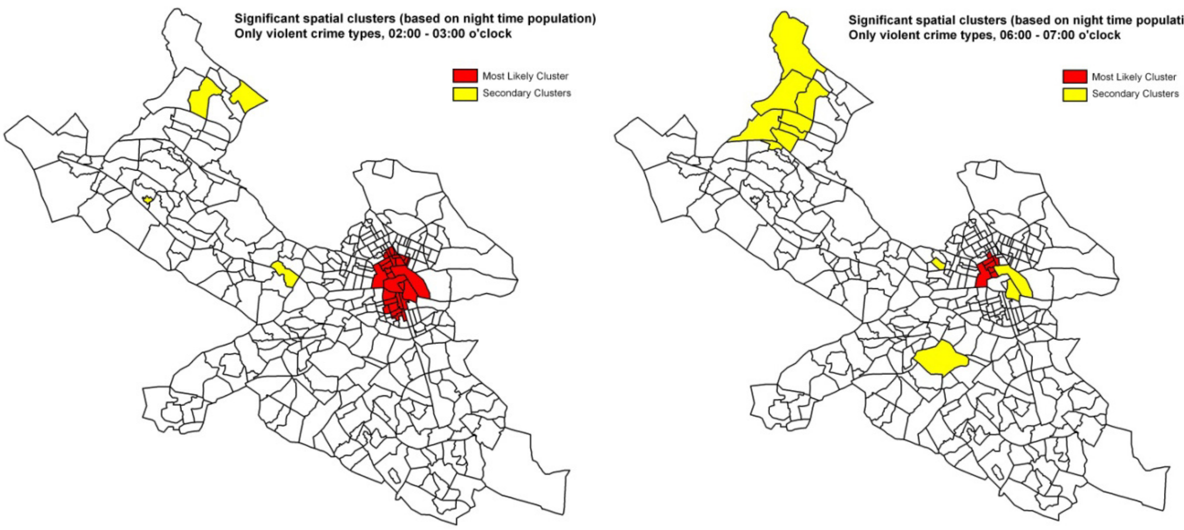


Figure 2. Clusters of violent crimes at a) 2am (peak frequency) and b) 6am (lowest frequency)

The spatial clusters appearing as hotspots during the night show a more concentrated violent pattern (Figure 2) that shrinks when moving towards the lowest peak at 06:00. Property crimes (Figure 3) increase in terms of clusters at the highest peak, 17:00, and creeps into more suburban areas where the population is lower during day-time as people are at not at home but are engaged in work or leisure activities.

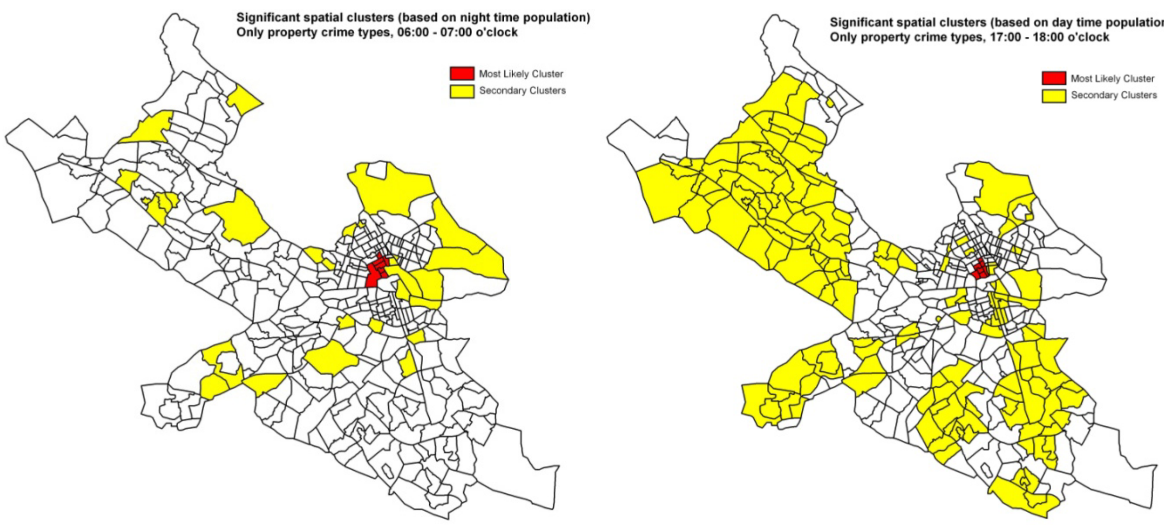


Figure 3. Clusters of property crimes at a) 6am (lowest frequency) and b) 5pm (peak frequency)

5.2 Clusters in the Week

The literature shows evidence of a significant difference in crime incidence between weekends and weekdays. Peak periods for assaults and robberies were found to be in the early hours of the morning on weekends, that is, between 00:01 and 03:00 on Saturdays and Sundays. Assault and robbery rates during these times were more than twice the average rates in Sydney, Australia (Jochelson, 1997).

In Stockholm, A-nova tests show a significant difference for both crime types between weekdays and weekends. Property crimes show significance at a 90 per cent level whereas violent crimes are significant at a 99 per cent level (Scheffe test). Results show that weekends tend to be more prone to crime activities as a consequence of the unstructured activities undertaken by people during the weekend, such as leisure. By selecting two data sets, for both weekdays (Monday – Thursday) and weekends (Friday – Sunday), as input for the Kulldorff's scan test, clustering was detected for both periods. Violent crime clusters shrink during the weekend and show a more concentrated pattern for specific locations in the suburbs. The city center shifts in direction for weekends, including the area in the east where more bars and clubs are located, contrary to the weekday's cluster which is more concentrated around the central station where most people meet while daily commuting from home to work.

5.3 Seasonal Clusters

Research has been inconclusive on whether crime varies seasonally (Cheatwood, 1988; Landau & Fridman 1993; Ceccato, 2005) but evidence tends to show that crime varies over time. In the Northern Hemisphere, Cheatwood (1988) shows that there was no specific season for homicide but homicide levels where found to be significantly higher during the months of December, July, and August. Landau and Fridman (1993) found that while homicide does not vary significantly over the year, robbery does and would peak during the winter (November through March). Assault and robbery incidents were more prevalent in the summer months in Sydney, Australia (Jochelson, 1997) whilst Hipp et al. (2004) show that both violent and property crimes vary seasonally. They indicate, for instance, that property crime rates are primarily driven by pleasant weather. Homicides show seasonal variations also in Sao Paulo, Brazil, one of the largest cities of the Global South (Ceccato, 2005), with peaks in the hot months of the year, when vacation and many social gatherings occur. Farell and Pease (1994), show that in Merseyside (UK) domestic disputes are highest in summer while burglary and theft peak during the winter. Do violent and property crimes also vary in Stockholm? To detect variations of crime over seasons, the full four year dataset was broken down into four parts (Winter from December till February, Spring from March to May, Summer ranged from June to August and Autumn includes September to November). The A-Nova test showed that levels of violent crimes differ between winter and summer; there is a significant difference of over five crimes a day (Table 2) but property crime does not vary significantly between seasons.

Table 2. Differences in violent crimes by season

	Crime Levels Mean	F-test	Scheffe
Winter (1)	48.19	2.901*	1.3/3.1
Spring (2)	51.90		
Summer (3)	53.54		
Autumn (4)	51.98		

* Significant at 90% level

Scans for both violence and property crimes were performed using the total population with 7 days as maximum length in time of a cluster (referring to a week). The first test used the default spatial limit of the population (50 per cent), but the results were unsatisfactory. For instance, violent crimes showed at first a surprising pattern where one secondary cluster covered half of the study area at only one point in time: the first of January, in the winter. A common practice is to decrease the spatial limit to 10 per cent of population at risk. Figure 4 shows the difference between summer and winter after adjusting for the spatial limit to 10 per cent of population at risk.

The city center is a stable hotspot for both crime types during different seasons, there is mixed land use, where activities and people converge at the central station on their way to and from places. Stockholm's city center is rather compact and concentrates shops, offices and bars. There is however a variation in time, as violent crimes in the inner city are concentrated during the winter months whereas, for property crimes, the city center comes up as a hot spot during summer months. This finding is in line with previous studies showing the increase of property crimes during the warmer months of the year (e.g. Jochelson, 1997).

Following the A-nova test, the space-time scan clusters show slightly different clusters for violence during the winter and summer. Moreover, the city center cluster has clearly shrunk while moving into summer months, when the violent crime clusters seem to be positioned more in the outer-suburbs of Stockholm (Figure 4). Areas in the periphery of Stockholm municipality mainly concentrate housing areas with (regional) shopping centres located at transportation hubs which present steady crime clusters over time and space.

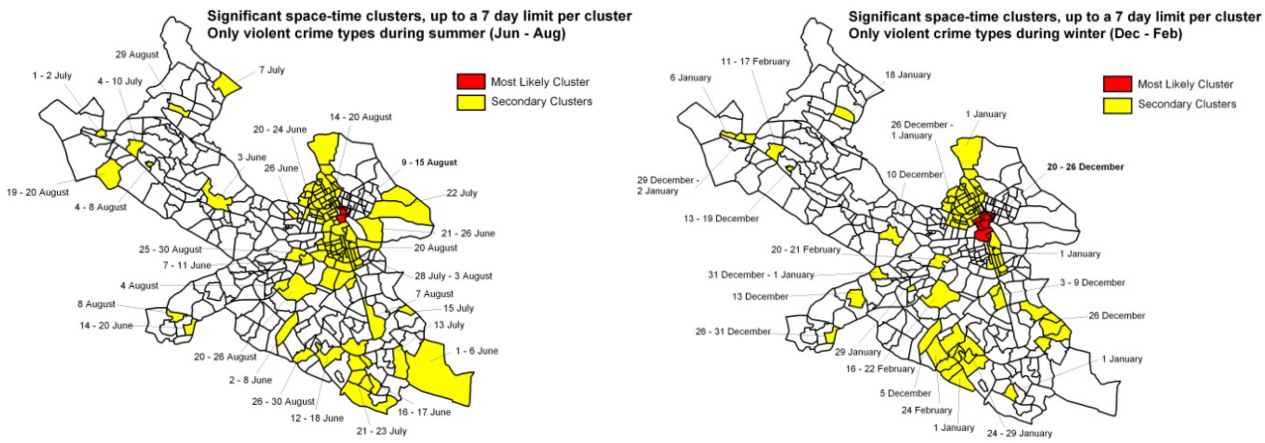


Figure 4. Violent crime clusters during a) summer and b) winter

6. Discussion of Results

The Kulldorff's scan test proved to be a useful tool to identify space-time hotspots of crime. This set of techniques was tested using Stockholm city as a case study and the models were built up to test clusters by hour, weekly and seasonally. Findings confirm the first hypothesis that events of different crime types vary over time and space. The change in levels of crime by hour provides a clear distinction between violent and property crimes, which seem to be closely related with individuals' routine activities (Cohen & Felson, 1979). Property crimes take place when people are not at home (burglary) or when people are going from work to home (and vice versa) in rush hour (theft), while violent crimes are committed in places with less social control; during the evening and nights in public spaces or in domestic environments. Seasonal variations as studied by Jochelson, (1997) and Ceccato (2005), amongst others, are also found in this study's results. In Stockholm, most housing areas are located outside the city center where one can find clusters of violence during the winter.

A more spread out pattern can be observed for summers as compared to winters but still clusters of crime tend to happen around some common areas, such as inner city and in suburban areas. This finding corroborates the second hypothesis prompting that crime opportunities are related to the place where people meet. Routine activity theory suggests that these are places where people move around, converge, meet and perform activities. These places can provide the optimal conditions for crime to happen, as offenders can easily access suitable victims without being detected (Cohen & Felson, 1979). Findings also show evidence that corroborates social disorganization theory. Most of the persistent clusters in the suburban areas are neighborhoods with long term social economic problems, and expected low levels of social control.

In a more technical account, findings show the effect of the population base used for the scan test. The Kulldorff's space-time scans provide the undeniable result of a constant hotspot for violent and property crimes in the city center regardless time or date or population base. However, for secondary clusters the night-time population causes the size of hotspots to shrink where people live (in the periphery of the city) while, on the other hand, day-time population increases the size of clusters in the periphery, as people head for work elsewhere (for instance, to the city center) when the population base is then lower, increasing the calculated risk for crime in those areas. These findings indicate that the selection of an adequate denominator such as population base is a fundamental step in the process of detection of space-time clusters.

7. Conclusions

This article assessed the detection of geographical clustering of offences over time using Kulldorff's scan test and police recorded data of Stockholm municipality, Sweden. Results showed distinct patterns of concentration for violence and property crimes over time and that the Kulldorff's scan test was a useful tool to identify these space-time hotspots of crime.

This study shares, however, limitations with other studies that deal with crime statistics geographically over time. For instance, crime records depend on the willingness of the public to report crimes to the police and therefore rarely cover all crime occurrences. The times attached to the records, defining the time spans of the events, can be uncertain as victims often do not remember the exact times and events are often recorded from the last time known up to the point the crime is administrated by police officials. For instance, theft is rather difficult to be recorded by the minute or even hour. Theft may happen without one realizing it and is only discovered at a later point in time. The same can be applied for burglary where one is not aware of the exact timing. This study based the daily analysis on hourly aggregated data, thereby avoiding as much as possible uncertainties in between hours.

For future research, the exploration of other types of analysis looking at the relations between the clusters (for examples, see details in Kulldorff (2010)) is suggested. Models with different parameters such as the maximum length of days and population at risk for clusters could be tested. The exclusion of the city center (which now tends to dominate the analysis) could also be an interesting strategy for future analysis. The detection of both hot and cold spots is also an important feature to be tested not only for research but also for crime prevention purposes. The Stockholm case indicates the role of population basis in cluster building - the appropriate population basis is an important step on cluster analysis over time that cannot be overlooked when selecting the dataset.

The results presented in this paper provide evidence for the clustering pattern of crime events in Stockholm - information that can be of importance for crime prevention and improvement of urban safety. With this information in hand, the police may act upon certain crime locations and align their prevention strategies over time. The increased presence of police in these hotspots at particular times might be desirable to deter crime. For instance, resources should be focused on evenings, holidays and weekends, and summer; with regards to space, they should be directed to commercial centers and some specific peripheral neighborhoods. Residents in these most targeted areas may want to engage in activities together with the police and crime prevention groups to define long term strategies (e.g., through safety audits, increased social control at certain times) to improve overall safety.

Acknowledgements

The research support of the Swedish Transport Administration and Stockholm municipality is gratefully acknowledged. Thanks also to Ulla Wittrock (Police in Stockholm County), Stefan Liljevall (Stockholm Statistics) for providing data for the analysis. Thanks also for the suggestions and comments received from the anonymous reviewers from this journal as well as from the participants during the *Spatial Statistics Conference*, held on 23rd-25th of March 2011 in Enschede, The Netherlands, where a first version of this article was presented.

References

Anderson, C. A., Anderson, K. B., Dorr, N., DeNeve, K. M., & Flanagan, M. (2000). Temperature and aggression. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (pp. 33-133). New York: Academic Press. http://dx.doi.org/10.1016/S0065-2601(00)80004-0

Anselin, L., Cohen, J., Cook, D., Gorr, W., & Tita, G. (2000). Spatial Analyses of Crime. *Measurement and Analysis of Crime and Justice, Criminal Justice, 4*, 213-262. U.S Department of Justice, Office of Justice Programs, Washington, U.S.

Brangtingham, P. J., & Brantingham, P. L. (1993). Nodes paths and edges: Considerations on the complexity of crime and the physical environment. *Journal of Environmental Psychology, 13*, 3-28. http://dx.doi.org/10.1016/S0272-4944(05)80212-9

Bromley, R. D. F., & Nelson, A. L. (2002). Alcohol related crime and disorder across urban space and time: evidence from a British city. *Geoforum, 33*(2), 239-254. http://dx.doi.org/10.1016/S0016-7185(01)00038-0

Cheatwood, D. (1988). Is there a season for homicide? *Criminology, 26*, 287-306. http://dx.doi.org/10.1111/j.1745-9125.1988.tb00842.x

Ceccato, V. (2005). Homicide in Sao Paulo, Brazil: Assessing spatial-temporal and weather variations. *Journal of Environmental Psychology, Elsevier, 25*, 307-321. http://dx.doi.org/10.1016/j.jenvp.2005.07.002

Ceccato, V. (2008). Crime and space: patterns of offences and offenders' paths to crime portrayed by Geographic Information Systems (GIS). In T. Lunden (Ed.), *Kartan och Verkligheten* (pp. 191-208). The Swedish Society for Anthropology and Geography YMER.

Cohn, E. G. (1990). Weather and crime. *British Journal of Criminology, 30*, 51-64.

Cohn, E. G., & Rotton, J. (2003). Even criminals take a holiday: instrumental and expressive crimes on major and minor holidays. *Journal of Criminal Justice, 31*, 351-360 http://dx.doi.org/10.1016/S0047-2352(03)00029-1

Cohen, L. E., & Felson, M. (1979). Social Change and Crime Rate Trends: A Routine Activity Approach. *American Sociological Review, 44*, 588-605. http://www.jstor.org/stable/2094589

Farrell, G., & Pease, K. (1994). Crime seasonality: Domestic disputes and residential burglary in Merseyside 1988-90. *British Journal of Criminology, 34*(4), 487-498.

Hipp, J. R., Bauer D. J., Curran P. J., & Bollen, K. A. (2004). Crimes of Opportunity or Crimes of Emotion? Testing Two Explanations of Seasonal Change in Crime. *Social Forces, 82*, 1332-1340. http://dx.doi.org/10.1353/sof.2004.0074

Hirschfield, A. F. G., Brown, P. J. B., & Bowers, K. J. (1995). Exploring relations between crime and disadvantage on Merseyside. *European Journal on Criminal Policy and Research, 3*(3), 93-112. http://dx.doi.org/10.1007/BF02242931

Jochelson, R. (1997). *Crime and Place: An Analysis of Assaults and Robberies in Inner Sydney, General Report Series.* Sydney: NSW Bureau of Crime Statistics and Research.

Johnson, S. D., Bernasco, W., Bowers, K. J., Elffers, H., Ratcliffe, J., Rengert, G., & Townsley, M. (2007). Space-Time Patterns of Risk: A Cross National Assessment of Residential Burglary Victimization. *Journal of Quantitative Criminology, 23*(3), 201-219. http://dx.doi.org/10.1007/s10940-007-9025-3

Johnson, S. D., & Bowers, K. J. (2004). The Stability of Space-Time Cluster of Burglary. *British Journal of Criminology, 44*(1), 55-65. Oxford Journals. http://dx.doi.org/10.1093/bjc/44.1.55

Kulldorff, M. (2010). SaTScan User Guide for version 9.0. Retrieved from http://www.satscan.org/cgi-bin/satscan/register.pl/Current%20Version:%20SaTScan%20v9.1.1%20released%20March%209%202011.?todo=process_userguide_download

Landau, S. F., & Fridman, D. (1993). The Seasonality of Violent Crime - The Case of Robbery and Homicide in Israel. *Journal of Research in Crime and Delinquency, 30*, 163-191. http://dx.doi.org/10.1177/0022427893030002003

LeBeau, J. L. (2000). *Demonstrating The Analytical Utility of GIS for Police Operations A Final report.* Southern Illinois University, United States.

Nakayo, T., & Yano, K. (2010). Visualising Crime Clusters in a Space-time Cube: An Exploratory Data-analysis Approach Using Space-time Kernel Density Estimation and Scan Statistics. *Transactions in GIS, 14*(3), 223-239. Blackwell Publishing. http://dx.doi.org/10.1111/j.1467-9671.2010.01194.x

Quetelet, A. J. (1842). *A treatise on man and the development of his faculties. A facsim. reproduction of the English translation of 1842.* Gainesville, Florida: Scholar's Facsimiles and Reprints; [1842] 1969.

Ratcliffe, J. (2010). Crime Mapping: Spatial and Temperol Challenges. In A. R. Piquero, & D. Weisburd (Eds.), *Handbook of Quantitative Criminology* (pp. 5-24). Springer Science. http://dx.doi.org/10.1007/978-0-387-77650-7_2

Shaw, C. R., & McKay, H. D. (1942). *Juvenile Delinquency in Urban Areas.* Chicago, IL: University of Chicago Press.

Sherman, L. W., Gartin, P. R., & Buerger, M. E. (1989). Hot spots of predatory crime: routine activities and the criminology of place. *Criminology, 27*(1), 27-56. http://dx.doi.org/10.1111/j.1745-9125.1989.tb00862.x

Original Article

Security in Stockholm's underground stations: The importance of environmental attributes and context

Vania Ceccato*, Adriaan Uittenbogaard and Roya Bamzar

School of Architecture and the Built Environment, Royal Institute of Technology, Sweden.
E-mail: vania.ceccato@abe.kth.se

*Corresponding author.

Abstract The aim of this article is to report on the security conditions in underground stations and surrounding areas in Stockholm, the capital of Sweden. The study is based on a comprehensive fieldwork combined with Geographical Information Systems techniques and regression models. Findings show that a relatively small share of reported events is crime; acts of public disorder are more common at the stations. Events tend to happen in the evenings – nights, holidays and weekends – and, at least for theft, in the hotter months of the year. Although the highest number of events is found in the central station, the so-called 'end-stations' show often higher rates than those located in the inner city. Results show that opportunities for crime are dependent on stations' environmental attributes, type of neighbourhood in which they are located and city context. These findings lend weight to principles of traditional urban criminology theory such as routine activity and social disorganisation. The article concludes with directions for future research and suggestions for policy.

Security Journal (2013) **26,** 33–59. doi:10.1057/sj.2011.32; published online 26 December 2011

Keywords: crime and disorder; transport nodes; GIS; regression models; Scandinavian capital

Introduction

A sustainable city enables the fulfilment of the mobility needs of their citizens via accessible, reliable and safe transportation systems. Security is one of many factors influencing the mobility of individuals in an urban environment. If one assesses security by the levels of crime events, how safe are the transport nodes, such as bus stops and underground stations? Literature shows that security in transport nodes is not necessarily worse than in other parts of the city in terms of crime incidents; on the contrary, studies show that at certain times one can be safer on public transport than in the city overall (LaVigne, 1997; Loukaitou-Sideris *et al*, 2002). However, several studies have shown that transport nodes facilitate the occurrence of crime and disorder in various ways (Sloan-Howitt and Kelling, 1990; Easteal and Wilson, 1991; Clarke, 1997; LaVigne, 1997; Loukaitou-Sideris, 1999; Church *et al*, 2000; Loukaitou-Sideris *et al*, 2001; Newton, 2004). Transport nodes are often called *crime generators* and *crime attractors* (Brantingham and Brantingham, 1993, 1995) as they concentrate large flows of people and are social spaces, which make it easier for offenders to commit crime. Some physical and social characteristics found in transport nodes may draw the attention of people with high levels of criminal motivation. They can potentially pull motivated offenders towards them. For instance, at certain times of the day, the crowds at a station may encourage the offender to pickpocket. In this article, we are interested in security conditions in transport nodes, particularly in underground stations.

Different parts of an underground station are exposed differently to crime and disorder. The design of these facilities and the internal and external environments of the stations may influence the level of crime. According to Smith and Clarke (2000), the targets of crime also vary and can include the system itself (vandalism, fare evasion), employees (assaults on ticket collectors) and passengers (pickpocketing, assault). At the stations, crime is a product of two dimensions: the environment of the transport node itself (for example, design of platforms, CCTVs, dark corners, hiding places) and social interactions that take place in these environments (for example, poor guardianship, crowdedness). Such vulnerability can also be associated with the context in which transport nodes may be embedded. Previous research indicated that the characteristics of the surrounding environment in which a transport node is located (for example, type of neighbourhood) is important for security at the station, but this effect is not well understood (for example, Loukaitou-Sideris *et al*, 2002).

In this article, we suggest that security in transport nodes is dependent on multi-scale conditions that act at various levels in an urban environment. These conditions are determined by the environmental attributes of the station, the characteristics of the immediate environment, the type of neighbourhood in which the station is located and the relative position of both the station and the neighbourhood in the city. To test this conceptual model, we use the underground stations of Stockholm city, Sweden. Stockholm's underground stations have been chosen for several reasons.

Most international literature on security in transport nodes is highly dominated by North American and British evidence (however, see, for example, Alm and Lindberg, 2004; Stangeby and Nossum, 2004). Stockholm is also an interesting case because, contrary to North American or British cities, the capital of Sweden has been shaped to a large extent by planning practices that were a result of welfare policies from the 1950s onwards. A typical characteristic of this was the fairly spatial distribution of the stations over the city, always followed by the construction of a new neighbourhood. Underground stations were planned and located as an integrative part of these new settlements. These areas are often lively places where people converge. There are reasons to believe that the stations' proximity to such a mixed land use makes the underground environment more criminogenic than its surrounding areas.

The objective of the article is to assess security conditions in underground stations and the surrounding areas where individuals' trips take place. This will be achieved by identifying the nature, levels and patterns of crime and disorder in the underground stations over time and space. The analysis also involves (i) an evaluation of the relationship between events of crime/disorder and environmental attributes of underground stations and surrounding areas, and (ii) an assessment of the importance of neighbourhood context (demography and socio-economic characteristics) on levels of crime in underground stations and areas close by. Geographical Information Systems (GIS) techniques and regression models are used in this research in combination with data from different sources.

In order to provide a comprehensive picture of what happens at the stations and in the surrounding areas, three databases were used: Stockholm Public Transport's calls for service, Veolia's personnel register and police-recorded data in an area within 100 m of the underground stations.

The novelty of this study is to make use of GIS, spatial data analysis and regression models to assess security conditions at underground stations with data from multiple sources. The article advances the knowledge basis in this area also by adding evidence of underground system of a Scandinavian city – a research area so far dominated by North American and British examples. The article is based on a conceptual model that stems from theories in urban criminology, situational crime prevention and crime prevention by design.

The structure of the article is as follows. First, the vulnerability of stations to crime is discussed, focusing on attributes of the station and its location in relation to the neighbourhood and overall city. Then, a conceptual model for assessing the stations' vulnerability to crime is suggested, followed by a set of hypotheses. We then discuss the nature, levels and patterns of crime and disorder in the underground stations over time and space. The results of modelling will show whether the environmental attributes of stations and their surroundings affect crime and disorder levels at the station. Directions for future work and the implications of the results for policy conclude the article.

Security at Transport Nodes: Theory and Hypotheses

Security in underground stations is dependent on multi-scale conditions that act at various levels in an urban environment. These conditions are determined by the environmental attributes of the station, the type of neighbourhood in which the station is located and the relative position of both the station and the neighbourhood in the city (Figure 1). Different types of crime occur in different places and vary over time (Jochelson, 1997; Cheatwood,

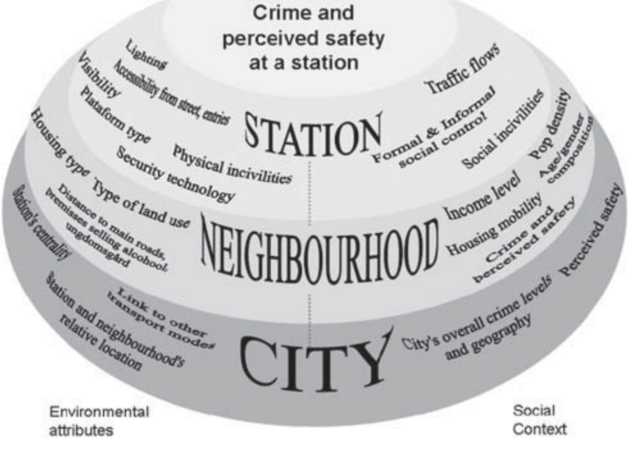


Figure 1: Security in underground stations: A tentative conceptual framework.

2008), which is also true for underground stations. Crime reflects people's activities and daily habits that are rhythmic and consist of patterns that are constantly repeated. Most crimes depend on the interrelation of space and time: offenders' motivation, suitable targets and absence of responsible guardians, as suggested by *routine activity theory* (Cohen and Felson, 1979). This convergence does not happen in a vacuum. The vast majority of crime occurs within the *offender's awareness and activity space* (Brantingham and Brantingham, 1995). An underground station can be the place where offender and victim awareness spaces converge, a condition that may lead to crime.

The conceptual model relies on principles of traditional theories of urban criminology, situational crime prevention and crime prevention by design. These theories underlie the discussion in the next sections.

Security conditions at the station

The station's design and layout affect its vulnerability to crime. Their design and layout affects the potential offender's likelihood of escaping without being detected (Clarke and Felson, 1993). According to *rational choice theory*, potential offenders evaluate their own risk before making a decision to commit a crime – and the environment plays an important role in their decision. For instance, the study by Harris (1971) suggested that the physical characteristics of stations – such as lighting, fencing, open design and security hardware – reduce crime opportunities. Different studies have indicated evidence of the effectiveness of street lighting as a crime prevention measure (Ramsey and Newton, 1991; Poyner and Webb, 1993; Pease, 1999; Welsh and Farrington, 2007), although not always conclusively (Barker *et al*, 1993). Nevertheless, if good illumination does not affect opportunities for crime, it may at least impact on passengers' perceived security. A case study in South Wales, UK, showed that poor lighting at railway stations was the main security concern among passengers (Cozens *et al*, 2003).

The location of escalators at the end of the platforms, ticket booths clearly visible at the entrance lounges, and overpass walkways for overviews and separation of passenger flows are factors affecting security at stations (Gaylord and Galliher, 1991; Myhre and Rosso, 1996; LaVigne, 1997). Loukaitou-Sideris *et al* (2002) suggested also the importance of the external layout of stations to security. Elevated stations (compared with underpass ones) suffer from poor visibility and are more often targeted by crime. They also indicated that crime against persons more often happens on platforms, escalators and access stairways, where the station design lacks good possibilities for surveillance.

Security relates directly or indirectly to the visibility of passengers, the possibilities of being seen and seeing others, in other words natural surveillance: the 'capacity of physical design to provide surveillance opportunities for residents and their agents' (Newman, 1972, p. 78) – a central concept in *defensible space theory* (Newman, 1972). Cozens *et al* (2003) found visibility to be the most crucial part of security at railways stations. In Los Angeles, a study of Green Line light-rail stations (Loukaitou-Sideris *et al*, 2002) showed strong links between crime rates and stations with dark, hiding places or with poor visibility of the surroundings (the opposite was shown for stations with good visibility).

Poor visibility can also be translated into poor surveillance. For instance, the evidence of the positive effect of Closed-Circuit Television Surveillance (CCTV) cameras on crime reduction has been shown in several studies, but its effectiveness may differ by offence type and results are not always conclusive (Tilley, 1993; Brown, 1995; Short and Ditton, 1996; Squires, 1998; Armitage, 2002; Welsh and Farrington, 2002). For instance, the installation of cameras on the London Underground showed some positive effects on the reduction of robberies and assaults (Webb and Laylock, 1992), as also CCTV usage on the Stockholm subway seems to have led to fewer property crimes but with no effect on assaults (Priks, 2009).

Formal and informal social control has an important role to play in determining crime levels in transport nodes. Disorder and physical deterioration promote the notion that no one is in control – a development that goes hand in hand with high levels of community social disorganisation (Shaw and McKay, 1942; Kornhauser, 1978) and low collective efficacy (Sampson *et al*, 1997; Sampson and Raudenbush, 1999). Chaiken *et al* (1974) showed, for instance, that crime rates on New York's subway were reduced when the number of police increased at a certain time, with no sign of crime displacement in the rest hours. Brit (1989) also showed evidence of the effect of guards in the station in the Dutch public transport system. A number of studies also indicate the role of informal guardians at the station in crime reduction (Reynald and Elffers, 2009). However, Felson (2006) suggests that the existence of informal surveillance does not necessarily guarantee that surveillance is occurring. Ceccato and Haining (2004) suggest that transport sites are often crowded but lack 'capable guardians', persons who, sometimes just by their presence, discourage crime from taking place.

Hypothesis 1: Crime and disorder rates at underground stations are affected by stations' environmental attributes (station design and social interactions). Different types of crime reflect different environmental conditions and may vary over time (daily, weekly and seasonally).

The station in the neighbourhood

High levels of crime at a station or bus stop are often correlated with high levels of crime in the surrounding neighbourhoods, sometimes triggered by the socio-composition of the population or particular land uses. The relationship between neighbourhood conditions and crime was assessed in the seminal work by Shaw and McKay (1942) in Chicago. They argued that low economic status, ethnic heterogeneity and residential instability led to community disorganisation. *Social disorganisation theory* links many forms of crime with the presence of weak informal social controls, often present in high-crime areas, regardless of where they are located. This lack of social organisation results, they argued, in a culture of violence and high rates of delinquency. According to Morenoff *et al* (2001), not until the 1970s and 1980s was the theory of social disorganisation explicitly conceptualised by Kornhauser (1978) and Bursik (1988) as 'the inability of a community structure to realise the common values of its residents and maintain effective social controls'. The literature show many examples of how deprived areas have higher risks of crime, as do transport nodes located in those areas (Pearlstein and Wachs, 1982; Hirschfield *et al*, 1995; Loukaitou-Sideris, 1999; Loukaitou-Sideris *et al*, 2002; Ihlanfeldt, 2003; Newton *et al*, 2004). There are, however, exceptions as well; LaVigne (1997) shows, with the exception of assaults, that Washington's subway crime rates by station did not covary with crime rates for the census tracts where Metro stations are located. Variations are found between above and below ground rates.

Incidents of vandalism plague transit systems (Loukaitou-Sideris *et al*, 2002) but not only this type of offence. There are reasons to believe that stations with high levels of physical damage and public disorder also attract other types of offences. The mechanisms are not well known for underground stations; however, according to Wilson and Kelling's 'Broken Window' Syndrome (Wilson and Kelling, 1982), unrepaired damage to property encourages further vandalism and other types of crimes. Public disorder and vandalism also promote the notion that no one is in control – a condition that goes hand in hand with high levels of community social disorganisation (Shaw and McKay, 1942; Kornhauser, 1978) and low collective efficacy (Sampson *et al*, 1997).

Pearlstein and Wachs' (1982) study showed that most crimes occurred on routes passing through typical high-crime areas in general, and all transit crimes were highly concentrated in these parts of the city. Ihlanfeldt (2003) shows evidence from Atlanta, USA, that rail stations have a significant influence on the levels of crime in the neighbourhoods and vice versa. Loukaitou-Sideris *et al* (2002) also produced similar findings in their study on station crime in Los Angeles, USA. By comparing population densities, high and low income levels, and ethnicity and gender and age distribution, they showed that crime rates at light-rail stations are related to the socio-economic levels of their surrounding neighbourhood. Table 1 summarises their findings.

The relationship between surrounding land uses and crime incidents tends to be significant as certain environmental features either attract offenders (potentially good opportunities) or influence criminal activities (as concentration of potential offenders and encouragement of anti-social behaviour) (Loukaitou-Sideris, 1999). Kinney *et al* (2008) suggest that commercial areas, shopping centres and entertainment locations, and multi-functional areas correlate with high concentration of crime events. In Merseyside, UK, the damage of bus shelters was related to the presence of youth, play parks, open spaces and schools with high truancy levels rather than pubs or other alcohol-related premises (Newton and Bowers, 2007). The impact of bars and liquor store on crime rates is not new but is not always straightforward. Block and Block (1995) found, surprisingly, that areas with the highest concentration of bars and liquor store were not necessarily the areas with the highest crime levels.

Hypothesis 2: The context in which stations are embedded has an impact on what happens in the underground stations in terms of crime and disorder.

Table 1: Socio-demographic variables related to station crime

Variables associated with higher crime rates	*Variables associated with lower crime rates*
High population density	Owner-occupied homes
More persons per household	High-income households
Younger population	Neighbourhoods with majority white population
Population with less than high school education	High numbers of population with college education

Source: Loukaitou-Sideris (2012).

The station in the city context

Transport nodes are also influenced by their relative position in the city. Urban criminology has shown plenty of evidence on how city centres are more criminogenic than other parts of the city (Sherman *et al*, 1989; Wikström, 1991; Ceccato *et al*, 2002; Loukaitou-Sideris *et al*, 2002; Smith, 2003; Ceccato, 2009). Thus, it could be expected that stations located in inner-city areas would tend to be more targeted by crime and disorder acts than those in the outskirts.

As Kinney *et al* (2008) discuss in their study on Burnaby (Vancouver, Canada), the greatest number of crime incidents are concentrated in and around commercial and civic-institutional land uses: assault rates, for instance, are six times the rates in residential areas. Policing operations along transportation routes in London and Liverpool, UK, showed that increased patrolling on the routes and along the routes decreased crime levels even up to 400 m from the route (Newton *et al*, 2004). A study on crime and bus stops in Newark (USA) suggested that both the presence of bus stops and commercial centres were related to higher levels of crime (Yu, 2009). The author points out that the presence of bus stops resulted in higher numbers of crime for all types of offences. Although much was explained by the geographical location of the bus stops in high-crime areas, the bus stops were found to function as high crime attractors towards their surroundings creating even more criminogenic places.

Hypothesis 3: The underground station's relative position in the city determines its levels of crime and disorder. As crime is often concentrated in city centres, it would be expected that the more centrally located a station is, the more criminogenic it is.

Study Area and Data Acquisition

Stockholm's underground system is composed of 100 stations, of which 47 are underground (most central) and 53 above ground. There are three lines: Red, Green and Blue (Appendix A). In this study, we will report on crime and public disorder events in the whole Stockholm underground system, but because of data limitation the modelling section ('Modelling public disorder and crime') will use 82 per cent of the stations, those located in Stockholm municipality.

Stockholm is part of an archipelago, and therefore water occupies a large part of the urban landscape as the city is spread over a set of islands on the southeast coast of Sweden. The islands are well connected by roads and an efficient public transportation system, comprising buses, the Stockholm underground system, rail systems and commuting trains. The main public transport junction is located in the Central Business District, in the central area of the inner city. All underground lines pass through the Central Station, which is the main railway station of the capital, making this area a place where many travellers and workers pass daily. The central station is the only station connected to all three lines. According to Stockholm Public Transport's Annual Report (2006), on a normal weekday, the flow of people travelling to and from the central station is around 215 000 people. The central square, and one of the main meeting points of the city, is a relatively high criminogenic area, where violence and drug-related offences tend to be concentrated (Ceccato *et al*, 2002).

The environment of underground stations follows some common standards, but they are far from being homogeneous, which potentially impacts on the stations' vulnerability to crime and disorder. In order to assess these differences, we conducted a systematic and detailed 'inspection' of all underground stations in the Stockholm underground system (including a photographic documentation), as well as a check on their surrounding areas, in summer 2010.[1] All underground stations were inspected on a weekday, between 10:00 and 16:00, avoiding atypical hours (rush hours and busy weekends). The inspection was based on fieldwork observation of five parts of stations, as shown in Appendix B. The station *platform* is constituted by the platform where the trains arrive and passengers wait, whereas the transition area is the area between the platform and the gates/ticket window, which commonly includes stairs and elevators to the platform. The *lounge* is the area before the gates/ ticket booth to the exits or tunnels. The *exits* are areas before entering the lounge area either directly from the street or via a tunnel. The *surroundings* included the immediate surroundings around each exit, the field of view from a station's exits. Figures 2 and 3 illustrate the environmental characteristics inspected in the fieldwork.

Data from the fieldwork inspection (checklists) were inputted in spreadsheets and then imported to GIS together with data on land use, crime and demographic and socio-economic data of the population. Stations and crimes were mapped as point data,

Figure 2: Environmental attributes of underground stations that promote security: (**a**) good overview of the whole station, clear sightlines of platforms in Odenplan station; (**b**) stations' external environment with clear overview from the train (and from outside) in Rågsved; (**c**) visible real-time train arrival display in lounge allows passengers better plan their trips in Akalla.

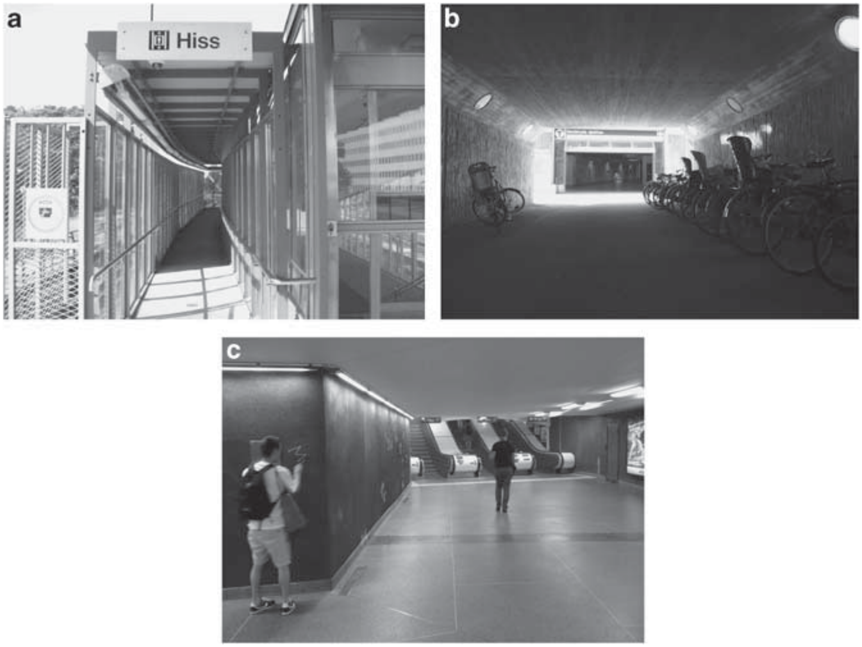


Figure 3: Environmental attributes of underground stations that do not promote security: (**a**) secluded entrance to an elevator in Råcksta station (on the left, 'keep away from danger' sign, entrance close to a motorway); (**b**) a dark tunnel as entrance to the underground station in Danderyd sjukhus station (during the day); (**c**) graffiti being applied on a wall behind a corner in Slussen station between the platform and the transition area.

whereas the Stockholm demographics and socio-economic data were linked to small unit statistics (*Basområde*). In order to assess the influence of the surroundings on crime and disorder events at each station, a number of criminogenic land-use indicators were manually mapped: the location of automated teller machines (ATMs), schools, police offices and state alcohol selling outlets (*Systembolaget*) in Stockholm.

Crime and public disorder data were gathered from Stockholm Public Transport (2006–2009), Veolia (2005–2008) in combination with 2008's Police recorded statistics obtained from the Stockholm Police Headquarters by *x*,*y* coordinates of all types of offences by date. Although coordinates were available, it was not possible to know where the event occurred (during the trip, at the station, wagon, other nearby premises). Instead of using crude data of crime events by stations, rates per 1000 passengers were calculated based on the passenger flow at each station.

The Nature and Levels of Crime over Time and Space

Public disorder is the most common type of event reported at stations (around 80 per cent of all events). Typical examples of such a report are cases of drunken people at the station or people found sleeping on a train, but also unjustified use of emergency brakes, fire extinguishers or fire hoses. More serious offences, often violence, thefts and vandalism, constitute about 20 per cent of events. Most reports of violence are against passengers and guards or other personnel. Threats against personnel are typical events, followed by threats against passengers and drivers. For robbery, data at the station show that most reports are made by passengers at the stations. The police robbery data also show a large number reported at the stations, although the majority of all records is related to places such as shops and supermarkets at the station. Theft can generally be divided in two types in underground stations: theft from persons and of objects at the station. The latter includes theft of bikes and cars, which is not uncommon around underground stations (parking lots or streets). The actual time of offence for car-related crime is likely to be an estimate and is biased towards the time of discovery (when the victim found out about the event). When recorded by the police, the time of discovery is often used as a (inaccurate) proxy. Given the volume of car crimes on public transport property, this factor could skew the mean times associated with property crimes overall. Theft from persons is mainly covered by stolen goods from transients and passengers using the underground system. Vandalism is frequent at underground stations. Acts of vandalism include graffiti on walls or floors, as well as damage to objects, rarely inside the trains. This section will take a closer look at these different acts of crime and disorder over time and space.

Figure 4(a) shows that regardless of the data source, records are stable over times of the day. Most crimes in underground stations, particularly violent ones, happen in the evenings and night (Figure 4). Although there are variations between data sources and crime types, the common trend is that people tend to be victimised after 15:00, with peaks between 19:00 and 22:00 and the early hours of the morning. Note that the underground stations have limited opening hours, and during weekdays most stations are closed between 03:00 and 05:00. Police crime data within 100 m of the stations show that theft is committed mainly around late afternoon, whereas vandalism happens in the evenings and violence offences are more reported in the night (Figure 4(b)). Holidays and weekends show higher reported rates for all types of crimes and events of public disorder than weekdays. Conflicts often reach a peak when people meet each other in their free time, at evenings, weekends and holidays. This temporal pattern reflects people's routine activity in the city (Cohen and Felson, 1979), when people are on the move.

As many as 62 per cent of all offences in Stockholm municipality take place within 500 m radius of an underground station, which are spread over just 28 per cent of Stockholm municipality's entire area. The surrounding areas of the stations are not criminogenic just because the stations are located there but because they are surrounded by mixed land uses that are known crime attractors (for example, pubs, restaurants, offices, alcohol selling stores, banks).

The central station might show a concentration of the highest number of events in Stockholm municipality, but it does not keep its top position after events are standardised by daily passenger flow. Instead of using crude data of events by stations, rates per 1000 passengers were calculated for the three databases and crime types. Three patterns stand out:

1. The so-called 'end-stations' often show higher rates of events than stations located in the inner city areas (exceptions are Medborgaplasten, Skanstull and T-centralen for thefts, for instance). Hjulsta, Farsta Strand and Hagsätra show high rates regardless of crime type. Some stations are 'crime specialised', showing more problems with violence, whereas others show high theft or vandalism.

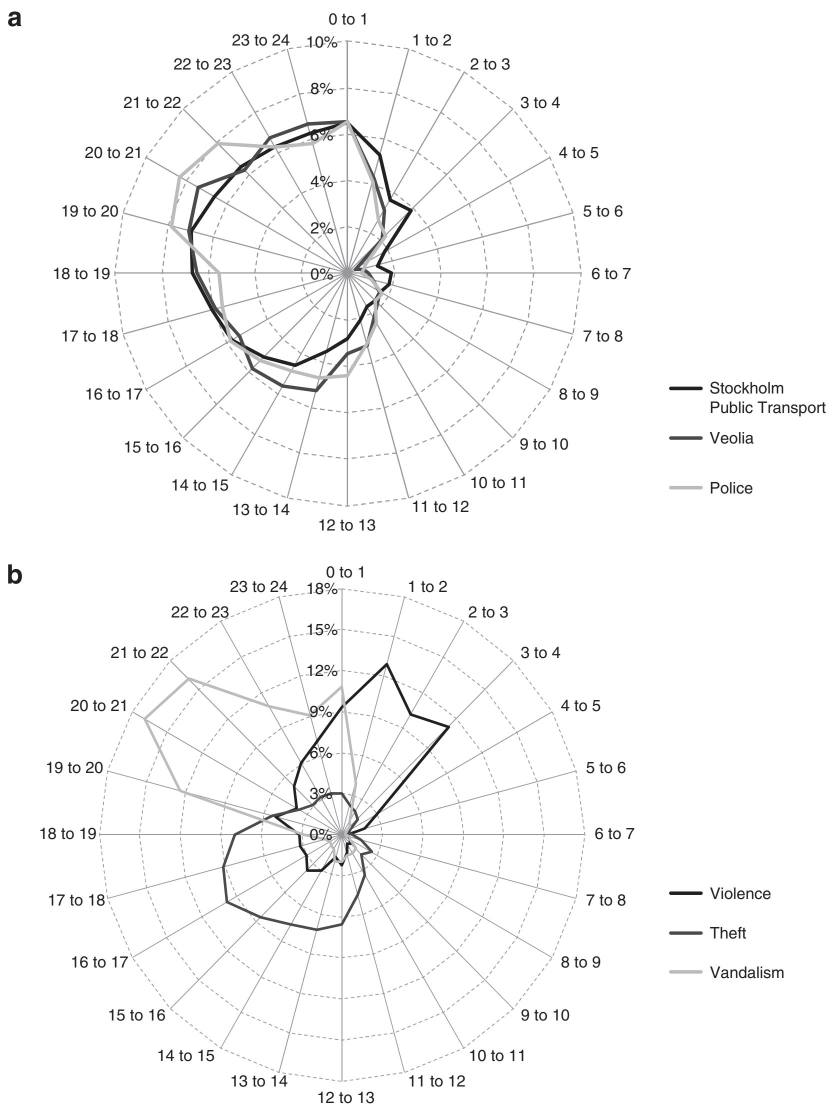


Figure 4: (**a**) Distribution of crime and disorder by hour of the day and data source;
(*Source*: Stockholm Public Transport Database (2006–2009), Veolia (2005–2008) and Police Statistics (2008),
(**b**) distribution of theft, vandalism and violence offences by hour of the day.
(*Source*: Police Statistics (2008).

2. By comparing maps of hot spot areas with the locations of the underground stations, we noticed that high crime rates in underground stations are often associated with hot spots of crime in the surrounding neighbourhoods; however, this relationship is context dependent – it happens either in the city centre or in the periphery of the city. This is clearer for violence than for property offences. Using visual inspection,

we see that as many as 60 per cent of the stations with top violence rates belong to a ‘significant hot spot area’,[2] taking into account the distribution of violence both in space and time. For thefts, 40 per cent of stations with highest rates are also part of Stockholm’s ‘hot spots’ for property crimes. However, note that sometimes areas may show high relative high rates but do not turn out to be a significant hot spot; thus, they are not included in these percentages.

3. The more peripheral a station is, the greater violence rates it tends to have. However, for property crimes, the picture is different. Stations located in more central areas tend to show higher theft rates than stations located in the Stockholm periphery (Figure 5).

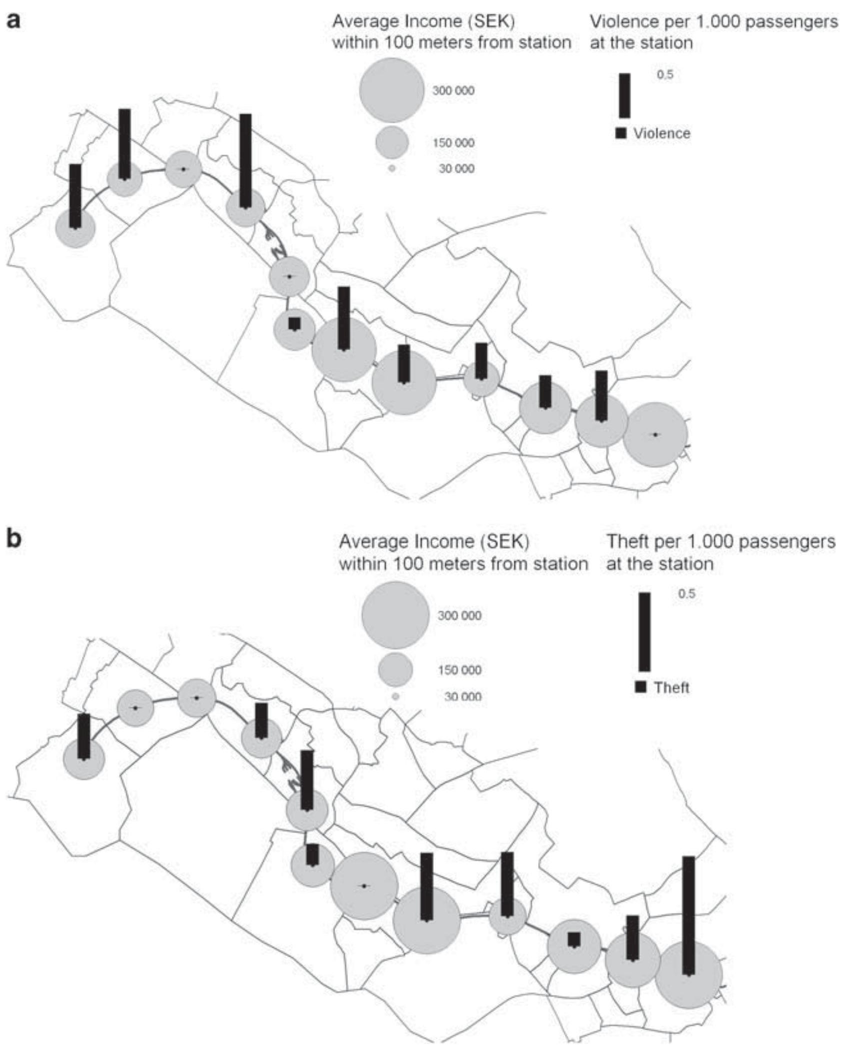


Figure 5: (**a**) Violence and (**b**) theft rates at stations and surrounding income levels.

Modelling Public Disorder and Crime

We now model the crime and public disorder rates in the underground stations using environmental attributes of the stations and demographic, socio-economic, and land-use covariates of the surrounding areas following the conceptual model shown in Figure 1. The purpose is to explain the variation in station-specific rates for various types of offences. The dependent variables in this study are rates for selected offences from data at the station (from Stockholm Public Transport) and within 100 m of the stations (police-registered offences). These 100-m buffer zones were created around the station objects and later used to calculate the total police records assigned to each station. These rates took into account the proportion of the population passing close to the station (daily population) using area interpolation procedures in GIS. The modelling is tested using 82 per cent of the Stockholm underground system, that is, all stations covering the whole Stockholm municipality. As Stockholm Public Transport and Veolia databases show events that happen at the station and they tend to show similar results in the modelling, we are going to report here only the results from the Stockholm Public Transport database. The results from the station's models are then compared with those based on offence rates created around 100 m from each station.

The modelling strategy is composed of three steps. First, using Ordinary Least Square regression (OLS),[3] we modelled offence rates at the station as a function of the environmental attributes of social interactions that happens at platform, lounge, transition area, exits/entrances.[4] Significant variables were selected at 90 per cent level and higher. In Step 2, crime and disorder rates were modelled for each crime type using only significant variables from Step 1. The result was a model for the whole station, type of event and data source. Then, in order to assess the effect of the surroundings, offences rates were modelled as a function of stations' attributes, neighbourhood context and station's relative location in the city in Step 2. Interaction effects were tested for a number of variables such as distance to city centre, and income in combination with other station's variables, but this strategy did not produce meaningful results. Moreover, we performed modelling centre and peripheral stations separately, but results turned out to be poor and limited by the number of stations/variables. Figure 6 illustrates the modelling strategy. The objective of testing several modelling frameworks was to attempt to show a complementary picture of the criminogenic conditions at these transport nodes generated from different modelling scales (at the station and surroundings) and data sources (Stockholm Public Transport database and police records).

We expected that some environmental attributes would become more important to explain crime and disorder rates in the winter than in the summer. As the seasonal variations of light and temperature are notable in Scandinavia, models were tested using a new set of variables during winter, such as illumination, overcrowding and littering in stations.

Results

Step 1

Social and physical environmental attributes of platforms, transition areas and lounges turned out to be more important in explaining the variation in crime and disorder rates at

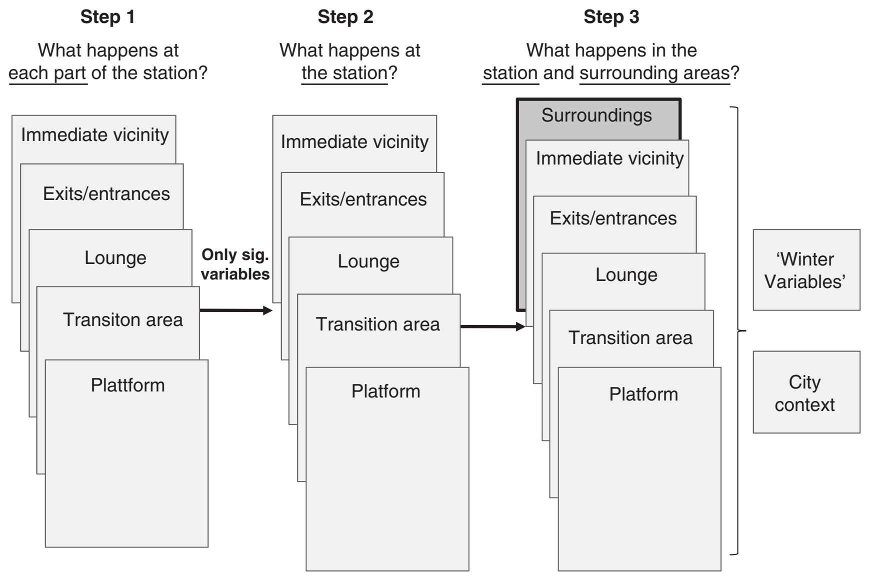


Figure 6: The modelling strategy.

the stations than those conditions found at exits/entrances. Across all parts of the stations, variables indicating barriers to formal and informal social control were related to higher rates of offences. According to the modelling results from Stockholm Public Transport database, high rates of disorder and offences were found on platforms with low guardianship (less crowded), often in stations with multiple platforms or transition areas with poor illumination. In models based on the police records, platforms seem to be less exposed to crime and disorder when CCTVs are present or visible. Lack of illumination in transition areas is often related to high rates of crime and disorder in both sets of models (Stockholm Public Transport data and police data). However, the role of CCTVs is not clear in transition areas, as the variable either does not come out as significant or shows different signs in different models. The presence of cafés in lounge areas tends to generate fewer offences recorded in the Stockholm Public Transport database. However, shops in lounge areas of the stations tend to promote crime, particularly for property offences. The effect of shops and cafés completely disappears in models based on the police data in lounge areas. More important to explain the variation of crime and disorder are indicators of informal social control (lack of benches, few people around, CCTVs and their visibility). The conditions found at exits of the stations and immediate surroundings have less impact on rates of crime and disorder than platforms, lounges and transition areas (fewer variables were significant and they showed contradictory signs depending on crime type).

Step 2

As suggested in Hypothesis 1, there are a number of environmental attributes of the stations that *together* affect crime and public disorder rates. Note that in these models, only significant variables deriving from Step 1 were regressed against crime and disorder rates. Results are discussed below and shown in detail in Table 2. Models based on Stockholm Public Transport database show that overall crime, violence and vandalism tend to be lower in transition areas with good illumination and platforms with many people around. These results are also confirmed by previous evidence found by Harris (1971) and Welsh and Farrington (2007). The number of platforms has the opposite effect. Rates of violence, threat, theft and social disturbance are higher in stations with more platforms, which is an indication that stations are larger, and more central underground stations. The pleasantness of the stations, with fewer observed events of social disturbance (for example, loud speech/kids fooling around) and littering tend to relate to fewer acts of violence, threats, robbery and other minor criminal events.

Models based on police records confirm the importance of formal and informal social control at stations (people around, existence of benches), but also show signs of the importance of other security dimensions. For instance, features that might hinder good visibility and consequently affect surveillance (for example, the presence of physical barriers, significant in half of the models) tend to be associated with higher rates of disorder and crime. Hiding places and existence of corners are significant in models of both violent and property crimes. Similar results were suggested by Gaylord and Galliher (1991), Myhre and Rosso (1996), LaVigne (1997), Loukaitou-Sideris *et al* (2002) and Cozens *et al* (2003). More often in models of the police data than in those based on Stockholm Public Transport's data, the number of CCTVs in the station and their visibility are linked to less crime and disorder (significant in five out of eight models). Table 3 summarises the attributes at the station related to crime and disorder from the two data sources.

The list presented in Table 3 reflects the frequency of the variables, which came out significant in the following models: total crime, violence, theft, vandalism, robbery, burglary and other types of events at the station. We tried to exclude from the table variables that showed different signs for different types of offences. For instance, seating places or benches seemed to reduce robbery but increase public disorder. The number of CCTVs also showed unexpected signs for two offences. For violence and burglary, findings show that having a visible CCTV camera at any part of the station is associated with greater rates when using Stockholm Public Transport database. These results are, however, not confirmed by the model using police records, where the variable for the number of CCTVs shows the expected sign for violence but unexpected for burglary. One of the reasons for this mismatch is that cameras were installed in certain stations in the first place because they were already known as 'problematic' (and may not yet have been effective enough to deter burglary). Similar reasoning can be used about the existence of mirrors as a supporting security device at stations. Contradicting signs for different offences is not new in the literature (see, for example, Webb and Laylock, 1992; Priks, 2009).

Step 3

Variables reflecting the conditions at the stations explain around 30 per cent of the variation of crime and disorder rates; this percentage varies by offence type and reaches its highest at 64 per cent for vandalism when variables indicating the conditions of the neighbourhood and city context were added to the model (Table 2). The addition of these variables

Table 2: Results of the regression analysis: Y=Log of offence rates at stations and surroundings

Database	R^2 *(per cent)*	*At station*	R^2 *(per cent)*	*Station and surroundings*
Crime				
Stockholm Public Transport	31.0	Pcrow***(−), Tillu**(−)	51.9	Pcrow***(−), Tillu***(−), CityD***(+), Cpolis***(−)
Police	39.9	CCTV***(−), Tvis***(+), Tcross***(+), Eesup***(−), Esocd**(−)	51.8	CityD***(+), CExit**(+), CCTV***(−), Lseat**(−), Tvis**(+), Tcross***(+), Eesup**(−), Esocd**(−), Forg**(−)
Violence				
Stockholm Public Transport	26.5	Psecu*(+), Pnum*(+), Tnice***(−)	44.2	Psecu**(+), Pnum***(+), Pcrow**(−), CAtm***(+), CCTV***(+), Cit-yD***(+), Forg**(−)
Police	43.9	Pcorn***(+), Cctv**(−), Lvis**(+), Lillu**(+), Lsur***(−), Lseat*(−) Thid**(+), Tvis*(+), Tcross**(+), Tdetr**(+), Esur***(+)	35.6	Pcorn***(+), Cctv**(−), Lvis*(+), Lillu*(+), Lsur***(−), Thid***(+), Tdetr**(+), Esur***(+)
Robbery				
Stockholm Public Transport	32.4	Pundr***(−), Lsun***(+), Lseat***(−), Lundr*(+), Lsocd ***(+), Tlitt**(+)	20.5	Pundr***(−), Lsun**(+), Lseat***(−)
Police	36.0	Tvis***(+), Thid**(+), Tesup**(+), Telvs***(+), Eopen**(+)	55.7	Ploun**(−), Tvis***(+), Thid***(+), Tesup***(+), Telvs*(+), Tcross**(+), Eopen***(+), CityD***(+), Popd*(+), Villa**(+)
Vandalism				
Stockholm Public Transport	54.6	CExit***(−), Proug*(+), Pcrow***(−), Tillu**(−), Tsur**(+)	64.0	CExit***(−), Proug**(+), Pcove***(+), Ldetr**(+), CityD***(+),Tillu**(−), Pin-out**(−)
Police	41.5	Cctv***(−), Eesup***(−)	41.5	Cctv***(−), Eesup***(−)

* Significant at 10 % level; ** Significant at 5 % level and *** Significant at 1 % level.
(+) positive effect
(–) negative effect
Pcrow=Overall crowded at platform; *Tillu*=Transition areas are well illuminated; *CityD*=Distance from city centre; *CPolis*=Number of police stations within 100 m; CCTV=Number of CCTVs placed at station; *Tvis*=Visibility in transition area; *Tcross*=Cross-sections/junctions/disruptions at transition areas; *Eesup*=Exits have escalator(s) going up; *Esocd*= Presence of social disorder at exits; *CExit*=Number of exits; *Lseat*=Presence of seats/benches at lounges; *Forg*=Percentage of population with foreign background in 2007 within 100 m; *Psecu*=Platform has CCTVs placed visibly; *Pnum*=Number of platforms at stations; *Tnice*=Transition areas have a nice/pleasant atmosphere; *CAtm*=Number of ATMs within 100 m; *Pcorn*=Presence of dark corners at platforms; *Lvis*=Visibility in lounges; *Lillu*=Lounges are well illuminated; *Lsur*=Possibility of surveillance by others in lounges; *Thid*=Presence of hiding places at transition areas; *Tdetr*=Transition areas have presence of physical deterioration; *Esur*=Possibility of surveillance by others at exits; *Pundr*=Platform located underground; *Lsun*=Sunlight easily illuminates lounge; *Lundr*=Lounges located underground; *Lsocd*=Presence of social disorder at lounges; *Tlitt*=Presence of any litter at transition areas; *Tesup*=Transition areas have escalators going up; *Telvs*=Elevator smells/has lot of graffiti in transition areas; *Eopen*=Exit layout is of open type without walls and roof; *Ploun*=Platform visibility towards lounge area; *PopD*=Population density within 100 m; *Villa*=Housing is villas (owned housing); *Tsur*=Possibility of surveillance by others at transition areas; *Pcove*=Platform covered by (rain) shield; *Ldetr*=Lounges have presence of physical deterioration; *Pin-out*=Net population(difference between population moving in and moving out from the area in 2007).

Table 3: Attributes at the station related to crime and disorder

Variables associated with higher crime rates	*Variables associated with lower crime rates*
Few people around at station	Good illumination (transition area)
Objects hindering visibility/surveillance	Less presence of social disturbance
Corners, hiding places	CCTV cameras
Number of platforms	Overall station's pleasantness, littering

Table 4: Attributes at the stations, neighbourhood surroundings and city context

Variables associated with higher crime rates	*Variables associated with lower crime rates*
Few people around at station	Good illumination/visibility
Corners, hiding places	CCTVs cameras
Peripheral stations	Fewer ATMs in the surroundings
Fewer police stations	Lower population density
Fewer residents moving out	Less presence of physical deterioration

improved the model's goodness of fit but not for all offences. Nevertheless, some of the variables reflecting the conditions at the stations hit strongly in Step 3, for instance presence of hiding places/corners, good illumination/visibility and, to some extent, CCTVs.

Confirming findings from the section 'The nature and levels of crime over time and space', stations far from the central area are more often targeted regardless of offence type and model (the variable distance to city centre turned out significant in most of the models) even after controlling for a number of other socio-demographic and economic characteristics in the surrounding areas (Table 4). We cannot therefore corroborate our hypothesis that stations located in inner city areas run a higher risk of all types of offences. Thefts and property crime rates tend to be higher in a couple of inner city stations, but this pattern does not hold for other types of offences.

For total crime and disorder, the goodness of fit of the models is very similar for both Stockholm Public Transport database and police databases. The significant variables are, however, different as the first data set reflects only what happens at the station, whereas the second database covers incidents over 100 m from the stations. Guardianship and illumination explain 30 per cent of the variation of the crime rates from the Stockholm Public Transport database; it goes up to 52 per cent when other variables (number of police stations within 100 m, distance to city centre) and city context are added to the model. The importance of formal control (police station close to the station) has shown a strong effect on crime and disorder as suggested by previous research (Chaiken *et al*, 1974; Brit, 1989), which surprisingly disappears in the model based on the police data.

For violence, R^2 nearly doubles when surrounding variables were added to the model for the Stockholm Public Transport database. For violent rates based on the model from police data, despite poorer goodness of fit, the model shows that more crime and disorder are found where there are more dark corners at platform, more hiding places at transition areas, fewer CCTVs, transition areas with signs of deterioration and poor surveillance in lounge and exit area. For robbery, the situation is inverse; rates based on police data perform much better than the ones from Stockholm Public Transport database. Surrounding variables such as open entrances, distance to city centre, population density and presence of villas are all related to high rates of robberies from police data.

The model based on the Stockholm Public Transport database shows that vandalism rates tend to be related to fewer number of exits (an indication of centrality but also the size of the station), lounge with signs of physical deterioration ('crime attracts crime'), platform covered by rain shield, poor illuminated transition areas and neighbourhoods with people moving out. Not surprisingly, whereas the previous model explained 64 per cent of vandalism rates, the police data explained only 40 per cent, half by variable numbers of CCTVs.

Surprisingly, some of the variables depicting the surrounding areas turned out to be non-significant or to have an unexpected sign. For example, no effect was found for the location of schools or for alcohol-selling premises in the surrounding area or for neighbourhood instability, as suggested in previous literature (for example, Block and Block, 1995; Loukaitou-Sideris *et al*, 2002). In this study, alcohol-selling premises do not include restaurants and pubs, only state alcohol outlets (Systembolag), which may explain our results. Only ATMs show an increasing effect on violence.

We expected that some environmental attributes would become more important to explain crime and disorder rates in the winter than in the summer. As the seasonal variations of light and temperature are notable in Scandinavia, models were tested using a new set of three variables during the winter. Results, however, show that illumination, overcrowding and littering in the winter were not important to explain the variation of station's crime and disorder rates as they may have been in the summer (as the results were in general poorer compared with summer, they are not reported in Table 2). Often, the snow, gravel and dirt in public environments change the tolerance level for litter and garbage on the floor in the dark months of the year, something that would not pass unnoticed in the summer. This may also suggest that the threshold for what is good and poor illumination changes over time, affecting an offender's perception of opportunity and consequently the decision to commit a crime.

Conclusions and Recommendations

Underground stations are criminogenic places, but certain stations are more often targeted by acts of crime and disorder than others. In this study, we set out to understand why the vulnerability to crime varies over space and time, using the Stockholm underground system as a case study. We first discussed the nature, levels and patterns of crime and disorder in these transport nodes over time and space. We then assessed the importance of environmental attributes of underground stations and surroundings to explain the variation in rates of crime and disorder of these environments.

Findings show that a relatively large share of reported events, regardless of data source, is composed of events of public disorder (unlawful activities or anti-social behaviour). Typical examples are cases of drunken people on platforms or unjustified use of fire hoses or fire extinguishers. The majority of recorded crimes at the station are fights, vandalism and threats, followed by reports of other types of violence. Property crimes are more often recorded by police official statistics than by databases of Stockholm Public Transport and Veolia. As suggested in Hypothesis 1, there are clear temporal and spatial variations of both crime and events of public disorder. They tend to happen more often in the evenings/nights, during holidays and weekends and, at least for thefts in the hot months of the year.

Stations and their surrounding areas are criminogenic places: 62 per cent of police-reported offences take place up to 500 m radius from an underground station (which is only a third of the municipality's area). This environment is highly criminogenic because it is composed of mixed land use (for example, pubs, restaurants, transport nodes) and because nearly one-third of the stations are located in the inner city areas of Stockholm, where crime rates tend to be greater than in surrounding areas.

The central station concentrate the highest number of events in Stockholm but it does not keep its top position after events are standardised by daily passenger flow (the only exception is for theft). This finding gives legitimacy to standardisation of crime events by passenger flow – a procedure that has not yet been tested in the current literature. The Stockholm underground system shows that a map of crime counts by station reveals a monocentric geography around the city centre, whereas a map of rates of offences by station (standardised by passengers) shows an entirely different geography: more dispersed and peripheral. This finding has a major impact for policy intervention as we may be 'chasing ghosts'[5] if passenger flows are not taken into account. However, although rates are better indicators than counts, they are not problem free. A couple of stations show relatively high rates because the flow of passengers is low (for example, Skärmabrink station) or the opposite; they show low rate because of large passenger flow (for example, Tekniska högskolan station). These cases constitute not more than five cases out of a hundred stations and are not peripheral, which would therefore not affect the conclusions drawn in this article. We take the view that if a station has a poor flow of people (in relation to the number of events), this can *per se* be regarded a criminogenic factor that makes the station more vulnerable to crime (because of lack of guardianship) than others.

The variable 'distance to city centre' is significant in nearly all models and indicates that when passenger flow is taken into account, 'end-stations' show higher rates of events (crime and public disorder) than stations located in the inner city areas (exceptions are Medborgaplatsen, Skanstull and T-centralen for thefts, for instance). The 'end stations' such as Hjulsta, Farsta Strand and Hagsätra show high rates regardless of crime type. Some of these peripheral stations are located in places that, although planned as part of the neighbourhood, do not easily allow guardianship and natural surveillance from outside. They are usually close to a motorway or are, to some extent, cut off from surrounding land uses by forests, lanes, far from people's movements, which potentially could be the 'eyes on the stations'.[6] Alternatively, if they are closely connected with the rest of the neighbourhood, they tend to be part of criminogenic environments, such as a shopping area with mixed land uses. These regional centres have an underground station as a landmark, readily identifiable places that serve as external reference points and concentrate external temporary population in one place. These dynamics produce routine activities that are more criminogenic than elsewhere.

Population density and housing mobility also show an effect on crime and disorder rates at the stations but unexpectedly not demographic and socio-economic characteristics of the population close to the stations. The significance of these variables lends weight to the suggested hypotheses derived from social disorganisation theory.

This study corroborates the hypothesis that a combination of social and physical attributes at a station, together with surrounding and city context, affects crime at the station.

The attributes that affect crime and disorder may vary by offence type and data source. However, some attributes at the station constantly appear to be important to explain events at the station and surroundings, such as the presence of corners and hiding places, and poor illumination, particularly in transition areas. Although there was strong evidence in the literature about the impact of stations' exits/entrances on crime events, our models do not corroborate such results; only the number of entrances seems to have some effect on crime and disorder. In the case of Stockholm, social and physical characteristics of platforms and lounges tend to be more important in the models than exits. These findings flag for evidence in favour of theories that claim a link between environment features and crime causation, such as defensible space, rational choice and routine activity theories. Data permitting, future research should link crime rates by different sections of stations (platform, transition areas, lounges and exits) to their specific physical and social characteristics.

Findings of this study have policy implications at least for local and regional planning authorities. The most important message from the study is that security in underground stations is a function not only of the local conditions, but also the surroundings in which these transport nodes are located. This means that security in underground stations should be tackled by authorities that aim to safeguard passengers' security, having a 'whole journey approach'. The effort cannot be put in practice without cooperation from those responsible for security for the wagons, for station premises and for the surrounding environs where people walk to and from transport nodes. Surveys show that most passengers feel safe in the wagon and at the station's environments, but their perceived security levels decrease as they walk to/from the stations (Stockholm Transport Survey, 2009). Actions should also be based on all stations of the underground system, which means that security interventions will be dependent to some extent on how well municipalities in Stockholm County can cooperate to make surrounding areas safer. Although they may not have the power to make structural changes that affect the long-term socio-economic context of these stations (for example, population density, housing mobility, police patrol in the neighbourhood), this analysis offers a number of indications of how some specific environmental aspects (design and land use of stations) may be reconsidered to better promote security at underground stations. Findings support improvements in visibility and surveillance opportunities (avoiding corners, hiding places, few people around, illumination) but also suggest control of broken-windows indicators (littering, social disturbance, overall station's pleasantness) at stations.

There is also a need for specific targeting of particular stations and at certain 'time windows'. For instance, for violence, the time window for intervention should be between 22:00 and 02:00, for property crimes the whole afternoon from mid-day to 19:00, and for vandalism between 19:00 and 22:00. Peripheral stations are more often targeted by crime and disorder than central stations (except for thefts). Security interventions must be defined as a function of crime type. For vandalism, for instance, particular graffiti, it can be helpful in investing vandal-resistant materials but also providing alternatives, such as places for legal graffiti elsewhere in the city. Finally, previous research shows that poor accessibility at underground premises makes the travel of women and less mobile individuals less comfortable and consequently less safe. More research is needed to identify stations in Stockholm that are more problematic from this point of view. More elevators for easy access of the underground station while having to carry objects, strollers or young children should be investigated.

We believe that the results from this study can contribute to the current research on relationships between crime and disorder events in transport nodes by providing empirical evidence from underground stations in a Scandinavian capital. The analysis also combines different data sources, often complementary, to provide a comprehensive picture of what happens at stations and in surrounding areas. The study makes use of events per passenger flow, instead of counts only. However, the study shares limitations with other analyses of this type, namely reliance on data of events reported either by personnel or by the victim, which implies different issues regarding data quality. Data recorded by personnel tend to reflect particular targeted actions that may bias the 'real' distribution of events at the stations (more events of a certain type to the detriment of others). This includes particular programmes against activities that take place at the station, which are perceived as disturbing for passengers, resulting in the end, in more records. For instance, more than half of all records of acts of public disorder are composed of people using station premises to sleep or showing signs of drunkenness – a category that has increased over time, perhaps indicating that the tolerance for these events in public spaces is now lower than it was in the past. On the other hand, acts of public disorder rarely reach police statistics as victims tend to report an event to the police only when they themselves feel victimised, which rarely includes vandalism and disorder. Another limitation is that the modelling section is based on data for underground stations within the boundaries of Stockholm city only (82 per cent of all stations). This does not affect results for the Green line, but potentially impacts on the ends of the Red and Blue lines. With the whole transport underground system, one of the main challenges of future studies is to better understand why end stations are more targeted by crime and disorder than other stations, particularly for violence. Future analysis should also take into account how other aspects of the city's geography and the presence of different geographical barriers, such as a lake, a river or a park, are also influential in defining regional patterns of offences. These regional criminogenic conditions indirectly affect the security conditions at an underground station for example, providing hiding places, as well escaping opportunities for motivated offenders at the stations.

This study links environmental features of each part of the stations (platform, transition areas, lounge and exit) to their overall rates. Data permitting, future analysis should consider linking the place of the event to each particular section of the station. One way to produce the data is by having access to the so-called 'free-text' (unavailable for this study), with details of each event. As it is now, it is not always possible to attach the exact place of the event at the station to specific internal features of these settings. It is equally important to separate out car-related crimes from other property offences, as these are likely to be dictated by whether or not stations have parking facilities. Moreover, the modelling strategy adopted here has proven to produce meaningful results, but future attempts to model crime and disorder rates could instead test the use of composites or indexes to reflect more general conditions at the stations and in surrounding areas. Instead of using the individual variables broken down by sections of the stations, aggregated variables could be tested as overall indicators for, for instance, good/poor visibility or formal and informal social control. Another, perhaps more appropriate strategy is multi-level modelling. This would better capture the nested nature of the conceptual model with stations nested in neighbourhoods, which in their turn are nested within larger socio-demographic areas.

When interpreting these findings, we must bear in mind that the analysis is based on offences data only. Our findings lend weight to principles of traditional urban criminology theory such as routine activity and social disorganisation, but also on the impact of environmental features on our behaviour. Future studies should consider how different types of people passing the stations (by crime propensity and by risk of being victimised) become affected by these environments. Situational Action Theory can help further the analysis of the role of the social environment in crime causation (Wikström *et al*, 2010, p. 56). More specific descriptions of these environmental attributes, particularly their temporal circumstances for both offenders and victims, will most likely identify which stations prove even more criminogenic for certain types of people. Environmental attributes of stations and surroundings can also be linked to passengers' levels of fear, during the trip, at transition nodes and on the way to/from them. The link between stations' surroundings and fear of crime must be better understood. We see this study as only an initial step to identifying what makes underground stations vulnerable to crime and disorder.

Acknowledgements

We thank the Swedish Transport Administration (Traffikverket), Stockholm Public Transport (SL) and Stockholm municipality for financing this research project. We also thank Ulla Wittrock (Police in Stockholm County), Stefan Liljevall (Stockholm Statistics), Mats Pergel (SL) and Peter Assor (Veolia) for providing data for the analysis.

Notes

1 In November 2010, stations were revisited on the evening/weekend to get a better idea of specific features, such as illumination.
2 Hot spots maps were produced using Kulldorff's scan test (SaTScan version 9.01; Kulldorff, 2010) and police-recorded data across Stockholm city. This technique has a rigorous inference theory for identifying statistically significant clusters (Kulldorff, 1997). The space–time scan statistics were used in a single retrospective analysis using data from 1 January 2006 to 31 December 2009. A 4-year data set was collapsed into 'one year'. All space and time dimensions of the data are kept (by day and location) except 'year'.
3 Statistical Package for the Social Sciences, Version 17.0 (2010), but virtually any other statistical package can be used for this purpose.
4 We employed Pearson's correlation for all independent variables in the five sets of covariates before Step 1 to identify variables that potentially contribute with similar information to the models. The histograms of the dependent variables showed skilled distribution. Thus, rates of crime and disorder were transformed into their natural logarithms.
5 This term was first suggested in urban criminology by Ratcliffe and McCullagh (2001), referring to mismatch between crime hot spots and police perception of high-crime areas.
6 Paraphrasing the known 'Eyes on the street' by Jane Jacobs (1961) in the book *The Death and Life of Great American Cities*, in which she suggested that people witnessing what happens in the streets reduces crime.

References

Alm, C. and Lindberg, E. (2004) *Betydelsen av upplevda risker och känslor av otrygghet vid resor med kollektivtrafik: En undersökning i Göteborg samt jämförelse med resultat från Norrköping och Stockholm*. Linköping: VTI meddelande 919.Statens väg- och transportforskningsinstitut.

Armitage, R. (2002) To CCTV or not to CCTV? A review of current research into the effectiveness of CCTV systems in reducing crime. NACRO Crime and Social Policy Newsletter, May.

Barker, M., Geraghty, J., Webb, B. and Key, T. (1993) The Prevention of Street Robbery. Police Research Group. London: Home Office Police Department. Crime Prevention Unit Series Paper no. 44.

Block, R.L. and Block, C.R. (1995) Space, place, and crime: Hot-spot areas and hot places of liquor-related crime. In: J.E. Eck and D. Weisburd (eds.) *Crime and Place*. Monsey, NY: Criminal Justice Press.

Brantingham, P. and Brantingham, P. (1993) Nodes, paths and edges: Considerations on the complexity of crime and the physical environment. *Journal of Environmental Psychology* 13(1): 3–28.

Brantingham, P. and Brantingham, P. (1995) Criminality of place: Crime generators and crime attractors. *European Journal on Criminal Policy and Research* 3(3): 1–26.

Brit, J. (1989) Crime prevention that works the care of public transport in the Netherlands. *British Journal of Criminology* 29(1): 47–56.

Brown, B. (1995) CCTV in Town Centres: Three Case Studies. Police Research Group Crime Detection and Prevention. London: HMSO. Series Paper 68.

Bursik, R.J. (1988) Social disorganization and theories of crime and delinquency: Problems and prospects. *Criminoligy* 26: 519–552.

Ceccato, V. (2009) Crime in a city in transition: The case of Tallinn, Estonia. *Urban Studies* 46(8): 1593–1610.

Ceccato, V. and Haining, R. (2004) Crime in border regions: The Scandinavian case of Öresund, 1998–2001. *Annals of the Association of American Geographers* 94(4): 807–826.

Ceccato, V., Haining, R. and Signoretta, P. (2002) Exploring offence statistics in Stockholm city using spatial analysis tools. *Annals of the Association of American Geographers* 22(3): 29–51.

Chaiken, J.M., Lawless, M.W. and Stevenson, K.A. (1974) *Impact of Police on Crime: Robberies on the New York City Subway System*. New York: R-1424-NYC, the New York City Rand Institute.

Cheatwood, D. (2008) Is there a season for homicide? *Criminology* 26(2): 287–306.

Church, A., Frost, M. and Sullivan, K. (2000) Transport and social exclusion in London. *Transport Policy* 7(3): 195–205.

Clarke, R.V. (1997) *Situational Crime Prevention – Successful Case Studies*, 92nd edn. New York: Harrow and Heston.

Clarke, R.V. and Felson, M. (eds.) (1993) Routine activity and rational choice. In: *Advances in Criminological Theory*, Vol. 5. New Brunswick, NJ: Transaction Books.

Cohen, L.E. and Felson, M. (1979) Social change and crime rate trends: A routine activity approach. *American Sociological Review* 44(August): 588–608.

Cozens, P., Neale, R., Whitaker, J. and Hillier, D. (2003) Managing crime and the fear of crime at railway stations – A case study in South Wales (UK). *International Journal of Transport Management* 1(3): 121–132.

Easteal, P. and Wilson, P. (1991) *Preventing Crime on Transport: Rail, Buses, Taxis, and Planes*. Canberra: Australian Institute of Criminology.

Felson, M. (2006) *Crime and Nature*. Thousand Oaks, CA: Sage publication.

Gaylord, M.S. and Galliher, J.F. (1991) Riding the underground dragon: Crime control and public order on Hong Kong's mass transit railway. *British Journal of Criminology* 31(1): 15–26.

Harris, O. (1971) A Methodology for Developing Security Design Criteria for Subway, Washington DC. Urban mass transit administration, Report no.: UMTA-URT- 5 (70)-71–4.

Hirschfield, A.F.G., Brown, P.J.B. and Bowers, K.J. (1995) Exploring relations between crime and disadvantage on Merseyside. *European Journal on Criminal Policy and Research* 3(3): 93–112.

Ihlanfeldt, K.R. (2003) Rail transit and neighbourhood crime: The case of Atlanta, Georgia. *Southern Economic Journal* 70(2): 273–294.

Jacobs, J. (1961) *The Death and Life of Great American Cities*. New York: Vintage Books.

Jochelson, R. (1997) *Crime and Place: An Analysis of Assaults and Robberies in Inner Sydney, General Report Series*. Sydney: NSW Bureau of Crime Statistics and Research.

Kinney, J.B., Brantingham, P.L., Wuschke, K., Kirk, M.G. and Brantingham, P.J. (2008) Crime attractors, generators and detractors: Land use and urban crime opportunities. *Built Environment* 34(1): 62–74.

Kornhauser, R. (1978) *Social Sources of Delinquency*. Chicago, IL: University of Chicago Press.

Kulldorff, M.A. (1997) A spatial scan statistic. *Communications in Statistics: Theory and Methods* 26(6): 1481–1496.

Kulldorff, M.A. (2010) SaTScan™. User Guide for version 9.0, http://www.satscan.org/techdoc.html, accessed 15 November 2011.

LaVigne, N.G. (1997) *Visibility and Vigilance: Metro's Situational Approach to Preventing Subway Crime*. National Institute of Justice–Research in Brief. U.S. Department of Justice, https://www.ncjrs.gov/txtfiles/166372.txt, accessed 15 November 2011.

Loukaitou-Sideris, A. (1999) Hot spots of bus stop crime: The importance of environmental attributes. *Journal of the American Planning Association* 65(4): 395–411.

Loukaitou-Sideris, A. (2012) Safe on the move: The importance of the built environment. In: V. Veccato (ed.) *The Urban Fabric of Crime and Fear*. Dordrecht, The Netherlands: Springer, pp. 85–110.

Loukaitou-Sideris, A., Ligget, R. and Iseki, H. (2001) Measuring the effects of built environment on bus stop crime. *Environment and Planning B: Planning and Design* 28(2): 255–280.

Loukaitou-Sideris, A., Liggett, R. and Iseki, H. (2002) The geography of transit crime: Documentation and evaluation of crime *incidence on and around Green Line Stations in Los Angeles*. *Journal of Planning Education and Research* 22(2): 135–151.

Morenoff, J.D., Sampson, R.J. and Raudenbush, S.W. (2001) Neighborhood inequality, collective efficacy, and the spatial dynamics of homicide. *Criminology* 39(3): 517–560.

Myhre, M. and Rosso, F. (1996) Designing for security in Meteor: A projected new metro line in Paris. In: R.V. Clarke (ed.) *Preventing Mass Transit Crime: Crime Prevention Studies*, Vol. 6. Monsey, NY: Willow Tree Press, pp. 199–216.

Newman, O. (1972) *Defensible Space: Crime Prevention Through Urban Design*. New York: Macmillan.

Newton, A. (2004) Crime on public transport: 'Static' and 'non-static' (moving) crime events. *Western Criminology Review* 5(3): 25–42.

Newton, A. and Bowers, K. (2007) The geography of bus shelter damage: The influence of crime, neighbourhood characteristics and land-use. *Internet Journal of Criminology*, http://www.internetjournalofcriminology.com.

Newton, A., Johnson, S.D. and Bowers, K. (2004) Crime on bus routes: An evaluation of a safer travel initiative. *International Journal of Police Strategies & Management* 27(3): 302–319.

Pearlstein, A. and Wachs, M. (1982) Crime in public transit systems: An environmental design perspective. *Transportation* 11(3): 277–297.

Pease, K. (1999) *A Review of Street Lighting Evaluation: Crime Reduction Effects*. Huddersfield, UK: University of Huddersfield Press.

Poyner, B. and Webb, B. (1993) What works in crime prevention: An overview of evaluations. In: R.V. Clarke (ed.) *Crime Prevention Studies*, Vol. 1. Monsey, NY: Criminal Justice Press.

Priks, M. (2009) *The Effect of Surveillance Cameras on Crime: Evidence from the Stockholm Subway*. Stockholm: Department of Economics Stockholm University.

Ramsey, N. and Newton, R. (1991) *The Influence of Street Lighting on Crime and Fear of Crime* (Crime Prevention Unit Paper 29). London, UK: Home Office.

Ratcliffe, J.H. and McCullagh, M.J. (2001) Chasing ghosts? Police perception of high crime areas. *British Journal of Criminology* 41(2): 330–341.

Reynald, D.M. and Elffers, H. (2009) The future of Newman's defensible space theory. *European Journal of Criminology* 6(1): 25–46.

Sampson, R.J. and Raudenbush, S.W. (1999) Systematic social observation of public spaces: A new look at disorder in urban neighborhoods. *American Journal of Sociology* 105(3): 603–651.

Sampson, R.J., Raudenbush, S.W. and Earls, F. (1997) Neighborhoods and violent crime: A multilevel study of collective efficacy. *Science* 277(5328): 918–924.

Shaw, C.R. and McKay, H.D. (1942) *Juvenile Delinquency and Urban Areas*. Chicago, IL: University of Chicago Press.

Sherman, L.W., Gartin, P.R. and Buerger, M.E. (1989) Hot spots of predatory crime: Routine activities and the criminology of place. *Criminology* 27(1): 27–56.

Short, E. and Ditton, J. (1996) *Does Closed Circuit Television Prevent Crime? An Evaluation of the Use of CCTV Surveillance in Aidrie Town Centre*. Scottish Office Central Research Unit, http://hdl.handle.net/10068/535511, accessed 15 November 2011.

Sloan-Howitt, M. and Kelling, G. (1990) Subway graffiti in New York city: 'Gettin' Up' vs. Meanin' it and cleanin' it. *Security Journal* 1(3): 131–136.

Smith, J. (2003) The Nature of Personal Robbery. London: Home Office. Research Study no. 254.

Smith, M.J. and Clarke, R.V. (2000) Crime and public transport. In: R. Clarke (ed.) *Crime and Justice: A Review of Research*. Chicago, IL: The University of Chicago Press, pp. 169–234.

Stangeby, I. and Nossum, Å. (2004) *Trygg kollektivtransport: Trafikanters opplevelse av kollektivreiser og tiltak for å øke tryggheten*, Oslo: Transport ekonomisk institut, http://www.toi.no/getfile.php/Publikasjoner/T%D8I%20rapporter/2004/704a-2004/704a-2004-el.pdf, accessed 11 October 2011.

Stockholm Public Transport. (2006) Storstockholms Lokaltrafik. Stockholm Public Transport's Annual Report, 2007-06-21, p. 17.

Stockholm Public Transport. (2009) Stockholm Public Transport Safety Survey. Stockholm (unpublished).

Squires, P. (1998) *An Evaluation of Ilford Town Centre CCTV Scheme*. Brighton, UK: Health and Social Policy Research Centre, University of Brighton.

Tilley, N. (1993) Understanding Car Parks, Crime and CCTV: Evaluation Lessons from Safer Cities. London: HMSO. Crime Prevention Unit Series Paper 42.

Webb, B. and Laylock, G. (1992) Reducing Crime on the London Underground: An Evaluation of Three Pilot Projects. London: Home Office Police Department. Crime Prevention Unit Paper no. 30.

Welsh, B. and Farrington, D. (2002) Crime Prevention Effects of Closed Circuit Television: A Systematic Review. London: Home Office. Home Office Research Study 252.

Welsh, B.C. and Farrington, D. (2007) *Improved Street Lighting and Crime Prevention*, Stockholm, Sweden: Swedish Council for Crime Prevention, http://www.bra.se/extra/faq/?module_instance=2&action_question_show.435.0.=1, accessed 15 November 2011.

Wikström, P.O. (1991) *Urban Crime, Criminals, and Victims: The Swedish Experience in an Anglo-American Comparative Perspective*. Stockholm: Springer-Verlag.

Wikström , P.O., Ceccato, V., Hardie, B. and Treiber, K. (2010) Activity fields and the dynamics of crime: Advancing knowledge about the role of the environment in crime causation. *Journal of Quantitative Criminology* 26(1): 55–87.

Wilson, J.Q. and Kelling, G. (1982) The police and neighbourhood safety: Broken windows. *Atlantic Monthly* 249(3): 29–38.

Yu, S.V. (2009) *Bus Stops and Crime: Do Bus Stops Increase Crime Opportunities in Local Neighbourhoods?* PhD dissertation at School-Newark Rutgers University: The State University of New Jersey, Newark, New Jersey.

Appendix A

Figure A1: The Stockholm underground system. — Red; — Green; — Blue.
Source: AB Storstockholms Lokaltrafik, 2011.

Appendix B

Table B1: The data set of study: variables from fieldwork and surroundings

Variables				
Platform	*Lounge*	*Transition area*	*Exit*	*Surrounding area*
PBlock, PCorn, PCove, PCrow, PDetr, PDist, PDrnk, PFenc, PGuar, PHid, PIllu, PLevl, PLitt, PLoun, PMirr, PNice, PNum, POpen, PRoug, PSeat, PSecu, PSocd, PSun, PSur, PUndr, PVend, PView, PVis, PWait, PWall, WIllu, WCrow	LAtm, LCafe, LCorn, LCrow, LDetr, LDist, LDrnk, Lelvs, LGate, LGuar, LHid, LIllu, LLitt, LMirr, LNice, LOpen, LPhon, LPhot, LPlat, LRest, LRoug, LSeat, LSecu, LShop, LSocd, LStor, LSun, LSur, LTick, LUndr, LVend, LView, LVis, LWind, WSocd, WLitt	TCorn, TCross, TCrow, TDetr, TDist, TDrnk, TElv, TElvs, TEsdw, TEsup, TGuar, THid, TIllu, TLevl, TLitt, TMirr, TNice, TPram, TRroug, TSeat, TSecu, TSocd, TStep, TStor, TStrs, TSun, TSur, TView, TVis, TWalk	ECorn, ECrow, EDetr, EDist, EDrnk, EEsdw, EEsup, EGuar, EHid, EIllu, ELitt, EOpen, ERoug, ESeat, ESecu, ESocd, EStep, EStrs, ESun, ESur, EView, EVis, EWalk.	SAtm, SBar, SBike, SBuss, SClose, SComm, SConn, SDrnk, SEvnt, SFenc, SGraf, SGree, SGuar, SHome, SLitt, SMall, SMeet, SOpen, SOuts, SPeds, SPlay, SPoli, SRecr, SResi, SRest, SRoad, SShop, SSkol, SSoci, SStreet, SSysb, STtaxi, SToil, STrans, Swall AVInc, CityD, Forg, P in-Out, PopD, Villa, YMal, CAtm, CCTV, CExit

P=PLATFORM, L=LOUNGE, T=TRANSITION AREA, E=EXIT AREA, S=SURROUNDING AREA, W=WINTER (variable's situation in Winter).

Notes: *Atm*=Presence of ATM inside the station; *AVInc*=Average Income (SEK/year) in 2006; *Bar*=Presence of bar(s); *Bike*=Bike lanes; *Block*=Many structures (objects) blocking view; *Buss*= Station is close to bus stops; *Cafe*=Presence of cafes; *CAtm*=Number of ATMs within 100 m; *CCTV*=Number of CCTVs placed at a station; *CExit*=Number of exits; *Close*= Station is a closed type (enclosed station); *CityD*=Distance from city centre; *Comm*=Station is connected with commercial area; *Conn*=Connection to other trains; *Corn*=Presence of dark corners; *Cove*=The place is covered by (rain) shield; *Cross*=Presence of cross-sections/junctions/disruptions of one station by another station; *Crow*=Overall crowded at the station (low (0–5), med (6–10), high (+=11)); *Detr*=Any other physical deterioration at the place; *Dist*=Presence of social disturbance (loud speech/kids fooling around); *Drnk*=Presence of drunk or homeless; *Drnk*=People drinking in public (only for surrounding area); *Elve*=Presence of any elevator; *Elvs*=Elevator smells/has lot of graffiti; *Esdw*=Escalator(s) going down; *Esup*=Escalator(s) going up; *Evnt*=Presence of event location/cinema/sports arena; *Fenc*=Use of fencing; *Fenc*=Surroundings of station is fenced off (only for surrounding area); *Forg*=Population with foreign background in 2007 within 100 m; *Gate*=Type of gates available at lounges (old=1, new=2, mix=3); *Graf*=Presence of any graffiti in surroundings (only for surrounding area); *Gree*=Station is surrounded by closed green area (low visibility); *Guar*=Presence of private guards; *Hid*=Hiding places; *Home*=Presence of homeless; *Illu*=Sufficient/effective illumination; *Levl*=Number of levels of station; *Litt*=Presence of any litter; *Loun*=Lounge is easily visible; *Mall*=Presence of shopping mall; *Meet*=Station is connected with square/meeting place (many people); *Mirr*=Presence of mirrors; *Nice*=The place has nice/pleasant atmosphere; *Num*=Number of platforms at station; *Open*=The place layout is open type without walls and roof; *Open*=Open layout of station in surroundings (only for surrounding area); *Outs*=Presence of pawn/eating out shops; *Peds*=Pedestrian paths; *Phon*=Presence of any phone; *Phot*=Presence of photo booth; *P in-out*=Net population (difference between population moving in and moving out from the area in 2007); *Plat*=Platform is easily visible; *Play*=Presence of recreational parks within a visible range; *Polis*=Number of police stations within 100 m; *PopD*=Population density; *Pram*=Track available for pram; *Recr*=Presence of car parks; *Resi*=Station is connected with residential area; *Rest*=Presence of rest room; *Rest*=Presence of restaurant (only for surrounding area); *Road*=Close to motorways/big roads (low surveillance); *Roug*=The area (partly) built of rough material; *Seat*=Presence of seats/benches; *Secu*=CCTVs are placed and visible; *Shop*=Presence of shops; *Shop*=Shops/cafes(only for surrounding area); *Skol*=Number of school within 100 m; *Socd*=Presence of social disorder; *Soci*=Presence of 'social help care'; *Step*=Size of stairs; *Stor*=Space used as storage for stuff; *Street*=On-street parking; *Strs*=Presence of any stairs; *Sun*=Sunlight easily illuminates the covered places; *Sur*=Possibility of surveillance by others; *Sysb*=Number of alcohol-selling premises within 100 m; *Taxi*=Close to taxi stops; *Tick*=Presence of more than one operated ticket booth (per lounge); *Toil*=Public toilet; *Trans*=Station is connected with transition area/low flow of people; *Undr*=Located underground; *Vend*=Vending machines; *View*=Clear view from outside; *Villa*=Housing is Villas (owned housing); *Vis*=Everything is visible at the place; *Wait*=Presence of waiting room; *Walk*=Long walking distance; *Wall*=Walls between two areas; *Wall*=Station is walled off (only for surrounding area); *Wind*=Open windows; *YMal*=Population comprises young men (aged 15–30 years).

Assessing guardianship opportunities at underground stations

Adriaan Cornelis Uittenbogaard

CEFIN-Architecture and the Built Environment

Royal Institute of Technology

Drottning Kristinas väg 30, Stockholm, Sweden

acui@kth.se

ABSTRACT Research has provided plenty of evidence of how crime is influenced by guardianship – people's capacity to affect crime. The aim of this article is to examine whether these opportunities for guardianship are in turn affected by the social and physical environments at underground stations. Stockholm, the capital of Sweden is used as a case study. Guardianship here constitutes two dependent variables, indicated by *visibility* and *surveillance*. The analysis combines data from fieldwork with secondary land use and socio-economic data as independent variables in a set of logistic regression models. After controlling for endogeneity, findings show that guardianship opportunities are affected by the flow of passengers, presence of security guards, good sightlines and tools for surveillance, e.g., mirrors. Nonetheless, the impact varies by different sections of the station. The article concludes by presenting how guardianship opportunities can be promoted as a means of reducing crime and disorder at transport nodes.

Key words: safety, transport nodes, social control, surveillance, GIS, Stockholm.

1. Introduction

The international literature is rich with examples of how guardianship affects crime and safety (Hollis-Peel et al, 2011, provide an extensive review; see also e.g., Painter and Tilley, 1999, on surveillance in public space; Reynald, 2011b, on property crime in neighbourhoods; and Pennell et al, 1985, on types of guardianship). In transport nodes, such as bus stops or underground stations, the potential of exercising guardianship has also shown to impact crime and perceived safety (e.g. Cozens et al, 2003; Loukaitou-Sideris, 1999; Loukaitou-Sideris et al, 2002; Smith and Clarke, 2000; Block and Davis, 1996). In Stockholm, Ceccato et al (2013) showed that possibilities for surveillance and visibility, in other words, opportunities for guardianship, explain a large portion of the variation in crime rates. Whilst their study showed how the environment relates to opportunities for crime at underground stations, it did not show how opportunities for guardianship are affected by the station's environment. Thus, there are still a number of questions about the role of the environment in promoting opportunities for guardianship.

Guardianship was originally defined as a crucial part of routine activity theory (Cohen and Felson, 1979) and includes any person or object that is able to supervise or simply watch other people or objects at any given point in time and at any place which may force offenders to refrain from committing a crime (Felson and Cohen, 1980). From a victimization perspective, guardianship may create a 'layer of protection' for individuals and targets in which a particular setting may form that would not occur otherwise, possibly deflecting the offender.

The objective of this article is to assess the opportunities for guardianship as provided by the characteristics of the environment at underground stations. In this study, overviews (layout), blocked sightlines (obstacles), out-of-sight places (corners), surveillance tools (CCTV cameras), illumination and potential guardians (security guards, passengers) are assessed by their potential to promote guardianship, that is, to make it easier for individuals to watch, supervise and intervene if anything happens. This study contributes to the current field of research by advancing the knowledge of crime prevention and the importance of guardianship at public transportation nodes. The study uses the Stockholm underground system as case study as it constitutes an interesting addition to current research, most of which is based on cities in North America and the United Kingdom.

The article has the following structure. A description is provided of the background theories informing the study, after which the aim and hypotheses are presented. Then, the case study and data are described, followed by the methodology and the results of the analyses. The article rounds off with a discussion of the results, and the conclusions and suggestions on the topic of guardianship opportunities at transport nodes.

2. Theory on guardianship

This section reviews earlier studies on the concept of guardianship in public places, the environment at public transport nodes and the relationship between crime occurrence and urban design.

2.1 Guardians and guardianship

The concept of guardianship has been around for some time, yet possibly under different denominations. *Social disorganization theory*, for instance, calls it "social control" (Shaw and McKay, 1942); *routine activity theory* suggests "suitable guardians" as a key component for safety (Cohen and Felson, 1979); Jacobs (1961) worded it as "eyes on the street"; and there are certainly other references to be found in the literature. Whilst these concepts are not completely equivalent to the term "guardianship", in that they may all serve different aims and explanations, they all, nevertheless like guardianship, link to a similar, more general topic: *control*. Social disorganization theory advocates that decreases in crime levels can be achieved by means of local social ties, which link to creating guidance and acceptance for informal rules within communities, which then control the acts of crime internally (Shaw and McKay, 1942). Routine activity theory regards opportunities for crime as being defined by the amount of control which is exercised over a place, stating that crime decreases if more formal (as well as informal) control is exercised by guardians (Cohen and Felson, 1979). Another example of control is Jacob’s “eyes on the street”; the informal watchmen keep an eye on what is happening and act as guardians of the place with a “controlling view” and responsibility that may result in lower crime levels (Jacobs, 1961).

The concept of guardianship has since then been refined and made operational so as to be more easily integrated into crime prevention schemes (e.g. Clarke, 1995). Recent theories of guardianship include “handlers” (looking over the offender), “place managers” (controlling the place) and “supervisors” (looking over the target) (Eck, 1994; Reynald, 2011a; Hollis-Peel et al, 2011). Guardianship can take many forms and can be performed by different types of persons or facilitated by objects. Guardians are those persons that can execute the role of guardianship (Reynald, 2011a). Even when an individual does not intend to play a guarding role, such a role can be performed without intention, for instance, through the mere presence of that person (Hollis-Peel et al, 2011). Further, guardianship may also be the capacity and the willingness to monitor (Reynald, 2011a), including knowledge of and familiarity with the environment, and issues of responsibility in relation to that environment. Persons may feel more willing to intervene if they feel responsible for the space, when they are familiar with the place and/or person, and if the environment makes intervention easy. Moreover, their willingness also depends on self-risk assessments and confidence: in order to intervene after detection of criminal behaviour, one’s own safety risks have to be considered low, which depends on training, the seriousness of the crime, physical abilities, etc. (Reynald, 2011a).

This article does not intend to address either the capacity of guardians or levels of guardianship; it rather focuses on the environment's role in promoting guardianship. Reynald (2011a) points out the importance of (natural) surveillance being part of defensible space principles in residential areas which provides possibilities to see what is happening outside. Visibility is closely related to this as it defines the extent to which a guardian can survey a place (Reynald, 2011a). On the other hand, visibility also defines the extent to which the guardian is visible. If visibility is poor, the offender will not notice the guardian and be discouraged from committing the crime (Reynald, 2011a). Moreover, if surveillance opportunities are good, this may increase the possible guardian's feeling of responsibility and willingness to act (Reynald, 2011a).

In the literature on guardianship and urban crime, the focus has mainly been on levels of active guardianship and guardianship opportunities within residential areas. Recent research in the Netherlands has assessed the capabilities and the role of residents in guarding against property crimes (Reynald, 2011b). In the study, Reynald (2011b) found that property crime decreases in street segments where the intensity of possible, active guardianship is higher. The intensity of guardianship in residential areas was influenced by the area's physical attributes of the street environment, particularly accessibility and surveillance possibilities, its socio-economic status, and its location (Reynald and Elffers, 2009). There remains however a need to extend the understanding of guardianship in other settings, such as at transportation nodes.

2.2 Guardianship at transportation nodes

Few studies have looked into guardianship possibilities in public spaces, such as underground stations. The safety of a public place is usually seen to by security guards and police. However, the major difference between public spaces and (semi) private places (like neighbourhoods) is that people generally feel less committed to guard a public place (Hollis-Peel et al, 2011; Hope, 1999). There is a difference in the role of different actors exercising guardianship in a public place (Eck, 1994). Handlers, place managers and supervisors control different levels of the environment (from the place to the individual) by different types of control (from active to passive control) (Eck, 1994). Active formal control may thus be viewed as having the primary responsibility for the place; yet, other actors play an equally important role in supervising a place. The general public can play a larger role in securing a public place even when official security guards are not around. At transportation nodes, the dynamics of different actors are strongly related to their actions and responsibilities towards crime prevention, however these roles and responsibilities are often ill-defined in the areas (public spaces) surrounding transport nodes (Ceccato, 2013). Compared to residential areas, public transport nodes may be located in a complex mixture of land uses which may affect guardianship opportunities (Reynald and Elffers, 2009; Reynald, 2011a).

Transport nodes present dynamic places that concentrate a variety of different people, some potential victims, others motivated offenders, whilst others may act as guardians – passengers, shop owners, employees, drivers, tourists, residents, guards, etc. There is a mix of handlers, managers, supervisors, and passers-by, creating a large potential for guardianship by formal and informal means (Figure 1).

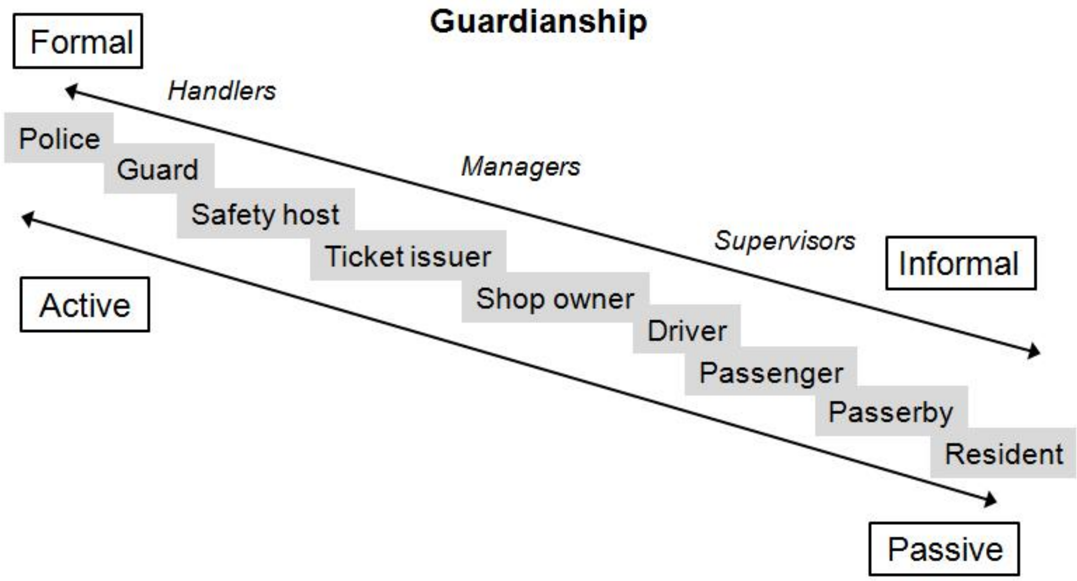


Figure 1 – Forms of potential guardianship at underground stations by key actors.

Moreover, transport nodes are often places with a complex layout over several levels, with tunnels, or with multiple entrances, affecting the possibility of guardianship. Opportunities for guardianship are conveyed through the environment and the opportunities that it provides (Reynald and Elffers, 2009). As in Newman's (1972) *defensible space theory*, places can be planned, adjusted, and improved in such a way as to optimize control and decrease opportunities for crime. Newman (1972) suggested that visibility can be enhanced to create direct and indirect social control, and that open layouts provide opportunities for the control and surveillance of a place. Underground stations often have varying layouts providing different opportunities for guardianship. These opportunities can be poor when the layout of a station includes many corners, blocking walls, and obstacles.

Potential guardians rely on the environmental state to provide them with good opportunities for guardianship. One aspect of guardianship, visibility, is strongly related to the physical environment, while the other aspect of guardianship, surveillance, depends both on the physical environment and the social environment. Both may be perceived differently by different types of guardians.

Visibility

This study approaches ‘visibility’ as the possibilities a person has for observing other others, others’ belongings and objects elsewhere. The environment may determine the possibilities for visibility in the way that sightlines, overviews, transparent screens, etc., will increase the opportunities for someone to be able to detect and notice other persons in the vicinity (Figure 2a). However, if many objects are in the way and block the view, e.g. many pillars, the possibilities for visibility may decrease drastically because it will be more difficult for a person to notice other persons or objects (Figure 2b).

Visibility possibilities may also relate to the use of certain security tools. For instance, well-placed mirrors can increase visibility by providing the possibility to see what is around the corner. However, the effectiveness of such tools can be compromised by for instance, the presence of many people in a section of the station. In a crowded place visibility may be poor; one may not be able to distinguish between different people at the same time despite of available security tools.

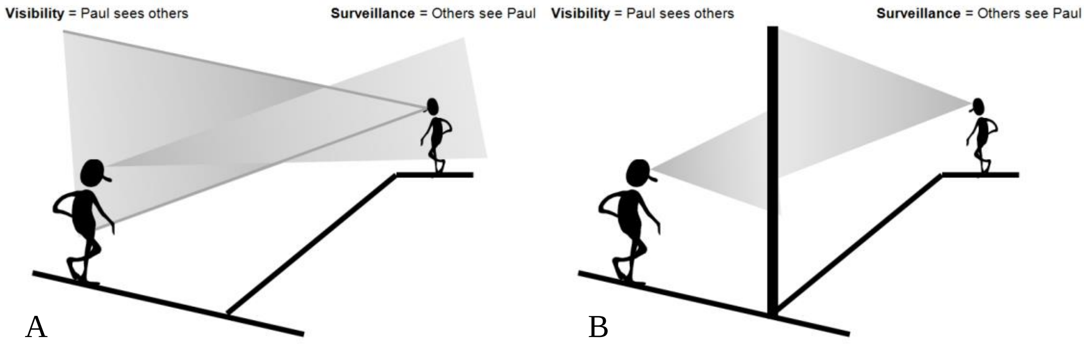


Figure 2 – (a) The environment promotes surveillance and visibility opportunities; (b) The environment restricts possibilities for surveillance and visibility.

Surveillance

'Surveillance', on the other hand, relates to the possibilities for others to observe a person, object, or place. Surveillance possibilities may increase when a section is free of obstacles or pillars and provides a good overview because that makes a person visible (Figure 2a). On the other hand, if corners exist and the section consists of several levels, others will be less likely to notice a person and/or detect abnormal behaviour (Figure 2b).

Surveillance can be increased in areas with by installing tools for guardianship such as CCTV cameras. CCTV may be able to see a person when other persons in the same place cannot. While crowdedness can provide good possibilities for surveillance as many possible guardians are present, it may also lower the opportunity for surveillance via CCTV as it may decrease the overview.

3. Hypotheses of the study

The analysis of this article is based on a conceptual model based on the understanding that safe underground stations (low crime) present good guardianship opportunities, and vice versa, which consist of one’s capacity to exercise informal and formal control, which in turn is influenced by the environment. This study examines the opportunities for guardianship and the environment at transportation nodes as follows:

Hypothesis 1 – The potential for guardianship is affected by different environmental attributes at underground stations. Stations that exhibit poor layout (e.g. closed spaces, poor sightlines/overviews) and crime-prone features (e.g. hiding places, dark corners) provide fewer possibilities for surveillance and visibility.

Hypothesis 2 – Environmental attributes affect guardianship opportunities differently in different places. For instance, corners may have a strong impact on guardianship opportunities in exit areas while not at platforms. On the other hand, crowdedness may be an important factor at platforms while not in exit areas.

Hypotheses 3 – Guardianship opportunities are a function of the conditions in which the stations are embedded. The environment of surrounding neighbourhoods plays a role in determining guardianship opportunities at stations: neighbourhoods with high population density, a busy square, housing, walking and bike lanes, can positively affect the potential for guardianship. Aboveground stations are potentially much more exposed to surrounding surveillance opportunities than belowground stations, thereby presenting better guardianship opportunities.

4. The case study

The study area is composed of underground stations in Stockholm municipality. The municipality has a population of around 900,000 inhabitants (Stockholm Stad, 2013). The city consists of several islands with an integrated public transport system, including underground, trams, commuter trains and busses, which provide inhabitants with effective city-wide communication reaching to adjacent municipalities.

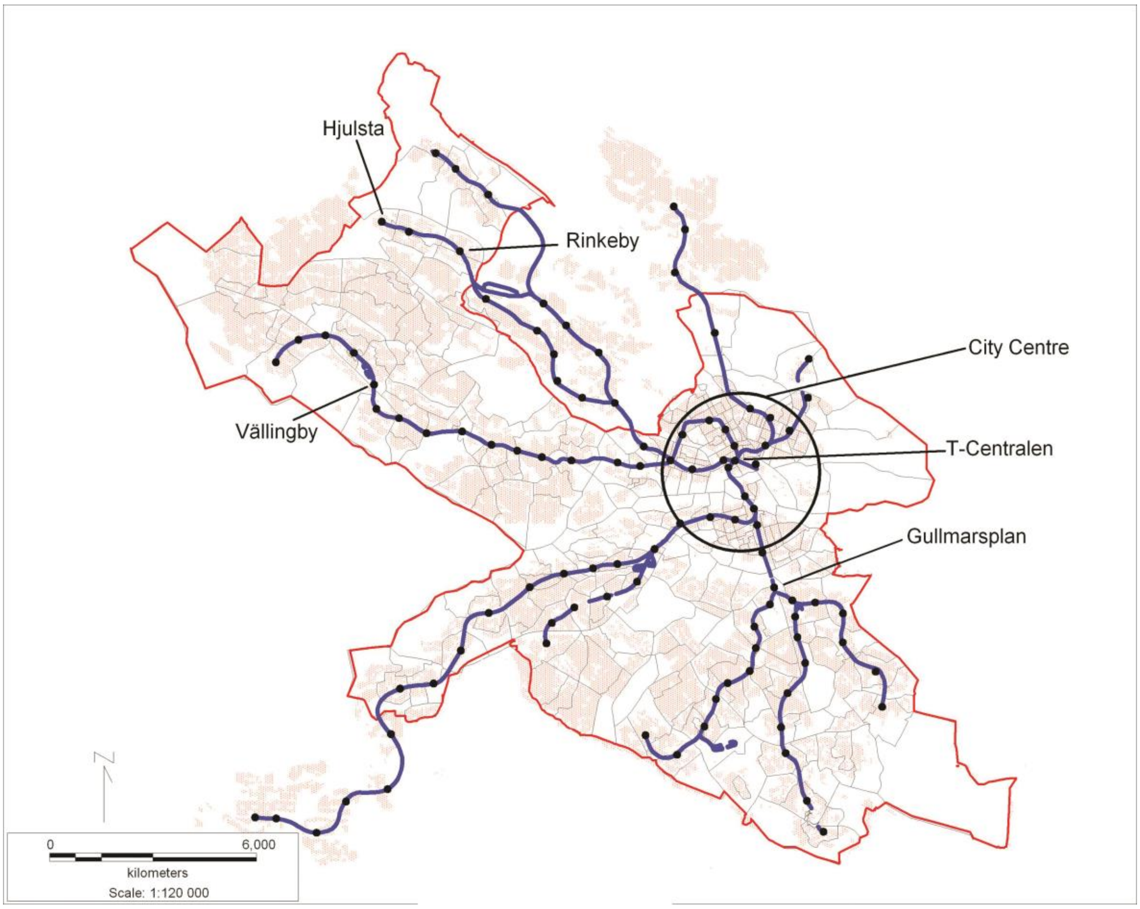


Figure 3 – The study area and underground system with stations.

The underground system (Figure 3) has 100 stations distributed over three lines (green, red and blue) that in total transport around 1.2 million passengers per day. The main node in the system is Central Station (T-Centralen), which receives around 236,000 passengers daily and is located in the Central Business District (Stockholm Public Transportation SL, 2012). Due to the lack of background data from surrounding municipalities, the study area is composed of the underground stations within Stockholm's boundary (Figure 3), which covers 82 % of all stations.

4.1 Data

During the fieldwork performed in 2010, all the underground stations were visited by two researchers in order to 'inspect' the stations' environments. The time spent at each station varied between 40 minutes and one hour. The first fieldwork round was executed during the summer; stations were visited between 10am and 4pm in order to avoid rush hours and get a 'clean' observation of a 'normal' day. Scaled-down revisits during the winter in the afternoon/evenings (4pm to midnight) showed the impact of the colder and darker season on the environment. During the visits, a list of possible environmental attributes, such as corners, cameras, illumination, etc., was checked for (based on previous studies, literature and theories), and afterwards these results were combined into a comprehensive database covering the environmental attributes, socio-economic aspects, and crime and disorder levels at all stations.

The environmental attributes were inventoried using "yes/no" or "high/medium/low" scales, providing a measure of the (level of) presence of each attribute (Table 1). Variables reflecting the immediate surroundings of the underground stations were assessed within a radius of about 25 meters from the exits of the stations, representing the field of view. These variables cover the land use of, activities occurring in, and the layout of the surrounding space, and were inventoried during fieldwork visits. For a more detailed description of the fieldwork, checklists, and database, see Ceccato et al (2013).

	Attribute (abr)	Control model	Scale	Description of variable
Dependent variables	Surveillance (Sur)	-	h/m/l	The possibility to be seen by others. High, with a clean view and everybody would be able see the observer. Low, when few to nobody would be able to see the observer.
	Visibility (Vis)	-	h/m/l	The possibility to see others. High, when observer was able see everybody. Low, when the observer was able to only notice a few people or nobody.
Independent variables	Crowdedness (crow)	yes	h/m/l	Section was crowded or not, basically up to 10 people was assessed as low, high was 30+ people.
	Illumination (illu)	no	y/n	Section well enough illuminated so that the whole place was lighted up.
	Dark corners (corn)	no	y/n	Dark corners present in the section
	Hiding spots (hide)	no	y/n	Hiding spots present in the section
	Object blocking the view (blok)	no	y/n	Objects were obstructing a clean view of the section
	Overview (view)	no	y/n	Section provided a clear, good overview
	Security guards (guar)	yes	y/n	Security guards present at the section
	CCTV visible (secu)	yes	y/n	CCTV cameras positioned in a way they were easily visible and recognizable in the section.
	Mirrors (mirr)	yes	y/n	Mirrors located in the section
	Open layout (open)	no	y/n	Section had an open layout with easy view to all sides
	Shop/Café (shop/café)	yes	y/n	A shop located in the section (mainly in the lounge and exit/entrance areas)
	Windows (wind)	yes	y/n	See-through windows located in the section
	Underground (under)	yes	y/n	Section located subterranean
	Long walking distance (walk)	yes	y/n	A long way to walk between sections
	Levels (lvl)	yes	y/n	Section consisted of several levels
	Number of CCTVs (CCTVno)	yes	count	Number of CCTVs in place at the station, SL data
	Passenger flow (Pax)	yes	count	Number of passengers going in and out of the station per day, SL data

Table 1 – Environmental attributes inspected at stations

5. Method

Logistic regression models were used for the analysis (Appendix A). Surveillance and visibility were set as the dependent variables (guardianship) while environmental attributes were the independent variables (Table 1): overview, open area, dark corners, blocking objects, hiding places, windows, subterranean location, crowdedness, presence of guards, illumination, presence of CCTV cameras, mirrors, shops, cafes, passenger flows, consisting of several floors/levels, long walking distance from the entrance to the lounge area, and surrounding residential area, public square, biking and walking paths, and taxi stands (Appendix A).

The two dependent variables were assessed through researchers' observations of the visibility and surveillance possibilities at the station (Table 1). This type of assessment opens up for causal loops between the dependent and independent variables (endogeneity). In order to control for this potential problem, a 'control model' was tested (Appendix B). This control model uses the same structure and steps as the original model illustrated in Figure 5, but excludes potential endogenous variables which relate to the layout of the sections (illumination, corners, hiding places, overview, open layout and obstructions).

This analysis is based on a model with continuous and ordinal data (Table 1 and Appendix A), suggesting the use of logistic regression, which, unlike OLS regression, can handle variables of different natures (Burns and Burns, 2009). The dependent variables were assessed as a three-level rating scale during the fieldwork. Although argued to be ordinal by some, rating scales can also be approximated as intervals (Norman, 2010). An interval approximation makes it possible to classify them as binary, which is required for dependent variables in logistic regression. The reclassification of both 'surveillance' and 'visibility' variables was based on the mean, where 0 (below mean) and 1 (above mean) represent low/poor and high/good opportunities for guardianship, respectively. A low level of opportunity means a poor possibility to see or be seen by others, and a high level opportunity provides a good chance to be seen or see others (Figure 4).

Figure 4 – (a) poor possibilities for surveillance/visibility at Blackeberg station; (b) good possibilities for surveillance/visibility at Hässelby Strand station.

The modelling follows several steps as shown in Figure 5. First, each section of the station was assessed separately (see 'Model 1' in Figure 5): platform, transition, lounge, exits/entrances. For each section, the dependent variables ('Sur' and 'Vis') are associated with the attributes of that section only, e.g. 'PSur' and 'PVis' are associated with the attributes of the platform (P) (Appendix A). The significant attributes from each individual section provided the basis to analyse the total station (see 'Model 1' Step 2 in Figure 5). For the total station, 'guardianship opportunities' are defined using the average of all the individual sections of a station (e.g. sum of surveillance in each section / 4 = avg. surveillance); here also using the mean for the total station to classify the binary dependent variables: 'average surveillance' and 'average visibility'.

Independent variables were not averaged because then it would only be possible to draw general conclusions for the whole station.

The second set of models assesses the impact of the immediate surroundings and characteristics of the neighbourhood on guardianship (Appendix A). The final step ('Step 4' in Figure 5) includes the significant attributes of Model 1 ('Step 2' in Figure 5) and significant attributes of the neighbourhood ('Step 3' in Figure 5). The surrounding environmental attributes may be particularly important for open stations, which can be viewed and "controlled" from outside. Because the Stockholm system includes stations located aboveground and subterranean, a selective model using only stations with aboveground platforms was tested in order to assess the potential difference between stations above and below ground.

Before running the models, all independent variables were checked for correlations. One of each highly correlated variable pairs (Pearson value > 0.6) was eliminated beforehand. For instance, the stations' 'open layout' is correlated with the 'view from outside' (0.733). The dependent variables were also subject to a correlation analysis but did not show any statistically significant (Pearson value > 0.6) correlation.

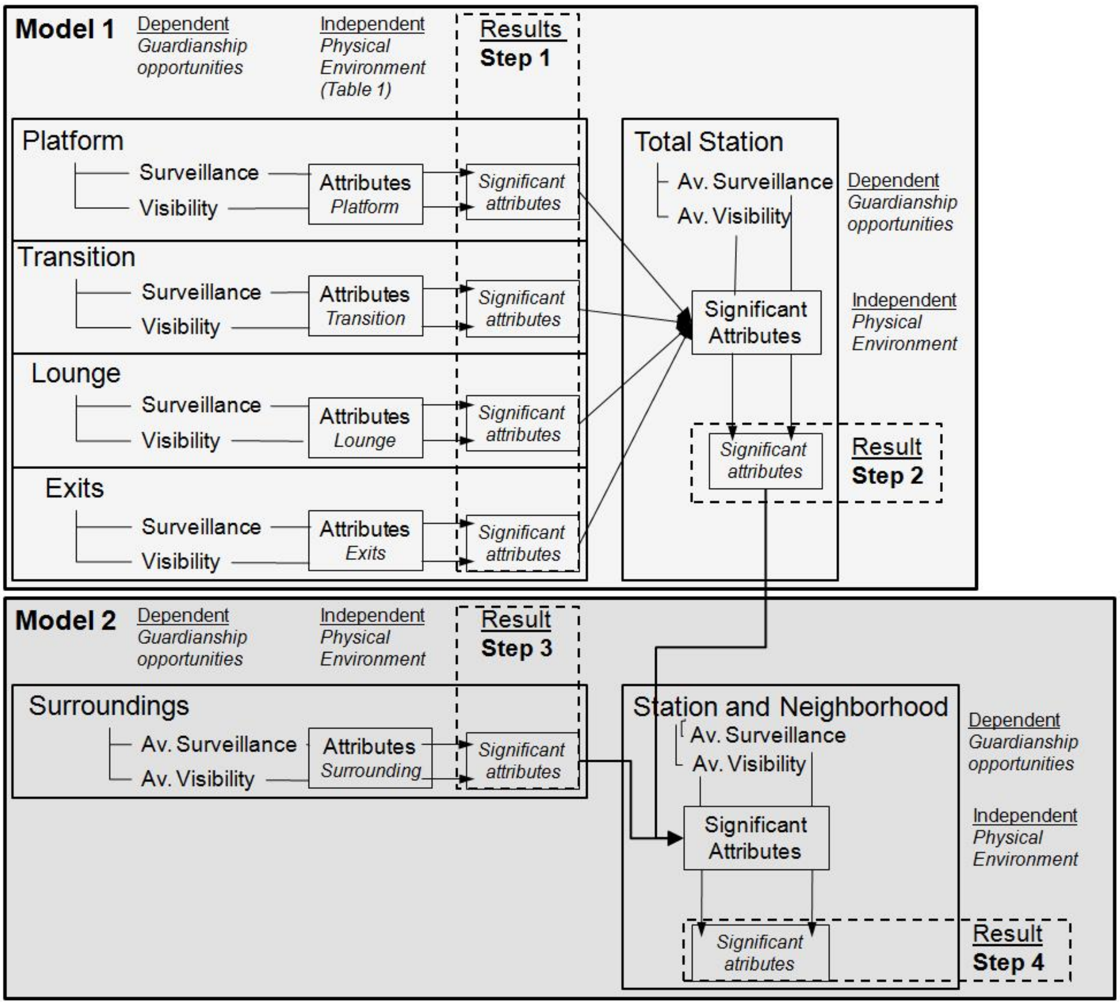


Figure 5 – Stepwise regression modelling; presenting results for separate parts of the stations (Step 1), total station (Step 2), stations surroundings (Step 3) and overall assessment (Step 4).

6. Results

Findings show that around 50 percent of the variation in guardianship opportunities (as indicated by Nagelkerke R-square ‘NR^2’ in the models) is explained by aspects related to the stations’ overviews and sightlines (Table 2). The most significant attributes in Table 2, Model 1, illustrate that opportunities for guardianship improve as surveillance opportunities improve, e.g. in open lounge areas, transition areas and exits with few corners. A good overview of the exit areas also provides better opportunities for guardianship. A less-crowded platform and fewer hiding corners in the lounge area increase guardianship opportunities because, as expected, visibility is better. Unexpectedly, stations that have many CCTV cameras installed exhibit a negative relationship to environments that provide good opportunities for guardianship.

Since there was a suspicion that some covariates, e.g. overview and layout, 'were contained' within the dependent variables (visibility and surveillance), a few variables were excluded from the models (Appendix B) but the new results were similar to the original models' results. When controlling for endogeneity (Appendix B), the 'number of CCTV cameras' is no longer significant. It can therefore be said that the potential effect of endogenous variables has little influence on the results for individual aspects in this case but the possible endogenous variables do contribute to explaining the overall variances for both surveillance and visibility (Table 2). For instance, surveillance possibilities at platforms are positively affected by an open layout (*'view'*), but an open layout does not contribute to explaining visibility possibilities at platforms (Table 2). The presence of an open layout may not affect visibility, as even if one can see others it does not mean that others can see you directly.

Guardianship Model 1

	Platform	Transition	Lounge	Exits	Total Station
Surveillance	NR^2 = 47,4 +View*** -Crowded** +PassFlow*	NR^2 = 59,5 -Illumination* -Corners* -Hidings* +View** +Mirrors** +Crowded**	NR^2 = 46,0 -ViewPlatform** +Open* +View* -Underground* -CCTV*	NR^2 = 68,0 -Corners** +View***	NR^2 = 56,9 *n=16* -TCorners* +LOpen* -ECorners*** +EView** -CCTV*
Visibility	NR^2 = 65,8 -Corners** -Blocking* -Crowded** +PassFlow*	NR^2 = 53,1	NR^2 = 31,7 -Hidings*** +Guards**	NR^2 = 61,2 -Corners** +Open** +View** +SecuVis** +Crowded*	NR^2 = 57,1 *n=11* -PCrowded* -Lhide** +ESecuVis*

				+PassFlow*	

Guardianship Model 2

	Total Station (Model 1)	Surroundings	Station & Neighborhood
Surveillance	*NR^2 = 56,9* *-TCorners** *+LOpen** *-ECorners**** *+EView*** *-CCTV**	NR^2 = 15,8	NR^2 = 46,3 *n=5* -TCorners** +LOpen* -ECorners*** +EView**
Visibility	*NR^2 = 57,1* *-PCrowded** *-Lhide*** *+ESecuVis**	NR^2 = 40,6 +Bike* +PassFlow**	NR^2 = 51,1 *n=5* -PCrowded* -LHidings** +ESecuVis***

Significance: * 10% level (.05), ** %5 level (.01), *** 1% level (.005)

Table 2 – Results of the logistic regression model; guardianship opportunities = influence of environmental design aspects. (***Note:*** *NR^2*=Nagelkerke R-square, +, **-** = resp. positive, negative relationship between dependent and independent variables).

6.1 Guardianship in different sections of the stations

The environmental attributes of platform, transition, and lounge areas are the most important in explaining the variance in guardianship opportunities. At the *platforms*, where passengers await the arrival of their train, opportunities for guardianship can provide possibilities to detect suspicious activities and protect people subject to possible offences. Guardianship opportunities relate to variables that explain the visibility at the platform: the possibility to engage in surveillance, and the presence of guardians. The opportunities for guardianship significantly increase when surveillance opportunities increase, through the presence of good overviews of the platform (Table 2). More dark corners and objects blocking the view decrease guardianship opportunities. Guardianship opportunities decrease when the platforms are more crowded, which may also have a negative influence on possible overviews and the ability to detect suspicious activities. On the other hand, better guardianship opportunities are partly explained by larger passenger flows, which may provide more possible guardians and ‘eyes on the platform’.

In the *transition areas*, may constitute stairs, escalators, elevators, several corners, and dark, invisible spaces. Here, guardianship opportunities are related to the availability of sightlines and views as well as the use of surveillance tools such as CCTV. Guardianship opportunities are strongly related to attributes explaining variances in surveillance possibilities (Table 2), e.g. opportunities for guardianship increase with better overviews of the transition area, as well as with the presence of mirrors and more people.

In the *lounge area,* passengers are often waiting to continue to the platform a few minutes before the train arrives; here guardianship opportunities are also explained by variables representing the vulnerability of the passengers. The results (Table 2) show that a connection to other parts of the station is important for guardianship opportunities. Opportunities for guardianship improve with better possibilities for surveillance, such as those provided by an open layout and good overview, and lounge areas that are not located underground. Surprisingly, the presence of CCTV is negatively related to guardianship possibilities. This may have to do with the fact that more CCTV cameras can be found at larger stations, often accommodating a more complex layout and with several lounge areas. Furthermore, guardianship opportunities are suggested to be higher in lounge areas where the view to the platform is poorer; this may prove that a clearly delineated space increases awareness of the lounge area which increases opportunities for exercising guardianship in this section. Strongly influencing opportunities for guardianship are also the presence of hiding spots in the lounge area: more hiding places reduce the opportunities. Also, the presence of formal guards in the lounge area contributes positively to the opportunities for guardianship, the guards themselves being a guardian and able to notice and act upon suspicious activities.

The *exits and entrances* of stations are places where passengers just pass by, and do not usually stop. Here guardianship opportunities relate to the flows of people and possible guardians present, but also the opportunities for guardianship in the surroundings. Table 2 shows that guardianship opportunities in the exit areas increase as the overview of the place increases. Areas with few corners and a good overview and open layout strongly increase the possibilities for guardianship.

6.2 Guardianship and the environment surrounding underground stations

The findings show that the attributes of surrounding environment of the station, including the presence of a busy square, biking and walking paths, residential surroundings, and taxi stands, seem to only decrease the significant effect of the stations' environment on guardianship opportunities. First, only the presence of bike paths near a station and passenger flows showed an effect on the possibility of guardianship (Table 2). Secondly, the stations located above ground did not show increased relationships between the surrounding environmental aspects and guardianship opportunities at the stations (Table 3). This could corroborate the thought that neighbourhood aspects mainly highlight the levels of guardianship in the neighbourhood, rather than helping in providing opportunities for guardianship at a transport node (Reynald, 2011a).

Guardianship Model 2 (aboveground)

	Total Station (Model 1)	Surroundings	Station & Neighborhood
Surveillance	*NR^2 = 56,9* *-TCorners** *+LOpen** *-ECorners**** *+EView*** *-CCTV**	NR^2 = 27,8	NR^2 = 24,7 *n=4* -ECorners*
Visibility	*NR^2 = 57,1* *-PCrowded** *-Lhide*** *+ESecuVis**	NR^2 = 46,6 +Bike*	NR^2 = 36,5 *n=5* -LHidings* +ESecuVis*

Significance: * 10% level (.05), ** %5 level (.01), *** 1% level (.005)

Table 3– Results of the logistic regression model using only stations with platforms aboveground: Guardianship opportunities = influence of environmental design aspects. **(*Note:*** *NR^2*=Nagelkerke R-square, +, **-** = resp. positive, negative relationship between dependent and independent variables).

7. Conclusions and looking ahead

This study's objective was to analyse if aspects of the environment can affect guardianship opportunities in underground stations, an under-researched area. Findings show that the environment does affect the opportunities for visibility and the capacity to exercise surveillance. The results from the modelling show that half of the variation in guardianship opportunities at stations was explained by environmental factors in general. Moreover, they confirm the second hypothesis that different aspects played a role in different places, such as the presence of people at platforms and transition areas, security guards in the lounge area, good sightlines and overviews at the platform and exit areas, and tools for surveillance (like mirrors and CCTV cameras) in the less crowded transition and exit areas.

Contrary to what was stated in the third hypothesis, the importance of the station's surrounding environment did not contribute as expected in explaining guardianship opportunities at underground stations. This may suggest that guardianship is a rather local action in micro-scale environments. It may also relate to the different responsibilities guardians perceive to have in different places, e.g., security guards inside versus outside stations. A point for further investigation can be to focus on the nature of guardianship, at the station and in the neighbourhood, and potential relationships between them.

What are the implications of these findings?

Firstly, the environment of transport nodes should provide as good overviews/open sightlines as possible, in particularly at platforms. Sightlines can be improved by having see-through structures and low-height objects. Objects hindering the view should be kept to a minimum. Corners should be rethought in terms of overall impact on visibility and surveillance. The possibilities for visibility, in particular, need to be improved at underground stations in areas which are desolated or less crowded, such as transition and lounge areas, in order to create better opportunities for guardianship.

Secondly, tools that help create better opportunities for guardianship (e.g., mirrors) should be better planned and, when necessary, tested and (re)located to locales that directly facilitate surveillance and visibility. These tools provide additional abilities besides human sight and presence and can be extra helpful for guardians to control larger, complex places, sometimes with several floors, such as transport nodes.

Finally, in order to increase opportunities for guardianship, individuals need to be in place, either consciously (security guards, safety hosts, place managers) or circumstantially (passengers, passers-by). At underground stations, it is positive when more people are around as they may provide informal control (although in other sections, overcrowded areas may decrease guardianship opportunities as the advantage of overview is diminished by the crowd). Providing spaces that are noticeably formally watched or supervised (via cameras or guards) and increasing the pleasantness of the section may attract passengers to wait in areas which were previously uncomfortable, desolated and unsupervised.

These findings suggest the need for a more thorough investigation of the role of the environment on people's movement at transport nodes. An analysis of the movement of passengers at the stations can provide an idea for the best possible routes of guardians, where they should be present.

One has to keep in mind that altering the environment, if at all possible, is not easy, particularly in well-consolidated, central areas. Nevertheless, opportunities for guardianship can be improved by enhancing the current state of the environment, as it has been suggested here.

A limitation of this study has been the nature of the fieldwork data. As with any observational technique, subjective judgment may lead to differences of opinion by the observers (the data was collected by two researchers). Another drawback was that visibility could be subject to the researcher's subjective assessment of the available view. Surveillance was more difficult to assess as the researcher cannot stand in the shoes of both the other and the possible target. Moreover, there was no standard definition from the literature on how one can assess guardianship and opportunities for guardianship in transit environments (and guidelines from previous research on neighbourhoods are not suitable for the environment of underground stations). Better definitions and observational procedures should be developed to distinguish between opportunities of surveillance and visibility. In terms of analysis, possible causal relationships between environmental variables are difficult to disentangle. Although, as the ‘control model’ showed, at least for the whole station, the results are strengthened via showing that the same variables continue to influence the opportunities for guardianship even when endogenous variables are taken out. Despite these limitations, this study makes a contribution to the field of research devoted to guardianship opportunities at transport nodes, drawing conclusions from the Stockholm underground system.

8. References

Block, R. and Davis, S. (1996) The environs of rapid transit stations: a focus for street crime or just another risky place? In: D. Clarke (ed.) *Preventing Mass Transit Crime*. Monsey, NY: Criminal Justice Press, pp. 238–257.

Burns R. and Burns R. (2009) Business Research Methods and Statistics Using SPSS. Chapter 24 Logistic Regression. http://www.uk.sagepub.com/burns/default.htm, accessed 26 September 2013.

Ceccato, V. (2013) *Moving Safely: Crime and Perceived Safety in Stockholm's Subway Stations*. Lanham, MD, USA: Lexington Books.

Ceccato, V., Uittenbogaard, A. and Bamzar, R. (2013) Security in Stockholm's underground stations: The importance of environmental attributes and context. *Security Journal* 26: 33-59.

Clarke, R.V. (1995) Situational crime prevention. In: M. Tonry and D. Farrington (eds.) *Building a Safer Society: Strategic Approaches to Crime Prevention.* Chicago: The University of Chicago Press, pp. 91-150.

Cohen, L.E. and Felson, M. (1979) Social change and crime rate trends: A routine activity approach. *American Sociological Review* 44(4): 588–605.

Cozens, P., Neale, R., Whitaker, J. and Hillier, D. (2003) Managing crime and the fear of crime at railway stations—a case study in South Wales (UK). *International Journal of Transport Management* 1(3): 121–132.

Eck, J. (1994) Drug Markets and Drug Places: A Case-Control Study of the Spatial Structure of Illicit Drug Dealing. Doctoral dissertation, University of Maryland, College Park.

Felson, M. and L.E. Cohen. (1980) Human ecology and crime: A routine activity approach. *Human Ecology* 8(4): 389−405.

Hollis-Peel, M., Reynald, D., Bavel, M., Elffers, H. and Welsh, B. (2011) Guardianship for crime prevention: a critical review of the literature. *Crime, Law and Social Change* 56(1): 53-70.

Hope, T. (1999) Privatopia on trial? Property guardianship in the suburbs. *Crime Prevention Studies* 10: 15-45.

Jacobs, J. (1961) *The death and life of great American cities*. New York: Random House.

Loukaitou-Sideris, A. (1999) Hot Spots of Bus Stop Crime. The Importance of Environmental Attributes. *Journal of the American Planning Association* 65(4): 395-411.

Loukaitou-Sideris, A., Liggett, R. and Iseki, H. (2002) The geography of transit crime: Documentation and evaluation of crime incidence on and around the Green Line Stations in Los Angeles. *Journal of Planning Education and Research* 22(2): 135–151.

Newman, O. (1972) *Defensible space: Crime prevention through urban design*. New York: Macmillan.

Norman, G. (2010) Likert scales, levels of measurement and the 'laws' of statistics. *Advances in Health Science Education* 15(5): 625-632.

Painter, K. and Tilley, N. (1999) Surveillance of Public Space: CCTV, Street Lighting and Crime Prevention. *Crime Prevention Studies 10*. Monsey, NY: Criminal Justice Press.

Pennell, S., Curtis, C. and Henderson, J. (1985) *Guardian Angels: An Assessment of Citizen Response to Crime*. National Institute of Justice, US. Association of Governments.

Reynald, M. (2011a) *Guarding Against Crime: Measuring Guardianship within Routine Activity Theory*. United Kingdom: Ashgate Publishing.

Reynald, M. (2011b) Factors Associated with the Guardianship of Places: Asseissing the Relative Importance of the Spatio-Physical and Sociodemographic Context in Generating Opportunities for Capable Guardianship. *Journal of Research in Crime and Delinquency* 48(1): 110-142.

Reynald, M. and Elffers, H. (2009) The Future of Newman's Defensible Space Theory: Linking Defensible Space and the Routine Activities of Place. *European Journal of Criminology* 6(1): 1477-3708.

Shaw, C.R. and McKay, H.D. (1942) *Juvenile delinquency and urban areas*. Chicago: University of Chicago Press.

Smith, M. and Clarke, R. (2000) Crime and Public Transport. *Crime and Justice* 27: 169-233.

Stockholm Public Transport - SL (2012) *Fakta om SL och länet, 2011*. AB Storstockholms Lokaltrafik. http://sl.se/sv/Om-SL/Det-har-ar-SL/Rapporter/Fakta-om-SL-och-lanet/, accessed 02 October 2013.

Stockholm Stad. (2013) http://www.stockholm.se/OmStockholm/Fakta-och-kartor/, accessed 26 September 2013.

Appendix A

Modelling setup

Table 1 - Dependent variables in the models

Guardianship variables per section

Model 1 (Figure 5)		Model 2 (Figure 5)	
Surveillance	Visibility	Surveillance	Visibility
PSur, TSur, LSur, ESur	PVis, TVis, LVis, EVis	AvSur	AvVis

P=PLATFORM, T=TRANSITION, L=LOUNGE, E=EXIT AREA, Av=AVERAGE (sum of mean of sections/4)

Notes: Sur=Surveillance possibilities (0/1); *Vis*=Visibility possibilities (0/1)

Table 2 - Independent variables in the models

Environmental variables per section

Model 1 (Figure 5)				Model 2 (Figure 5)
Platform	Transition	Lounge	Exit/Entrance	Surroundings
Pillu, Pcorn, Phide, Pblok, Pview, Punder, Psecu, Pmirr, Pguar, Pcrow, Pax, CCTVno	Tillu, Tcorn, Thide, Tlvl, Tview, Tsecu, Tmirr, Tguar, Tcrow, Pax,	Lillu, Lcorn, Lhide, Lopen, Lwind, Lsecu, Lmirr, Lshop, Lcafe, Lguar, Lcrow, Pax,	Eillu, Ecorn, Ehide, Ewalk, Eopen, Eview, Esecu, Eguar, Ecrow, Pax, CCTVno	Smeet, Sresi, Sbike, Speds, Staxi, Sguar, Sopen, Pax, CCTVno

	CCTVno	CCTVno		

P=PLATFORM, T=TRANSITION, L=LOUNGE, E=EXIT AREA, S=SURROUNDINGS

Notes: illu=Sufficient/effective illumination (y/n); *corn*=Presence of dark corners (y/n); *hide*=Presence of hiding places (y/n); *blok*=Many objects blocking the view (y/n); *view*=Clear overview (y/n); *under*;= Subterranean section (y/n); *secu*=CCTVs easily recognizable/visible (y/n); *mirr*=Presence of mirrors (y/n); *guar*=Presence of guards in section (y/n); *crow*=Overall crowdedness in section (h/m/l); *Pax*=Daily passenger flow at station (#); *CCTVno*=Number of CCTVs placed at station (#); *lvl*=Section consisting of several levels (y/n) *open*=Open lay-put of the place (y/n); *wind*=Presence of open windows (y/n); *shop*=Presence of shops (y/n); *cafe*=Presence of café; *walk*=Long distance from entrance/exit to lounge (y/n); *meet*=Immediate surroundings is a meeting place (e.g. square); *resi*=Immediate surroundings is residential; *bike*=Bike lanes present (y/n); *peds*=Pedestrian pathways present (y/n); *taxi*=Taxi pick-up/parking place present

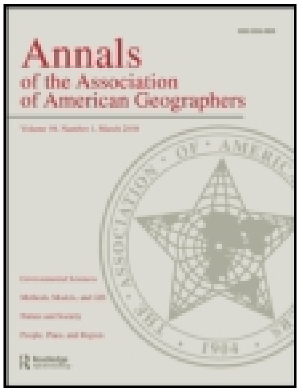
Appendix B
Control modelling setup, controlling for possible endogeneity.

Independent environmental variables per section

Model 1 (Figure 5)				Model 2 (Figure 5)
Platform	Transition	Lounge	Exit/Entrance	Surroundings
Punder, Psecu, Pmirr, Pguar, Pcrow, Pax, CCTVno	Tlvl, Tsecu, Tmirr, Tguar, Tcrow, Pax, CCTVno	Lwind, Lsecu, Lmirr, Lshop, Lcafe, Lguar, Lcrow, Pax, CCTVno	Ewalk, Esecu, Eguar, Ecrow, Pax, CCTVno	Smeet, Sresi, Sbike, Speds, Staxi, Sguar, Pax, CCTVno

P=PLATFORM, T=TRANSITION, L=LOUNGE, E=EXIT AREA, S=SURROUNDINGS

Notes: under=Subterranean section (y/n); *secu*=CCTVs easily recognizable/visible (y/n); *mirr*=Presence of mirrors (y/n); *guar*=Presence of guards in section (y/n); *crow*=Overall crowdedness in section (h/m/l); *Pax*=Daily passenger flow at station (#); *CCTVno*=Number of CCTVs placed at station (#); *wind*=Presence of open windows (y/n); *shop*=Presence of shops (y/n); *cafe*=Presence of café; *walk*=Long distance from entrance/exit to lounge (y/n); *meet*=Immediate surroundings is a meeting place (e.g. square); *resi*=Immediate surroundings is residential; *bike*=Bike lanes present (y/n); *peds*=Pedestrian pathways present (y/n); *taxi*=Taxi pick-up/parking place present



Annals of the Association of American Geographers
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/raag20

Space-Time Dynamics of Crime in Transport Nodes

Vania Ceccato [a] & Adriaan Cornelis Uittenbogaard [a]

[a] CEFIN-School of Architecture and the Built Environment , Royal Institute of Technology , Stockholm , Sweden

Published online: 20 Nov 2013.

Space–Time Dynamics of Crime in Transport Nodes

Vania Ceccato and Adriaan Cornelis Uittenbogaard

CEFIN–School of Architecture and the Built Environment, Royal Institute of Technology, Stockholm, Sweden

This article assesses space–time variations of crime rates in underground stations. 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. Data from extensive field work at the stations was combined with crime records and passenger flow to test whether stations' environmental attributes affect crime at different times. Geographical information systems, spatial statistic techniques, and modeling underpin the methodology used in the study. Findings show that crimes tend to happen more often in the evening, at night, on holidays, and on weekends. There is also evidence of seasonal variations of crime. In the winter, stations with social disturbance and signs of deterioration show high levels of crime, whereas in the summer, offenses are concentrated in stations nearby alcohol selling outlets. Stations with hiding spots are often targeted for crime during daily peak hours, whereas during holidays, crowded stations and those with alcohol selling outlets attract more criminal activities. Results suggest that the role of the stations' environment on crime causation varies over time—an important fact for safety interventions. *Key Words: cluster analysis, GIS, offenses, space–time dynamics.*

本文评估地下车站犯罪率的时空变异。本研究运用时间地理学、例行活动原理, 以及可防御的空间理论, 探究瑞典首都斯德哥尔摩的地下车站中, 每日、每週以及季节性的犯罪变异。自车站的田野工作中广泛搜集的数据, 将与犯罪纪录和客流相互结合, 用以测试车站的环境特徵是否在不同的时间点上影响了犯罪。本研究运用地理信息系统、空间统计技术, 以及模式化的方法论。研究结果显示, 犯罪更常发生于晚上、深夜、假日以及週末。同时亦有证据显示, 犯罪具有季节性的变异。在冬天, 有着社会扰动以及倾颓迹象的车站, 显示具有高度的犯罪; 在夏天, 攻击事件则是集中于附近设有贩卖酒精场所的车站。在每日的尖峰时段, 具有藏身之处的车站经常是犯罪的目标; 而在假日中, 拥挤的车站与贩售酒精商品处附近的车站则吸引更多的犯罪活动。研究结果显示, 车站环境在导致犯罪中所扮演的角色随着时间改变——而这对安全性介入而言是重要的事实。 *关键词: 集群分析, 地理信息系统, 攻击, 时空动态。*

Este artículo sopesa las variaciones del espacio-tiempo en las tasas de criminalidad de las estaciones subterráneas. A partir de supuestos de la geografía del tiempo, principios de actividad rutinaria y teoría del espacio defensable, el estudio investiga las variaciones diarias, semanales y estacionales del crimen en las estaciones subterráneas de Estocolmo, la capital sueca. Los datos obtenidos mediante amplio trabajo de campo en estas estaciones fueron combinados con registros criminales y flujo de pasajeros para probar si los atributos ambientales de las estaciones afectaban al crimen en tiempos diferentes. La metodología utilizada en el estudio incluyó cosas tan importantes como sistemas de información geográfica, técnicas estadísticas espaciales y modelación. Los descubrimientos del estudio muestran que los crímenes tienden a ocurrir con más frecuencia en la tarde, en horas de la noche, durante festivales populares y los fines de semana. Hay también evidencia sobre las variaciones estacionales del crimen. En invierno, las estaciones que presentan perturbaciones sociales y signos de deterioro muestran altos niveles de criminalidad, en tanto que en verano los hechos delictuosos se concentran en estaciones cercanas a sitios donde se expenden bebidas embriagantes. Las estaciones en donde existen escondrijos a menudo son blanco de acciones criminales durante las horas pico, en tanto que durante los días festivos las estaciones congestionadas y las que tienen sitios para vender licores atraen mayor actividad criminal. Los resultados sugieren que el papel del entorno de las estaciones en términos de causalidad criminal varía con el tiempo—hecho muy importante en cuestiones de seguridad. *Palabras clave: análisis de aglomeraciones, SIG, delitos, dinámica del espacio-tiempo.*

To occur is to take place. In other words, to exist is to have being within both space and time.

—Peuquet (2000, 5)

The daily life of a city provides the targets for crime and removes them. The sleeping, walking, working, and eating patterns of offenders affect the metabolism of crime. . . . We must study these rhythms of live if we wish to understand crime.

—Felson (2006, 6–7)

Annals of the Association of American Geographers, 104(1) 2014, pp. 131–150 © 2014 by Association of American Geographers
Initial submission, October 2012; revised submission, March 2013; final acceptance, May 2013
Published by Taylor & Francis, LLC.

As early as 1968, in the children's book *What Do People Do All Day*, Richard Scarry (1968) showed a lively picture of a city: a dynamic and pulsing environment where people's movement patterns were determined by the activities they performed in different places. As in our cities of today, people were portrayed as active beings, talking to each other, driving, taking buses, or crossing dangerous streets. Scarry's classic book lacked, however, a time–space frame for what happened in the city. Scarry can hardly be blamed. Forty years on, researchers and planners are still struggling to answer questions of how and when people move around in space and how this information can be used to improve our quality of life. Despite the theoretical advancements of time geography (Hägerstrand 1970; see, e.g., Lenntorp 1976; Thrift 1977; Kwan 1998; Kwan and Lee 2003; Miller 2004), lack of data and adequate methods were and still are an important barrier to our capacity to track individuals and use the information to improve people's quality of life (Ceccato 2013).

If we take urban safety, for instance, the capacity of researchers and planners to predict victimization over time and space has so far been limited by ecological methods using aggregated data of low space–time resolution, such as census based data tracked by year. By making use of time geographic principles, we disregard the need for data with high space–time resolution (e.g., individual data by day). We submit that this is feasible because individuals' movement patterns (1) follow dynamic but regular rhythmic patterns (Song et al. 2010) and (2) are limited by a number of constraints in space and time (Hägerstrand 1970). The regularity means that one can extrapolate patterns over space and time. Thus, the risk for crime is dependent on people's movement patterns that are rhythmic: rush and off-peak hours, weekdays and weekends, and winter and summer (Loukaitou-Sideris, Liggett, and Iseki 2002; Smith and Cornish 2006; Ceccato, Uittenbogaard, and Bamzar 2013). Equally important are the constraints that characterize individuals' movements and help to frame cities as places of convergence and dispersion.

Typical areas of convergence are, for example, transport nodes, such as bus and train stations. Transport nodes play an important role when planning safe environments because they have an absolute location in space; they are linked to human activities that are regulated by a rhythmic schedule of buses or trains. It is thus suggested here that they also have the capacity to reflect the dynamicity of the city as a whole. Stations are often called crime generators and crime attractors (Brantingham and Brantingham 1993, 1995). Transport nodes concentrate large flows of people, which make it easier for offenders to commit crime. Some physical and social characteristics found in stations might draw the attention of people with high levels of criminal motivation. They can potentially pull motivated offenders toward them. Not all stations are equally safe, however, and even within a station, certain environments are more vulnerable to crime than others (e.g., Loukaitou-Sideris, Liggett, and Iseki 2002; Ceccato, Uittenbogaard, and Bamzar 2013). Thus, the effect of the stations' environmental features (physical and social) on crime varies over time and space as a result of their internal characteristics but also their contexts.

This article suggests a methodology for assessing crime over time and space in areas of convergence, namely, at underground stations. The theoretical framework enables us to assess crime at underground stations in relation to daily, weekly, and seasonal variations of passenger flows. Focusing on crime in transport nodes provides us with snapshots of a city's overall risk over time and space using aggregated data by station. This study builds on the study by Ceccato, Uittenbogaard, and Bamzar (2013) by adding the space–time dimension of crime and making a direct contribution to the growing literature on the criminological conditions in transport nodes, responding to calls by Loukaitou-Sideris, Liggett, and Iseki (2002), Cozens et al. (2003), and Newton (2004), among many others.

The Stockholm underground system is used as the study area. Stockholm is well supplied by its one hundred stations, connected to buses and commuter trains. Stockholm is also peculiar because it is a Scandinavian city; the short days of its cold, dark winter limit life outdoors but allow for days full of activities in the spring and summer. Stockholm is also an interesting case study because, contrary to North American or British cities on which most studies are based, the capital of Sweden has been shaped, to a large extent, by planning practices that were a result of welfare policies. A typical characteristic of this planning is, for instance, the fairly spatial distribution of public transportation over the city, with rather uniform points of population convergence, often linked to areas of mixed land use (e.g., residential and commercial areas).

Data from extensive fieldwork at the stations in 2010 were combined with crime records and passenger flow (from Stockholm Public Transport for 2006–2009) to test whether stations' environmental attributes affect crime at different times. Geographical information systems (GIS), spatial data analysis, and modeling underpin the methodology used in the study. Space–time differences are simultaneously scrutinized by looking at variations over time for the whole underground system as well as the three different lines separately. Later the focus shifts to the environmental attributes that might contribute to increased crime levels at stations during the different moments in time.

Theory and Hypotheses

The urban fabric works as a guiding template for individuals' movements.[1] Transportation systems, as part of the urban fabric, reduce the time required for activities by compressing "lives into relatively small spaces" (Miller 2005, 381) and dispersing passengers through the network and reuniting them in areas of convergence. Transport nodes concentrate large flows of people in one place, making it easier for offenders to commit crime. For example, at certain times of the day, the crowds at a station might encourage the offender to pickpocket.

Time Geography and Crime in Transport Nodes

Hägerstrand (1970) was one of the first scholars to state that neither time nor space can be left out when one refers to human activities and movements (see also Hawley 1950, 1973). Time geography shows the involvement of people in their actions to be basically controlled by the limited resources of time and space (Thrift 1977). Any type of human activity is limited by amount of time available each day. Time is both a necessary condition and a constraint for any activity. Committing a crime is just an example of these activities. Constraints are relevant for understanding the nature of transport nodes as places with varied levels of crime, which is dependent on hourly, daily, weekly, and seasonal movement patterns of individuals. Hägerstrand used the space–time path to demonstrate how human spatial activity is affected by spatial or temporal constraints. He identified three categories of constraints for human movement: capability, coupling, and authority.

The first category is capability constraint, which is perhaps the most basic one and refers to individuals' limitation of only being in one place at any time; in other words, individuals are unable to be in two underground stations at the same time. Individuals are exposed to a single place at a time, but as they move, they will be exposed to each place's characteristics as time passes by. Researchers have shown that the risk of being a victim of crime is not evenly distributed (Wikström 1991; Bromley and Nelson 2002; Loukaitou-Sideris, Liggett, and Iseki 2002; Andresen 2006; Ceccato and Oberwittler 2008) neither in space nor in time (Sherman, Gartin, and Buerger 1989; Ceccato 2005; Weisburd, Morris, and Groff 2009). At a transport node, such as an underground station, crime is a product of two dimensions: the environment of the transport node (e.g., design of platforms, closed-circuit television cameras [CCTVs], dark corners, and hiding places) and social interactions that take place in these environments (e.g., poor guardianship, crowdedness, and disturbances). Knowing where and when the risks are (or are perceived to be) in the city affects the way people move around and plan daily activities (Ross 1993; Loukaitou-Sideris 2006; Foster and Giles-Corti 2008; Jackson and Gray 2010).

Despite their freedom of movement, however, individuals are constrained by the means with which they move around. They might be limited by their "awareness of space" (Brantingham and Brantingham 1984, 365). If public transportation is the alternative, individuals need to be at a certain time at the platform to catch the nine o'clock train. Individuals' space–time paths must be temporarily linked up with other individuals (e.g., both the passengers and the train conductor must be on time) to accomplish that particular activity (e.g., catch the train). Such a compulsory convergence was denominated by Hägerstrand as a *coupling constraint* and the overlap of paths in space–time was called *bundled* by Hägerstrand. In safety terms, some couplings are desirable (e.g., meeting a friend) and others are not (e.g., meeting an offender). Crime happens only when a motivated offender and potential victim or target coexist for a given length of time and space (also virtual space). Routine activity theory suggests that for crime to occur there must be three elements in place in both space and time: the presence of a motivated offender, a suitable target, and an absence of capable guardians (Cohen and Felson 1979; Felson 1994; Felson and Clarke 1998).

Urban environments are composed of public, semiprivate, and private places, varying from free to limited access. Hägerstrand was also concerned with the selective access to places, which he included in his authority constraint. This constraint sets limits of access to individuals to certain spatial domains (e.g., carriages or buses tailored for women only) or time domains (e.g., cheap fares that encourage retired individuals to avoid rush hours at stations, consequently limiting access of this group to off-peak hours). From an urban criminology perspective, this constraint is relevant to interpret variation of levels of targeted group victimization (e.g., harassment and assault of females at evening hours) but also sudden low or high concentration of crimes (e.g., at the stations after midnight, when the stations are closing down). Authority constraint interacts with monthly variations of human activities that are regulated by seasons and weather. Due to extreme weather in Scandinavia, some places are completely shut in the winter, and others open only in the summer vacation season. Quetelet (1842) suggested that the greatest number of crimes against people is committed during summer and the fewest during winter. Researchers have found evidence on how crime levels vary over time and space either as a result of psychological response to weather stressors or an imposed calendar of activities (for a review, see Cohn 1990; Anderson et al. 2000; Bromley and Nelson 2002; Cohn and Rotton 2003; in the tropics see Ceccato 2005).

Not all transport nodes are exposed to crime in the same way. This is because social interactions, including those that result in victimization, are dependent on multiscale conditions that act at various levels in an urban environment. These conditions are determined by the environmental attributes of the transport node (e.g., a station), the type of neighborhood in which the station is located, and the relative position of both the station and the neighborhood in the city (Ceccato, Uittenbogaard, and Bamzar 2013). In the next section, we discuss these factors in more detail.

The Role of Environment on Crime in Transport Nodes

A transport system is a multifaceted arena, with a complex interaction of settings (buses, trains, and trams), facilities (stops, stations, and interchanges), and users (staff and passengers). The design of these facilities and the internal and external environments can all influence the level of crime (or perceived safety) experienced on the system (Newton 2004). According to Smith and Clarke (2000), the targets of crime also vary and could include the system itself (vandalism, fare evasion), employees (assaults on ticket collectors), and passengers (pickpocketing, assault). Some of these transport nodes are self-contained entities (e.g., underground stations) and others are part of a system (e.g., bus stops in a road) but, in both cases, they are often regarded as crime generators or crime attractors (Brantingham and Brantingham 1993, 1995). The increased opportunity for offenders to commit the crime in transport nodes is related to the easy access to transport nodes, the unfamiliarity of the passengers in these public places, and their poor willingness to exercise guardianship in areas of convergence, such as in stations (Piza and Kennedy 2003; Ceccato and Haining 2004). The rational choice theory postulates that the potential offender evaluates his or her own risk before making a decision to commit a crime (Becker 1968; Clarke and Cornish 1985; Cornish and Clarke 1986; Clarke and Felson 1993). Thus, an underground station as a premise with its all auxiliary features can provide a proper environment for crime. The presence of hiding places, dark corners, insufficient illumination, and lack of formal and informal social control might contribute to an offender's decision to commit an offense.

During the past half-century, researchers have confirmed the influence of a city's design and layout on the vulnerability to crime (e.g., Jacobs 1961; Newman 1972; Stark 1987; Fagan and Freeman 1999). This is also true for transport nodes. Their design and layout affect the potential offender's likelihood of escaping without being detected (Clarke and Felson 1993). Some station designs make it difficult for outsiders to see what is happening because of obstructed visibility, as hidden corners and darkness (Loukaitou-Sideris 2012). Lighting, fencing, specific security hardware, and open design that allow opportunities for surveillance can discourage crime (Harris 1971). On the other hand, if set within dense urban environments, with good visibility from their surroundings, stations could provide natural surveillance opportunities (Felson et al. 1990). The literature also indicates that location of escalators at the end of the platforms, ticket booths clearly visible at the entrance lounges, overpass walkways for overviews, and separation of passenger flows are factors affecting safety at stations (Gaylord and Galliher 1991; Myhre and Rosso 1996; LaVigne 1997).

The environment of stations is important because it directly or indirectly affects visibility, the possibility to be seen and to see others; in other words, the natural surveillance of the location. Jacobs (1961) coined the term *eyes on street*, stressing that the design has a role to play in defining opportunities for surveillance and therefore for crime occurrence. A decade later, Newman (1972) developed a theory based on the interaction between the individuals and their environment, which he referred to as *defensible space*. A fundamental concept of this theory is that of natural surveillance: the "capacity of physical design to provide surveillance opportunities for residents and their agents" (Newman 1972, 78). Cozens et al. (2003) found visibility to be the most crucial part of safety at railway stations. Evidence from the United States and Sweden shows strong links between crime rates and stations with dark, hidden places or with poor visibility from the surroundings (Loukaitou-Sideris, Liggett, and Iseki 2002; Ceccato, Uittenbogaard, and Bamzar 2013)—all elements that are important for natural surveillance. Researchers might argue that the defensible space theory is generally in line (or integrated) with the main principles of routine activity theory. Poorly lighted space reduces the probability of being caught after committing a crime. This is accounted for in the element of place (poor vs. good management of place) in the routine activity theory.

Despite the fact that there are places that allow good surveillance, individuals might not be willing to (or cannot) exercise social control or guardianship over the area (Reynald 2011). Social disorganization theory has long suggested that disorganized communities have a negative impact on the effectiveness of social control (Shaw and McKay 1942), which could affect crime levels. Deriving from neighborhood clues of disorder, Wilson and Kelling (1982) suggested that unrepaired damage to property encourages further vandalism and other, more serious types of crimes, the so-called broken window syndrome. The presence of incivilities, signified by deteriorating building stock and public environments, with concentration of graffiti and litter, is also likely to have an impact on neighborhood crime (Wilson and Kelling 1982; Skogan 1990; Perkins et al. 1993). In relation to transport nodes, Loukaitou-Sideris, Liggett, and Iseki (2002) showed that crime rates at light-rail stations were related to the socioeconomic levels of their surrounding neighborhood when comparing population densities, high and low income levels, ethnicity, gender, and age distribution. Furthermore, specifically particular land uses (e.g., schools, bars, liquor stores, pawn shops, and abandoned buildings) have been found to attract more crime in their vicinity (Byrne 1986; Greenberg 1986; Roneck and Maier 1991; Block and Block 1995, 2000). Equally important for crime levels and geography is the relative position of the station and the neighborhood in the city (Loukaitou-Sideris 1999). City centers are often high-crime areas; thus, it would be expected that the more centrally located a station is, the more criminogenic it will be. The city's geography and the presence of different geographical barriers, such as a lake, a river, or a park, are also influential in defining regional patterns of mobility and, consequently, offenses, because they affect space–time frames of escape, for instance. Different types of crime will occur in different environmental conditions and might vary over time (e.g., rush hours tend to concentrate pickpocketing, whereas late hours attract more vandalism).

The Conceptual Framework

The conceptual model relies on principles of time-geography and urban criminology and defensible space theories (Figure 1). These theories underlie the methodology adopted in the study and the discussion of the results in the following sections of the article.

Space–time geography principles help us to understand the relations between rhythmic variations of human activities, including crime, over time and in space. During certain time and space windows, people disperse or converge through the transportation system following constraints of movement as suggested by Hägerstrand (1970). For crime to happen in a transport node, a synchronization of elements in time and space must occur: a motivated offender who identifies a potential victim, based on his or her assessment of "right" time and "right" place. Routine activity principles recognize the fact that people move around in fairly determined patterns along specified trajectories and thereby induce crime levels at certain time periods and places. Research is increasingly focusing on the importance of space–time dynamics of crime (Ratcliffe 2006; Uittenbogaard and Ceccato 2012) and particularly the movement of offenders (Bichler, Christie-Merrall, and Sechrest 2011; Ceccato and Wikström 2012; Rey et al. forthcoming).

Hypothesis 1 is that crime in underground stations reflects rhythmic variations of human activities (hourly, daily, weekly, and seasonally). For instance, the coupling constraint makes transport nodes typical areas of convergence. Rush hours would be more targeted for crime than nonpeak hours. The same applies for evening hours over weekends or summer versus winter.

Underground stations are criminogenic places, but certain stations are targeted for acts of crime and disorder more often than others (Ceccato, Uittenbogaard, and Bamzar 2013, 18) and their vulnerability may change over time.

Hypothesis 2 is that the specific vulnerability to crime of a transport node varies over time and space. A transport node's environmental features are perceived as risky by offenders when active guardians are around, during the day, and during the summer. On the contrary, stations with hidden corners and low visibility at night or during winter tend to be crime targets more often.

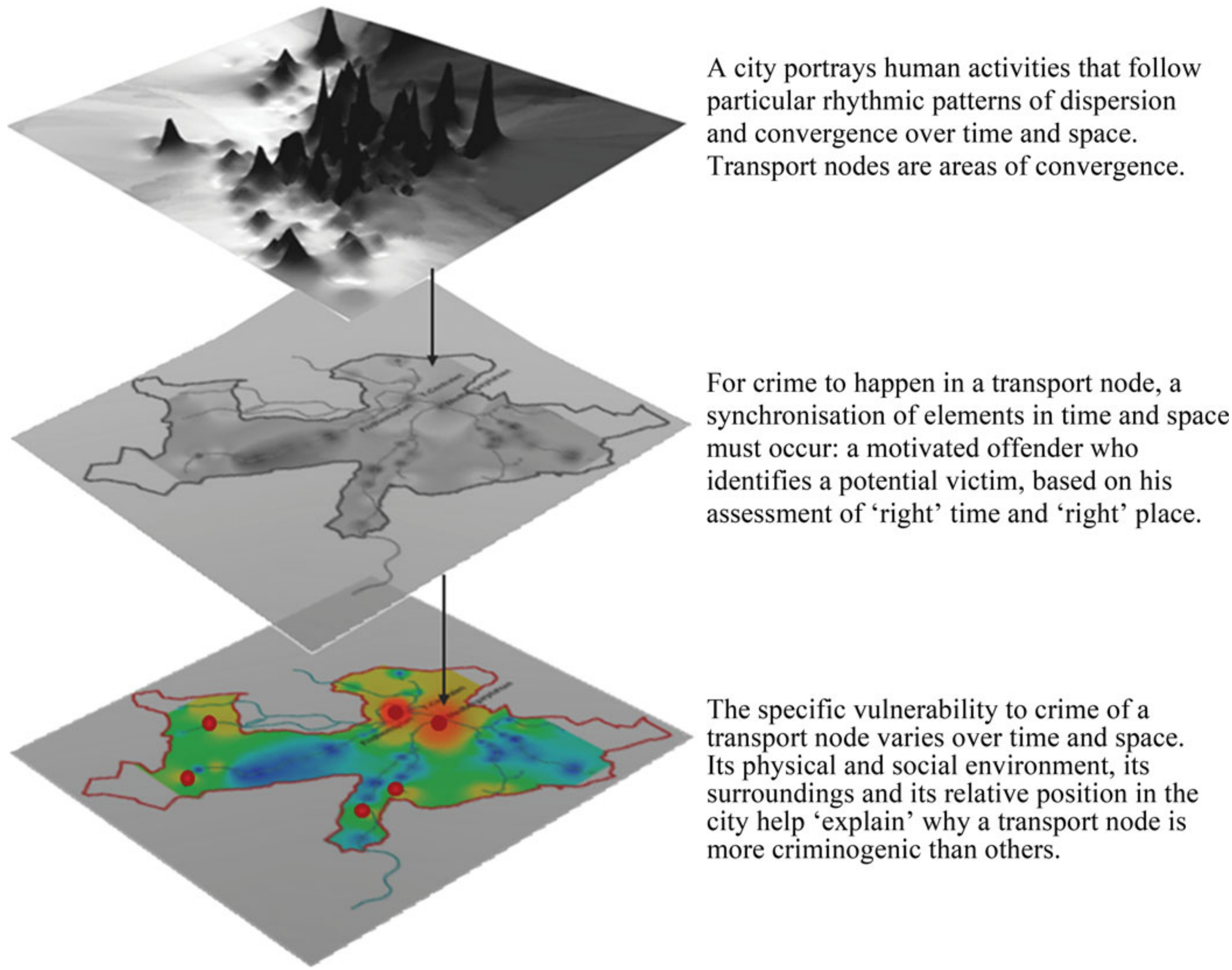


Figure 1. The conceptual framework: Mobility and crime at underground stations. (Color figure available online.)

The Stockholm Case Study

Stockholm is a dynamic place. Figure 2 illustrates two snapshots in time (night and day) of the population of Stockholm by zones. Two million people live in Stockholm County, half of them in the city of Stockholm. There are three underground lines with more than one hundred stations (see Appendix A), 5,000 taxicabs, and 2,000 buses. Around 230,000 people travel with commuter trains to get to their destination in the Stockholm area and more than 1.8 million passengers travel every day in the city's undergrounds. All of these numbers provide a rough idea of people's movements, often canalized by private and public transportation. The study area includes the Stockholm underground network, constituted by three lines (green, red, and blue). The underground system is part of Stockholm's main transportation modes and besides covering Stockholm municipality (82 percent of all stations), it reaches out to surrounding municipalities and suburbs. The study area is limited to the Stockholm municipality.

In criminogenic terms, the seasonal change in the length of day and night is worth noting in Stockholm. In midwinter, darkness and cold prevail (around six hours of light, with mean temperature in February of −3°C). In midsummer, however, daylight takes over, promoting long days in June and July (around eighteen hours, with average daytime temperatures of 20–22°C).

Temporal patterns of crime show city-wide differences in geography. Uittenbogaard and Ceccato (2012), using police data and Kulldorff's method (which is a spatial scan statistic; Kulldorff 2010), suggested that Stockholm's summer violence concentrations of crime were more spread out toward the outer suburbs and

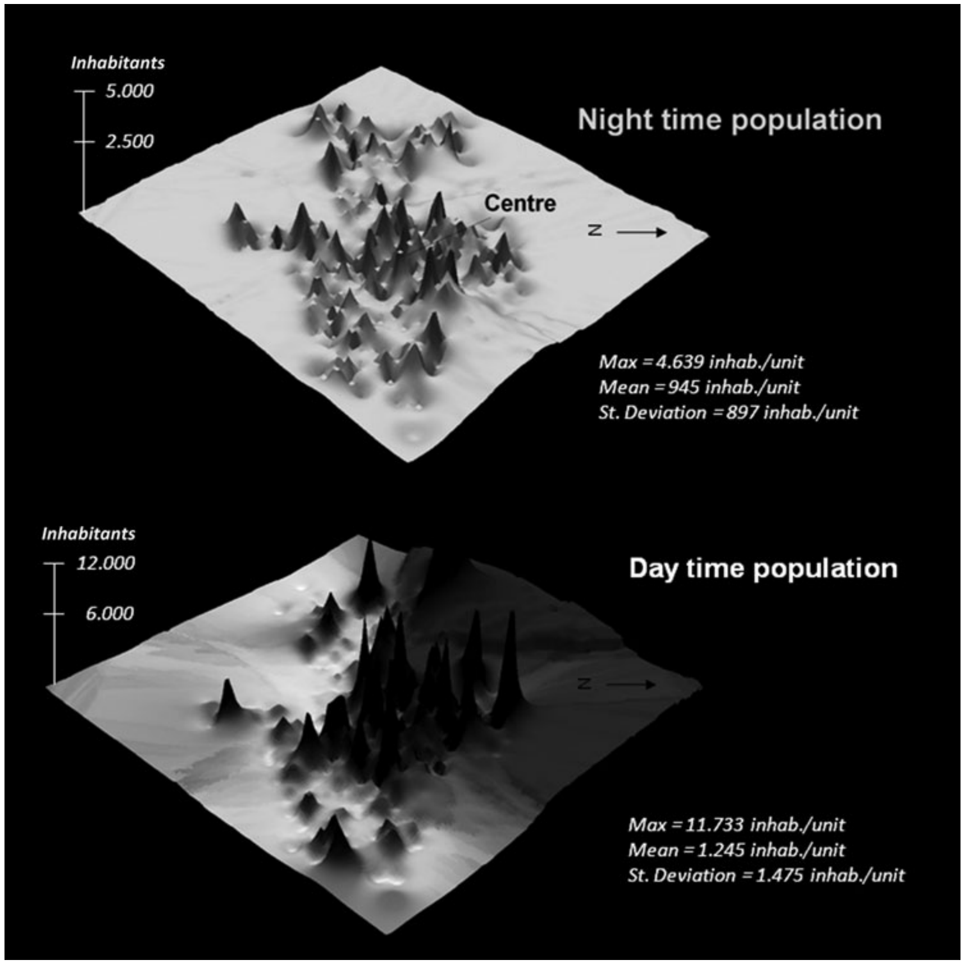


Figure 2. Night and daytime population in Stockholm municipality.

greenery areas, whereas during the winter, violence was concentrated in the inner city and around underground stations. The city center, however, was a stable cluster for both violence and property crimes regardless of season, as there are always people converging in that area. This is not a surprise, as the literature in the United States shows that 3 percent of addresses produce 50 percent of reported crimes. These places are so crime prone that they are labeled *hotspots of crime* (Sherman, Gartin, and Buerger 1989; Andresen and Linning 2012).

Around 60 percent of all crime events in Stockholm municipality were found to happen within 500 m of underground stations (accounting for only 28 percent of Stockholm's land cover). Although the surroundings of the stations are often commercial centers of mixed land use, previous research has shown that the stations' environments are more important to explain crime levels than their surroundings (Ceccato, Uittenbogaard, and Bamzar 2013).

Data and Method

The data used are from the Stockholm Public Transport (SL) database, which consists of crime events reported to the central alarm service covering from 2006 to 2009. These records are categorized according to year, date, time of day (by minute), station, line, crime code, crime type, and description. Over the three years, 62,265 events were reported. Eighty percent of all events registered at the stations related to cases of drunken people at the station or people found sleeping on a train, as well as unjustified use of emergency brakes, fire extinguishers, or fire hoses. Crimes, often acts of violence, thefts, and vandalism, constitute about 20 percent of events. Most reports of violence are against passengers (fights) and guards or other personnel. Threats against personnel are the most typical events, followed by threats against passengers and drivers. Vandalism includes graffiti on walls or floors, as well as damage to objects, although rarely inside the trains. Theft can generally be divided into two types in underground stations: theft or robbery from persons and of objects at the station. The latter includes theft of bikes and cars, which is not uncommon around underground stations (parking lots or streets). Note that the underground stations have limited opening hours; during weekdays most stations are closed between 3 a.m. and 5 a.m., resulting in missing data.

The fieldwork database consists of observations gathered during an extensive inspection of the environment of all underground stations and their immediate surroundings in summer 2010 and winter 2010–2011. This "inspection" was at first conducted during daytime, between 10 a.m. and 4 p.m., to avoid rush hours and the darker hours of the day to get a picture of the stations at "normal operation times." The researchers spent around one hour at each station. The fieldwork was repeated, in a scaled-down version, in the winter to check for specific differences during the darker hours of the day (during winter times from 2 p.m. until midnight) and how winter climates changed the characteristics of the stations.

Theories of urban criminology and situational crime prevention were the basis for selecting the features to be checked. From previous studies on transport and crime, results show that various environmental features, indicators of social control, and socioeconomic variables affect levels of crime at stations (see previous literature review). Examples include checking for visibility at platforms (suggested by, e.g., Cozens et al. 2003), natural surveillance (from, e.g., situational crime prevention and rational choice theory), presence of CCTVs (e.g., Webb and Laycock 1992), and mixed land use in the surrounding areas (e.g., Loukaitou-Sideris, Liggett, and Iseki 2002). The attributes were assessed during the fieldwork by using a yes–no scale (e.g., presence of dark corners, well illuminated, open layout, disturbance) or a high–medium–low scale (e.g., crowdedness, visibility, littering). This assessment is, of course, prone to subjectivity, but a comparison of both the researchers' results showed that the variance was minimal. As an example, visibility and surveillance were each checked using a high–medium–low scale by assessing the situation and perception of space from an expert point of view, having in mind suggestions from previous studies. The possibility of surveillance at the place was defined as "how well others can see you," thereby taking into consideration a multitude of aspects such as direct view, number of people (guardianship), view from outside toward the place, mirror placement, illumination of the place, and objects disturbing the sight line. This allowed for a comprehensive and uniform assessment of surveillance. Visibility was, on the other hand, defined as the opposite, "how well can you see others." It does not imply that these two features are the same, as you might be able to notice someone else, while this other person might not be aware or have a direct view of what is happening to you. More on this is explained in Ceccato, Uittenbogaard, and Bamzar (2013).

The station's platform is constituted by the platform where the trains arrive and passengers wait, and the transition area is the area between the platform and the gates and ticket window, which commonly includes stairs and elevators to the platform. The lounge is the area before the gates and ticket booth to the exits or tunnels. The exits are areas prior to entering the lounge area either directly from the street or via a tunnel. The surroundings included the immediate surroundings around each exit, the field of view from a station's exits.

The underground stations were divided into sections: platform, transition area, lounge area, and exits (for details, see Ceccato, Uittenbogaard, and Bamzar 2013). These environmental attributes describe the layout of the stations (e.g., design, lighting, lack of visibility, presence of littering, property damage) and features that characterize potential guardianship and the overall atmosphere. As the seasonal variations of light and temperature are notable in Scandinavia, models were tested using a set of new variables during winter: illumination, overcrowding, social disturbance, and littering in stations.

The database with all stations, their attributes, and crime rates was gathered in GIS. GIS was used also to count land use attributes around the stations (e.g., number of cash machines within at specific buffer distances) and produce the input data for the cluster analyses using police recorded data. Crime data from Stockholm police were extracted from 2006 to 2009. These years were collapsed into one year to create a more robust data set (keeping the information on hour, day, and month). The records contained information on the offense, place (x, y coordinates), and time (by minute). Note that the police data cover a 100-m area around the stations (which often covers the station area and includes both entrances), whereas the SL database only covers events that happened at the stations. These two independent data sources, although not free of problems, are expected to complement each other in showing what happens at the stations over time. Administrative (*basområde*) and demographic and social economic data were obtained from Stockholm municipality and also added to the basic map of Stockholm using GIS.

To check for crime variations over time, analysis of variance (ANOVA) tests with Scheffe's test were used. Tests looked for significant differences in events between peak and off-peak hours of the day, weekdays, weekends, and holidays, as well as between seasons, which are discussed in detail in the next section.

Ordinary least squares models were used, having natural log of crime rates (for selected time frames) as the dependent variable and stations' attributes as covariates (see Ceccato, Uittenbogaard, and Bamzar [2013], for details). These time frames were based on peak hours and off-peak hours (based on rates of crime by passenger flow), which vary by crime types. Because different crimes take place during different time windows, these slices of time vary. For example, for total crime, peak hours are from 6:00 p.m. to 10:00 p.m. and off-peak hours are from 6:00 a.m. to 10:00 a.m. For violence, peak hours are from 10:00 p.m. to 2:00 a.m. and off-peak hours are from 5:00 a.m. to 9:00 a.m. Vandalism peak hours are from 7:00 p.m. to 11:00 p.m. and off-peak hours are between 6:00 a.m. and 10:00 a.m.

The rates for weekdays and holidays were based on the number of events by 1,000 passengers, where weekdays are from Monday to Thursday. Holiday rates were based on bank holidays from the Swedish calendar in 2006 to 2009. For the weekly variations, the ANOVA test showed that the only significant difference was between weekdays (Monday–Thursday) and holidays. A trial was carried out using the sole highest peak hour. As an example here, at the peak hour for violent crimes (counts and rates) at 1 a.m., the model showed similar results to the one combining several peak hours. The main attributes explaining most of the variation in crime rates were the presence of cash machines, social disturbance, and littering or physical deterioration. Seasonal crime rates were based on the number of reports for each season by passenger flow; for instance, December to February was regarded as winter, whereas June to August was summer. Data for the winter variables that indicated the quality of illumination, overcrowding, and littering in stations were collected in the winter months, replacing those from the summer.

The modeling strategy consisted of three steps. First, correlations between independent variables were checked and highly correlated variables ($R > 0,6$) were excluded. Although this cutoff is arbitrary, this threshold helped in eliminating variables that were likely to contribute in the same way to the model. This preselection was a necessary step given the relatively large number of variables. Then, for each section of the stations (platform, transition area, lounge area, and exits), crime rates were regressed for the time frames (peak vs. off-peak, weekdays vs. holidays, and winter vs. summer). The significant variables from this stage were input in models for the whole station by each time frame.

Results

Temporal Patterns of Crime at the Station

Most of the reported events in the Stockholm underground network happen in the late afternoon and evening, more precisely between 4:00 p.m. and midnight. This peaks between 8:00 p.m. and 9:00 p.m. (Figure 3), which is when people are either getting back home (4:00 p.m.–7:00 p.m.) or performing unstructured activities after work, such as leisure (after 6:00 p.m.).[2] This pattern reflects the moments when people are on the move, when the risk of victimization is greatest because, as hypothesized earlier, it is when there is a greater chance of potential victims being in the same place as motivated offenders. People's bundling of space–time paths in specific periods affects the crime peaks at rush hours, when individuals are either on their way to or home from work. The effect of movement constraints also plays a role in defining crime by hour: Stations' opening hours restrict access to the stations and therefore their crime levels over the day. Unexpectedly, not all peaks of passengers at the station lead to crime. Thieves do not start to act before 11:00 a.m., with a peak at 4:00 p.m. Rush hours in the morning are not as criminogenic as those in the afternoon.

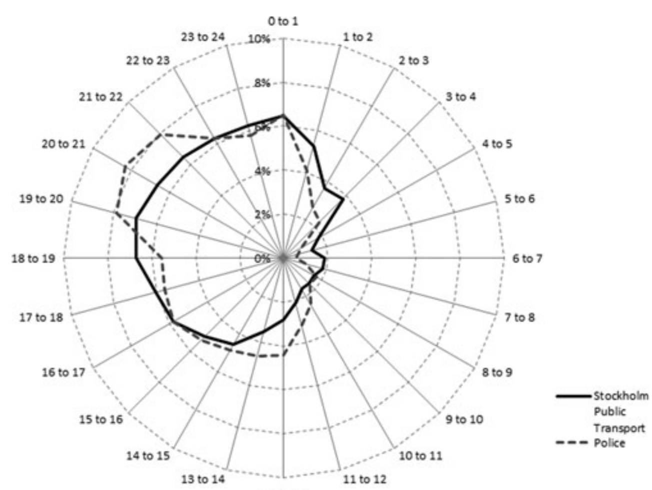


Figure 3. Distribution of crime and disorder by hour of the day and data source.

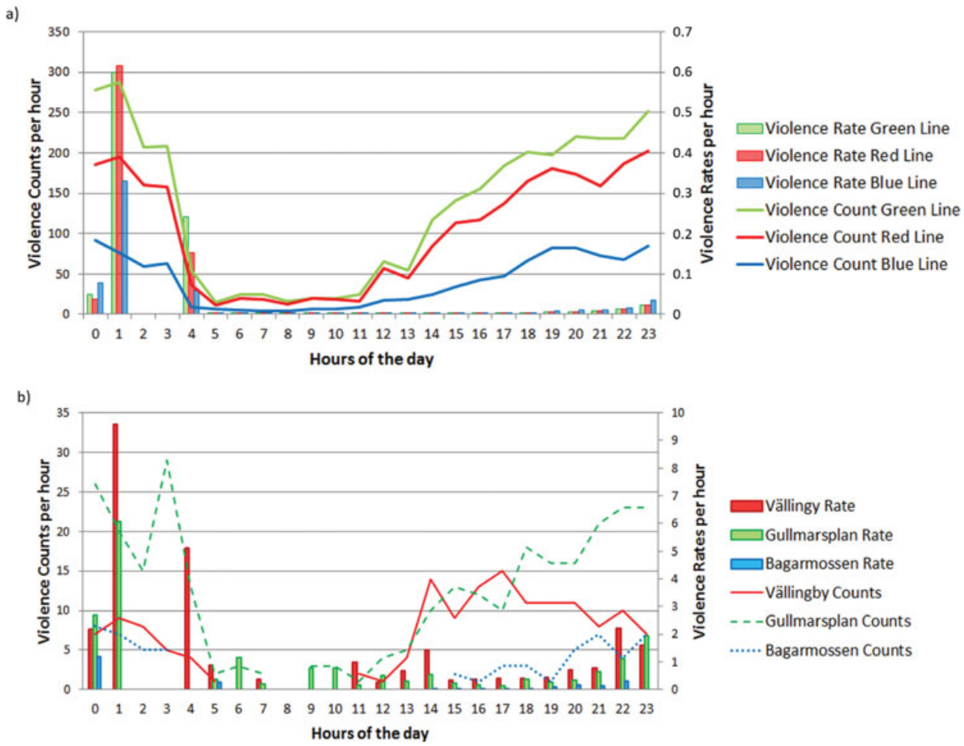


Figure 4. (A) Counts and rates of violence per hour of the day at all stations. (B) Counts and rates of violence per hour of the day in selected stations on the green line. (Color figure available online.)

Most crimes at underground stations that take place in late evening and at night are violent ones. Vandalism takes place more often during late evenings and thefts in the afternoon and early evening hours. If we take the example of events of violence (Figure 4A), a similar pattern over the day by hour in underground lines but with different gradients (first the green line, then the red and blue lines) is identified. The green line has more stations than the other lines, which affects the counts of crime in a number of ways: First, some of the green line stations are open longer than the rest of the underground system, which also affect the line's criminogenic conditions. Second, the green line is also embedded in a couple of high-crime neighborhoods. The crime rates on passenger flow vary according to different surroundings and geographical location in the city, presented by each different line. Moreover, particular stations on the same line can show a different crime pattern according to time and location (Figure 4B).

The difference between crime rates is also associated with the flow of passengers using the underground system (capability and coupling constraints), the stations' opening hours (authority constraint), and an expected time lag for recording each event. More interestingly, it can also be suggested that there are less people around during later hours, with fewer capable guardians present, and thus crime happens more easily. In addition, fewer travel companions are present and people are less personally secure, creating opportunities for crime (Cohen and Felson 1979). As some evening activities might not be performed on a daily basis, individuals' unfamiliarity with the station or lack of awareness of the area (Brantingham and Brantingham 1984) makes them potentially more vulnerable and a more likely target of crime.

Holidays show the highest crime rates, followed by weekends and weekdays. Fluctuations in passenger flows and routine patterns also affect crime activities, which increase when more people are on the move and develop unstructured activities. As expected, ANOVAs results show that the difference is statistically significant when it comes to differences between weekdays (Monday–Thursday) and holidays. A significant difference in levels of crime between weekdays and weekends was not found at the stations, however (Table 1).

Crime at stations varies seasonally (Table 2), but data sources show different patterns of concentration. Whereas police statistics show differences between winter and summer in favor of the warmer season, corroborating Quetelet's (1842) early results, the Stockholm Public Transportation data indicate that the greatest number of crimes against people was committed in the winter. Low temperatures forces passengers to wait indoors for trains at the stations, creating situations

Table 1. Differences in crime: Weekends, weekdays, and holidays

	Crime events	Crime average/day	*F* test	Scheffe
Weekend (1)	29,259	61.69	2,560.828*	1–3
Weekday (2)	27,823	48.28		2–3
Holiday (3)	5,152	132.10		3–1/3–2

Note: Data are from Stockholm Public Transportation database (2006–2009). Note that Scheffe 1–3 means that crime on the weekends (1) and on holidays (3) is statistically different from each other.
*Significant at 99% level.

more prone to violence than in the summer. Darker and snowy days in the winter make citizens more likely to take public transportation instead of cars. Alternatively, another reason for this mismatch between the police and the SL database is that police data cover a 100-m area around the stations (which often covers the station area and includes both entrances), whereas the other database only covers events that happened at the stations.

The effect of time variations depend on crime type. For instance, as compared to winter and autumn, better opportunities for thefts appear in the spring when people start going out more often. For vandalism, rates rise during the colder months of the year, as even for the offender it is more comfortable to damage or spray graffiti at the station than outdoors. Regardless of which season shows the highest concentration, the literature relates differences of crime to the influence of weather on human behavior (e.g., Anderson et al. 2000) and to changes in people's routine activities over the year (e.g., Ceccato 2005).

Table 2. Differences in crime by season

	Crime events	Crime levels mean	*F* test	Scheffe
All crime types SL				
Winter (4)	17,145	2.55	2,560.828*	4–1/4–2/4–3
Spring (1)	15,787			1–2/1–3/1–4
Summer (2)	13,503			2–1/2–3/2–4
Autumn (3)	15,830			3–1/3–2/3–4
Violent crime types SL				
Winter (4)	1,592	2.65	176.570*	4–1/4–2/4–3
Spring (1)	1,210			1–2/1–3/1–4
Summer (2)	1,054			2–1/2–3/2–4
Autumn (3)	1,583			3–1/3–2/3–4
Property crime types SL				
Winter (4)	79	2.43	24.207*	4–1/4–2/4–3
Spring (1)	99			1–3/1–4
Summer (2)	61			2–4
Autumn (3)	76			3–1/3-4
Vandalism crime types SL				
Winter (4)	1,100	2.53	167.238*	4–1/4–2/4–3
Spring (1)	1,072			1–2/1–3/1–4
Summer (2)	932			2–1/2–3/2–4
Autumn (3)	1,130			3–1/3–2/3–4

Note: Data are from Stockholm Public Transportation database (2006–2009). Note that Scheffe 4–1 means that crime in the winter (4) and in the spring (1) is statistically different from each other.
*Significant at 99% level.

Modeling Space–Time Variations of Crime at Underground Stations

Stations are not the same and, as previously suggested, their environments are bound to affect crime opportunities differently at different times of the day, week, and year. This section assesses whether different environmental features at the stations affect crime rates over time. Table 3 shows the results for total crime (for full details about violence and vandalism, see Appendix B).

Crime tends to happen during peak hours in peripheral larger stations (with many CCTVs), with hiding spots at the lounge area, the presence of drunk people but with not many people around. For off-peak hours, overcrowding in transition areas of the station affects crime: A higher number of people at stations tends to be associated with greater levels of crime. Regardless of time of day, presence of CCTV explains the variation in crime, suggesting that crime tends to be concentrated in bigger stations where more cameras are installed. Models of weekly variations of crime are associated with the following variables, operating for both holidays and weekdays: station being located centrally, having a cash machine installed, and visible security cameras. Holiday crime rate variations (Model C3) are also significantly influenced by crowded stations, the presence of physical deterioration, and an open layout of the lounge area. Weekday levels of crime see a strong influence of the presence of *systembolaget* (state alcohol selling outlets), littering, and the presence of drunken people (Model C4). During winter, crime at the stations is related to crowded stations that show signs of physical deterioration and those that are gathering places for drunks (Model C5). During the warmer months of the year, the proximity of outlets selling alcohol near the station is an important indicator of high crime rates.

There are variations by crime type (see Appendix B for results for violence and vandalism). Stations with cash machines, hidden corners, littering, and disturbances tend to have more violence during peak hours

Table 3. Ordinary least squares regression results of crime rates at underground stations (Log): Day variation, weekly variation, and seasonal variation models

	Peak hours (C1)		Off peak (C2)		Holidays (C3)		Weekdays (C4)		Winter (C5) December–February		Spring (C6) March–May	
Total crime	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values
Distance city	0.070	2.827	0.067	2.135	0.109	4.697	—	—	0.053	2.398	—	—
No. CCTV	0.013	4.048	0.012	3.345	0.031	9.892	0.029	11.839	0.033	11.976	0.031	9.858
P_Crowded	–0.233	–2.614	—	—	—	—	—	—	—	—	—	—
P_VendingMach	–0.126	–1.034	—	—	—	—	—	—	—	—	—	—
P_Seats	0.310	0.947	—	—	—	—	—	—	—	—	—	—
P_Disturbance	0.348	1.025	—	—	—	—	—	—	—	—	—	—
T_Sunlight	0.191	1.460	—	—	—	—	—	—	—	—	—	—
T_Hiding	0.255	1.971	—	—	—	—	—	—	—	—	—	—
T_Crowded	—	—	0.252	2.719	0.302	2.809	0.177	1.976	—	—	0.145	1.413
T_EscalatorU	–0.007	–0.052	—	—	—	—	—	—	—	—	—	—
T_Niceness	–0.114	–1.343	—	—	—	—	—	—	—	—	—	—
T_View	—	—	–0.223	–1.441	–0.073	–0.620	—	—	—	—	—	—
T_ElevatorSmell	—	—	–0.092	–0.922			—	—	—	—	—	—
T_Litter	0.009	0.017	0.312	0.656	—	—	1.011	3.045	—	—	—	—
T_Drunken	—	—	–0.842	–1.754	—	—	—	—	—	—	—	—
E_Hiding	–0.329	–2.563	–0.187	–1.067	—	—	–0.319	–2.779	—	—	–0.372	–3.022
E_EscalatorU	–0.451	–2.983	–0.469	–2.232	—	—	—	—	—	—	—	—
E_EscalatorD	0.313	1.660	0.373	1.522	—	—	—	—	—	—	0.156	0.994
E_Drunken	0.589	1.900	0.515	1.106	0.589	1.874	0.635	2.262	0.780	2.531	—	—
E_Visibilty	–0.118	–1.218	–0.133	–0.967	—	—	—	—	—	—	—	—
E_OpenSpace	0.029	0.227	–0.145	–0.859	—	—	—	—	—	—	—	—
E_RoughMaterial	0.169	0.746	0.282	1.029	—	—	—	—	—	—	—	—
No. ATM	—	—	—	—	0.347	4.903	0.299	4.733	0.369	5.671	0.262	3.733
Systembolaget	—	—	—	—	0.344	2.016	0.453	3.062	0.341	2.102	0.482	2.989
P_Blocking	—	—	—	—	–0.073	–0.497	—	—	—	—	–0.257	–1.908
P_Walledoff	—	—	—	—	0.036	0.270	—	—	—	—	–0.113	–0.940
L_OpenSpace	—	—	—	—	0.246	1.898	—	—	—	—	—	—
L_VendingMach	—	—	—	—	0.559	1.011	—	—	—	—	—	—
L_Crowded	—	—	—	—	–0.044	–0.422	—	—	—	—	—	—
E_Longwalk	—	—	—	—	–0.654	–4.458	—	—	–0.446	–3.524	—	—
E_Deterioration	—	—	—	—	0.360	2.625	0.196	1.688	0.324	2.496	0.238	1.893
E_Crowded	—	—	—	—	0.031	0.287	0.053	0.608	—	—	0.051	0.499
E_Sunlight	—	—	—	—	0.188	1.558	—	—	—	—	0.186	1.656
T_Guards	—	—	—	—	—	—	—	—	—	—	0.266	1.061
L_Crowded	—	—	—	—	—	—	—	—	—	—	0.043	0.445
L_Hiding	—	—	—	—	—	—	—	—	0.098	0.836	—	—
W_Crowded	—	—	—	—	—	—	—	—	0.139	1.836	—	—
W_Disorder	—	—	—	—	—	—	—	—	0.036	0.246	—	—
R^2	0.535		0.404		0.815		0.816		0.802		0.811	
Input variables	$n = 18$		$n = 14$		$n = 16$		$n = 9$		$n = 10$		$n = 13$	

Note: P = platform; L = lounge; T = transition area; E = exit area; W = winter (variable's conditions in the winter); No. ATM = presence of ATM inside the station; Blocking = many structures (objects) blocking view; No. CCTV = number of CCTVs placed at a station; Distance City = distance from city center; Crowded = overall crowded at the station: low (0 – 5), med (6 – 10), high (11+); Deterioration = any other physical deterioration at the place; Disturbance = presence of social disturbance (loud speech, kids fooling around); Drunken = presence of drunk or homeless; ElevatorSmell = elevator smells or has lot of graffiti; EscalatorD = escalator(s) going down; EscalatorU = escalator(s) going up; Guards = presence of private guards; Hiding = hiding places; Litter = presence of any litter; Niceness = the place has nice, pleasant atmosphere; OpenSpace = layout is open without walls and roof; RoughMaterial = area (partly) built of rough material; Seats = presence of seats or benches; Disorder = presence of social disorder; Sunlight = sunlight easily illuminates the covered places; Systembolaget = number of alcohol selling premises within 100 m; VendingMach = vending machines; View = clear view from outside; Visibility = everything is visible at the place; Longwalk = long walking distance; Walledoff = walls between two areas.

(Model V1), whereas during off-peak hours, fights happen in larger peripheral stations, indicated by number of platforms and distance to the city center (Model V2). Regardless of the time of day, vandalism takes place in stations with few passengers around but during peak hours (Model D1). The significant variables are the presence of a cafe, light platforms, fewer entrances, and stations farther from the center of the city. During off-peak hours, vandalism is often associated with increased visibility (Model D2), which may indicate that these are modern, more peripheral, above ground stations.

Two thirds of the variation in violence rates at stations is explained by the stations' locations, their environmental features, and characteristics of the surrounding areas. Models of the variations of violent crimes on holidays (Model V3) show that variables such as peripheral stations with a high population density within 500 m of stations, stations with cash machines, crowded stations, and the presence of social disorder are significant. For weekdays, however, the model shows that CCTVs and high visibility at platforms do not deter violence, perhaps because a station's layout has many hiding spots (Model V4). Surprisingly, vandalism during the holidays is not related to the location of schools (Model D3), but it is often related to large crowded stations with cash machines, location on the outskirts of the city, and the presence of drunken people. On weekdays, large and open peripheral stations (with CCTVs and cafes) are more targeted by vandalism.

In the winter, when violence is highest, violent acts take place in those open stations with many hidden corners and littering (Model V5). During the spring, crime rates are related to stations with outlets selling alcohol nearby but, unexpectedly, with few hiding spots (Model V6). Regardless of the season, violence often happens in bigger stations that have cash machines. During the winter, vandalism happens in stations with corners at platforms, seating opportunities (benches), and social disturbances (Model D5), whereas in the spring, the stations most affected by vandalism are open stations and those with escalators (Model D6).

Discussion of Modeling Results

The effect of stations' physical and social environments on crime varies over time. For example, crime is concentrated in peripheral stations with fewer people around during peak hours (when individuals are intensively moving around and perhaps because offenders run a lower risk of being caught at those transport nodes) but, during off-peak hours, the crime dynamics change. For the offender to couple up with a passenger's routine paths, he or she has to seek targets in busy stations during off-peak hours where more targets are present and, as suggested by rational choice theory (Becker 1968), where the risk of being caught might be low. Despite the fact that people are at stations, they might not be willing to (or might be unable to) exercise social control over the area because they are on the move. In certain areas, the stations belong to a socially disorganized neighborhood (Shaw and McKay 1942), where the effectiveness of social control is low. Couplings of activities at the station (Hägerstrand 1970), particularly in the colder months of the year, promote opportunities for crime (Cohen and Felson 1979) that would not happen otherwise. The cold also makes people want to wait inside the stations at the platform or entrance for the train to arrive. Frictions could arise easily in a crowded station. In the city, during the cold months, drunken people seek warmer places with easy access, often using the entrances to underground stations. Our findings show that the increased presence of litter and drunken people spending time at stations are often associated with increased recorded levels of offense. Safety at the stations is therefore an expression of the conditions in the neighborhoods in which they are located. Seasonal variations are closely related to individuals' activities, and promotion of crime opportunities during summer activities (e.g., leisure, party, drinking outside) is a catalyst for crime to happen, particularly violent crimes.

The international literature has indicated that certain land uses (e.g., schools, restaurants) attract crime (Byrne 1986; Greenberg 1986; Roneck and Maier 1991; Block and Block 1995, 2000). In Stockholm's underground stations, mixed results have been found. Distance to schools had no effect on crime or, as in the case of vandalism, a negative one. If the station is close to a state outlet that sells alcohol, however, crime is higher during weekdays, holidays, and spring. Previous literature has indicated the effect of inner-city areas on crime levels at the underground stations (e.g., Loukaitou-Sideris 1999; Loukaitou-Sideris, Liggett, and Iseki 2002). In Stockholm, however, particularly during holidays and the winter season, when more violence takes place, large stations on the outskirts of the city (in some cases, end stations) are also vulnerable to fights and other acts of violence as those located in the inner-city areas.

There are, however, common patterns regardless of the environment of these transport nodes. Daily crime patterns are mostly a result of an individual's daily activities and crime opportunities at different parts of the underground system and at certain sections of the stations. As proposed by Hägerstrand (1970), most people are bound to follow particular patterns of movement during the week with fixed schedules. Crime might happen because these patterns are confined in time and space, offenders have a very specific target time span, and people are concentrated in a small space. An underground station is a perfect example of a small space that forms part of a daily routine for many and where an offender can be sure to find a suitable victim during peak hours. It is here that the space–time paths of people line up together (Hägerstrand 1970). Weekly crime variations are mainly a result of individuals' patterns of structured and unstructured activities, such as work and leisure. Variations of crimes during weekdays, weekends, and holidays reflect changes in people's routine activity. Besides these times, crime during weekdays is affected by abnormal or out-of-schedule activities. Alcohol consumption seems to play a role in defining crime during holidays, in contrast to normal weekdays when it is rather unusual things such as social disturbance and litter that motivate offenders to choose that place for crime.

Seasonal crime variations are dependent on previously mentioned factors but also on constraints of weather imposed on the individual's movement patterns, with more use of public transportation and crowded stations with poor guardianship, as our results presented for winter conditions. Peripheral large stations (with CCTVs, cash machines, and state outlets selling alcohol) with signs of physical deterioration and the presence of drunken people are often the more problematic stations that concentrate all sorts of crime. As previously indicated by Wilson and Kelling (1982), places that show signs of low social control, where litter is left on the floor and not taken care of, attract offenders, who see the opportunity and take advantage of the uncontrolled circumstances. In the same line of thought, our findings indicate that fights happen as the individuals are caught or pushed to dark corners of the station where no one has any view of what really is going on. These results corroborate the evidence that dark corners and hiding places decrease the potential for surveillance, as suggested by Loukaitou-Sideris, Liggett, and Iseki (2002) and Ceccato, Uittenbogaard, and Bamzar (2013).

Conclusions and Looking Ahead

The city's urban fabric guides individuals' movement patterns, as one is bound to follow the layout of routes on the transportation system toward the destination. Coupling constraints make transport nodes typical areas of convergence at certain time windows, where social interactions intensify and where crime might take place. By making full use of the detailed crime data available, this study shows shifts in crime patterns over time at the stations, following rhythmic cycles that characterize people's movement through the city, over the week, and even seasonally.

As previously suggested, for crime to occur there must be three elements in place in both space and time: the presence of a motivated offender, a suitable target, and absence of capable guardians (Cohen and Felson 1979; Felson 1994; Felson and Clarke 1998). The dynamics of crime at peak hours and off-peak hours are not the same, however, as they are associated with particular conditions at the stations (e.g., opportunities for crime and social control) but also with the individual characteristics of passengers who pass by. This obligatory temporary encounter between motivated offenders and a potential victim is a condition for crime to occur but it does not always explain why and when it happens (and often it does not). One way to interpret this is to assume that the urban environment does not affect individuals equally; its impact might interact with individuals' characteristics and settings to which the individual might be exposed over time (Wikström 2005). Although this reasoning was initially applied to explain individuals' decisions to offend, it is suggested here that this principle can be applied to understand why certain places and times are chosen by offenders to offend. In other words, the specific vulnerability to crime of a transport node varies over time and space, according to the way settings and their environmental contexts affect individuals passing by.

Indicators of the physical environment of the stations (e.g., presence of CCTV, hiding spots, physical obstacles) together with those that characterize their social environment (e.g., events of social disturbance at platforms, crowded transition areas) were significant to explain the variation of crime rates. These findings indicate that (1) safety at the underground stations is not only a function of the internal physical environment, but also of the social interactions that take place at the stations; (2) events at the station are a result of the type of surroundings wherein these transport nodes are embedded, in relation to both the type of neighborhood (e.g., deprived area) and the place the station has in the city contexts, for instance, as a peripheral transport hub; (3) an assessment of crime in underground stations provides us with snapshots of a city's overall risk over time and space using aggregated data.

The study provided the possibility to capture snapshots of movement in slices of time of a pulsing city. The methodology, as presented in this study, allows the assessment of crime at underground stations over time, which is an indicator of passenger flows and the city's overall risk using aggregated data. One of the advantages of this methodology is that it does not require individual-based data to produce an indication of risk for crime as in most current studies on space–time crime, based on offenders' movement patterns (Bichler, Christie-Merrall, and Sechrest 2011; Ceccato and Wikström 2012; Rey et al. forthcoming). Moreover, instead of crime counts only (which often overestimate the levels of crime in large stations), this study shows the importance of using number of events per passenger flow. The analysis also combines different data sources, often complementary, to provide a comprehensive picture of what happens at the transport nodes. The article does, however, share limitations with other analyses of this type, for instance, on the reliance on data of events reported by personnel or by victims at the stations, which implies different issues regarding data quality. Another limitation is that the fieldwork in the winter covered a selection only of variables that were thought to be vulnerable to seasonal variations (illumination, overcrowding, and littering). An extensive inspection of the physical and social environmental features of the stations should be performed for a complete and comparable seasonal analysis. Moreover, the modeling strategy adopted here has proven to produce meaningful results. Another, perhaps more appropriate, strategy, however, is multilevel modeling, which potentially has the capacity to capture the nested nature of the parts of the stations as well as the station in winter context.

The method also has practical implications. As suggested by Hirschfield, Brown, and Bowers (1995), the discovery of spatiotemporal patterns of regularities is the first step in the definition of more finely targeted resources to tackle unsafe places and formulate preventive strategies, as done in this study. For planning safety, this development potentially affects how safety services are guided by the level of detailed data on individuals in time and space and the level of interactivity they could share with agencies and data holders using aggregated data by station. In the near future, however, better grounds to assess the risk of crime can help individuals to make dynamic decisions as they move, as well as helping police enforcement to be in the right place at right time. This means that geographical information captured by opportunistic sensors (e.g., mobile phones) can be used to gather data on individuals' behaviors, their risks, and their safety perceptions in real time across city environments. Although individuals' daily mobility seems to be characterized by a deep-rooted regularity, explicit predictions on user whereabouts can be explored by using data-mining algorithms and geographical information to improve urban safety. The challenges in using detailed geographical information-related techniques as support for research and planning in urban safety are not merely linked to the data, theory, or tools themselves but to the way in which all of these are used in practice. For instance, the location and mobility information requires privacy-enhancing solutions that are not yet in place, which is perhaps one of the main challenges for future research on urban safety.

Acknowledgments

We are grateful for the comments from participants of the session of 2011's conference of the American Society of Criminology in Washington, DC, particularly, Professor Kim Rossmo, Texas State University, as well as from anonymous referees and the editor of this journal. We thank the Swedish Transport Administration (Traffikverket), Stockholm Public Transport (SL), Stockholm municipality and CEFIN-KTH for financing this research project. We also thank police in Stockholm County, Stockholm Statistics, Stockholm Public Transport (SL), and Veolia for providing data for the analysis.

Notes

1. For an extensive discussion of the concept of urban fabric, see Ceccato (2012).
2. Note that although both the police-recorded data and SL data show similar temporal recording patterns, they differ by crime type and different parts of the transportation network. For more details see Ceccato, Uittenbogaard, and Bamzar (2013).

References

Anderson, C. A., K. B. Anderson, N. Dorr, K. M. DeNeve, and M. Flanagan. 2000. Temperature and aggression. In *Advances in experimental social psychology*, ed. M. P. Zanna, 33–133. New York: Academic.

Andresen, M. A. 2006. Crime measures and the spatial analysis of criminal activity. *British Journal of Criminology* 46:258–85.

Andresen, M. A., and S. J. Linning. 2012. The (in)appropriateness of aggregating across crime types. *Applied Geography* 35:275–82.
Becker, G. 1968. Crime and punishment: An economic approach. *The Journal of Political Economy* 76:169–217.
Bichler, G., J. Christie-Merrall, and D. Sechrest. 2011. Examining juvenile delinquency within activity space: Building a context for offender travel patterns. *Journal of Research in Crime and Delinquency* 48:472.
Block, R. L., and C. R. Block. 1995. Space, place, and crime: Hot-spot areas and hot places of liquor-related crime. In *Crime and place*, ed. J. E. Ech and D. Weisburd, 145–84. Monsey, NY: Criminal Justice Press.
———. 2000. The Bronx and Chicago: Street robbery in the environs of rapid transit stations. In *Analyzing crime patterns: Frontiers in practice*, ed. V. Goldsmith, P. McGuire, J. Mollenkopf, and T. Ross, 137–53. London: Sage.
Brantingham, P. J., and P. L. Brantingham. 1984. *Patterns in crime*. New York: Macmillan.
———. 1993. Nodes paths and edges: Considerations on the complexity of crime and the physical environment. *Journal of Environmental Psychology* 13:3–28.
———. 1995. Criminality of place: Crime generators and crime attractors. *European Journal on Criminal Policy and Research* 3 (3): 1–26.
Bromley, R. D. F., and A. L. Nelson. 2002. Alcohol related crime and disorder across urban space and time: Evidence from a British city. *Geoforum* 33 (2): 239–54.
Byrne, J. 1986. Cities, citizens, and crime: The ecological/nonecological debate reconsidered. In *The social ecology of crime*, ed. J. Byrne and R. J. Sampson, 77–101. New York: Springer-Verlag.
Ceccato, V. 2005. Homicide in São Paulo, Brazil: Assessing spatial-temporal and weather variations. *Journal of Environmental Psychology* 25:307–21.
———. 2012. Introduction. In *The urban fabric of crime and fear*, ed. V. Ceccato, 3–33. Dordrecht, The Netherlands: Springer.
———. 2013. From "defensible space" to "space of flows": Integrating geographical information into urban safety research and planning. *Urban Design and Planning* 166:15–23.
Ceccato, V., and R. Haining. 2004. Crime in border regions: The Scandinavian case of Öresund, 1998–2001. *Annals of the Association of American Geographers* 94:807–26.
Ceccato, V., and D. Oberwittler. 2008. Comparing spatial patterns of robbery: Evidence from a Western and an Eastern European city. *Cities* 25 (4): 185–96.
Ceccato, V., A. C. Uittenbogaard, and R. Bamzar. 2013. Security in Stockholm's underground stations: The importance of environmental attributes and context. *Security Journal* 26:33–59.
Ceccato, V., and P. Wikström. 2012. City environments, individual activity patterns and offending. In *The urban fabric of crime and fear*, ed. V. Ceccato, 165–90. New York: Springer.
Clarke, R. V., and D. B. Cornish. 1985. Modeling offenders' decisions: A framework for research and policy. *Crime and Justice: An Annual Review of Research* 6:147–85.
Clarke, R. V., and M. Felson. 1993. *Routine activity and rational choice: Advances in criminological theory*. Vol. 5. New Brunswick: NJ: Transaction Books.
Cohen, L. E., and M. Felson. 1979. Social change and crime rate trends: A routine activity approach. *American Sociological Review* 44:588–605.
Cohn, E. G. 1990. Weather and crime. *British Journal of Criminology* 30:51–64.
Cohn, E. G., and J. Rotton. 2003. Even criminals take a holyday: Instrumental and expressive crimes on major and minor holidays. *Journal of Criminal Justice* 31:351–60.
Cornish, D. B., and R. V. Clarke. 1986. *The reasoning criminal: Rational choice perspectives on offending*. New York: Springer-Verlag.
Cozens, P., R. Neale, J. Whitaker, and D. Hillie. 2003. Making crime and the fear of crime at railway stations—A case study in South Wales (UK). *International Journal of Transport Management* 1:121–32.
Fagan, J., and R. B. Freeman. 1999. Crime and work. *Crime and Justice: A Review of Research* 25:225–90.
Felson, M. 1994. *Crime and everyday life: Insights and implications for society*. Thousand Oaks, CA: Pine Forge Press.
———. 2006. *Crime nature*. London: Sage.
Felson, M., and R. Clarke. 1998. Opportunity makes the thief. Police Research Series, Paper 98, Policing and Reducing Crime Unit, Research, Development and Statistics Directorate, London. http://www.skywallnet.com/data_server/CA/OMT_PP_CP.pdf (last accessed 21 May 2013).
Felson, M., D. Dickman, D. Glenn, L. Kelly, G. Lambard, L. Maher, L. Nelson-Green, et al. 1990. Preventing crime at Newark subway stations. *Security Journal* 1 (3): 137–42.
Foster, S., and B. Giles-Corti. 2008. The built environment, neighborhood crime and constrained physical activity: An exploration of inconsistent findings. *Preventive Medicine* 47 (3): 241–51.
Gaylord, M. S., and J. F. Galliher. 1991. Riding the underground dragon: Crime control and public order on Hong Kong's mass transit railway. *British Journal of Criminology* 31 (1): 15–26.
Greenberg, S. 1986. Fear and its relationship to crime, neighborhood deterioration, and informal social control. In *The social ecology of crime*, ed. J. Byrne and R. J. Sampson, 47–62. New York: Springer-Verlag.
Hägerstrand, T. 1970. What about people in regional science? *Papers of the Regional Science Association* 24:7–21.
Harris, O. 1971. A methodology for developing security design criteria for subways. Report No. UMTA-URT-5 (70)-71-4. Urban Mass Transit Administration, Washington, DC.
Hawley, H. A. 1950. *Human ecology: A theory of community structure*. New York: Ronald.
———. 1973. The presidential address: Cumulative change in theory and in history. *American Sociological Review* 43:787–96.
Hirschfield, A. F., P. J. Brown, and K. J. Bowers. 1995. Exploring relations between crime and disadvantage on Merseyside. *European Journal on Criminal Policy and Research* 3 (3): 93–112.
Jackson, J., and E. Gray. 2010. Functional fear and public insecurities about crime. *British Journal of Criminology* 50 (1): 1–22.
Jacobs, J. 1961. *The death and life of great American cities*. New York: Vintage Books.

Kwan, M. P. 1998. Space–time and integral measures of individual accessibility: A comparative analysis using a point-based framework. *Geographical Analysis* 30 (3): 191–216.

Kwan, M. P., and J. Lee. 2003. Geovisualization of human activity patterns using 3D GIS: A time-geographic approach. In *Spatially integrated social science: Examples in best practice*, ed. M. F. Goodchild and D. G. Janelle, 48–66. Oxford, UK: Oxford University Press.

Kulldorff, M. 2010. *SaTScan user guide for version 9.0*. http://www.satscan.org (last accessed 21 October 2013).

LaVigne, N. G. 1997. *Visibility and vigilance: Metro's situational approach to preventing subway crime*. National Institute of Justice-Research in Brief. Washington, DC: U.S. Department of Justice.

Lenntorp, B. 1976. *Paths in space–time environments: A time geographic study of movement possibilities of individuals*. Lund Studies in Geography Number 44. Lund, Sweden: Royal University of Lund.

Loukaitou-Sideris, A. 1999. Hot spots of bus stop crime: The importance of environmental attributes. *Journal of the American Planning Association* 65 (4): 395–411.

———. 2006. Is it safe to walk? Neighborhood safety and security considerations and their effects on walking. *Journal of Planning Literature* 20 (3): 219–32.

———. 2012. Safe on the move: The importance of the built environment. In *The urban fabric of crime and fear*, ed. V. Ceccato, 85–110. Dordrecht, The Netherlands: Springer.

Loukaitou-Sideris, A., R. Liggett, and H. Iseki. 2002. The geography of transit crime: Documentation and evaluation of crime incidence on and around Green Line Stations in Los Angeles. *Journal of Planning Education and Research* 22 (2): 135–51.

Miller, H. 2004. Activities in space and time. In *Handbook of transport 5: Transport geography and spatial systems*, ed. D. Hensher, K. Button, K. Haynes, and P. Stopher, 647–60. Amsterdam: Elsevier Science.

———. 2005. Place-based versus people-based accessibility. In *Access to destinations: Rethinking the transportation future*, ed. D. Levinson and K. J. Krizek, 63–89. London: Elsevier.

Myhre, M., and F. Rosso. 1996. Designing for security in meteor: A projected new metro line in Paris. *Preventing Mass Transit Crime: Crime Prevention Studies* 6:199–216.

Newman, O. 1972. *Defensible space*. New York: Macmillan.

Newton, A. 2004. Crime on public transport: "Static" and "non-static" (moving) crime events. *Western Criminology Review* 5 (3): 25–42.

Perkins, D. D., A. Abraham, R. Richard, and B. Taylor. 1993. The physical environment of street crime. *Journal of Environmental Psychology* 13:29–49.

Peuquet, D. J. 2000. Space–time representation: An overview. In *Time in GIS: Issues in spatio-temporal modeling*, ed. L. Heres, 5. Delft, The Netherlands: Geodetic Commission.

Piza, E., and D. Kennedy. 2003. Transit stops, robbery, and routine activities: Examining street robbery in Newark, NJ subway environment. http://proceedings.esri.com/library/userconf/proc04/docs/pap1303.pdf (last accessed 21 May 2013).

Quetelet, A. J. 1842. *A treatise on man and the development of his faculties: A fascism reproduction of the English translation of 1842*. Gainesville, FL: Scholar's Facsimiles and Reprints.

Ratcliffe, J. 2006. A temporal constraint theory to explain opportunity-based spatial offending patterns. *Journal of Research in Crime and Delinquency* 43:261.

Rey, S. J., A. T. Murray, T. H. Grubesic, E. Mack, R. Wei, L. Anselin, and M. Griffin. Forthcoming. Sex offender residential movement patterns: A Markov chain analysis. *The Professional Geographer*. doi:10.1080/00330124.2013.765293.

Reynald, D. M. 2011. *Guarding against crime. Measuring guardianship within routine activity theory*. Surrey, UK: Ashgate.

Roneck, D., and P. Maier. 1991. Bars, blocks, and crimes revisited: Linking the theory of routine activities to the empiricism of hot spots. *Criminology* 29:725–54.

Ross, C. E. 1993. Fear of victimization and health. *Journal of Quantitative Criminology* 9 (2): 159–75.

Scarry, R. 1968. *What do people do all day?* New York: Random House.

Shaw, C. R., and H. D. McKay. 1942. *Juvenile delinquency in urban areas*. Chicago: University of Chicago Press.

Sherman, L. W., P. R. Gartin, and M. E. Buerger. 1989. Hot spots of predatory crime: Routine activities and the criminology of place. *Criminology* 27 (1): 27–56.

Skogan, W. G. 1990. *Disorder and decline: Crime and the spiral of decay in American neighborhoods*. New York: Macmillan.

Smith, M., and R. Clarke. 2000. Crime and public transport. In *Crime and justice: A review of the Research*, ed. M. Tonry and N. Morris, 169–233. Chicago: University of Chicago Press.

Smith, M. J., and D. B. Cornish. 2006. *Secure and tranquil travel—Preventing crime and disorder on public transport*. London: UCL Jill Dando Institute of Crime Science, University of London.

Song, C., Q. Zehui, N. Blumm, and A. L. Barabás. 2010. Limits of predictability in human mobility. *Science* 327:1018.

Stark, R. 1987. Deviant places: A theory of the ecology of crime. *Criminology* 25:893–909.

Stockholm Public Transport (SL). 2006–2009. *Databases of crime reports to the central reporting point*. Stockholm: SL.

Thrift, N. J. 1977. *An introduction to time geography*. Norwich, UK: University of East Anglia.

Uittenbogaard, A. C., and V. Ceccato. 2012. Space–time clusters of crime in Stockholm, Sweden. *Review of European Studies* 4:148–56.

Webb, B., and G. Laycock. 1992. Reducing crime on the London Underground: An evaluation of three pilot projects. Paper No. 30, Crime Prevention Unit, London.

Weisburd, D., N. Morris, and E. Groff. 2009. Hot spots of juvenile crime: A longitudinal study of Arrest Incidents at Street Segments in Seattle, Washington. *Journal of Quantitative Criminology* 25:443–467.

Wikström, P-O. 1991. *Urban crime, criminals, and victims: The Swedish experience in an Anglo-American comparative perspective*. Stockholm, Sweden: Springer-Verlag.

———. 2005. The social origins of pathways in crime: Towards a developmental ecological action theory of crime involvement and its changes. In *Testing integrated developmental/life course theories of offending: Advances in criminological theory*, ed. D. P. Farrington, 211–45. New Brunswick, NJ: Transaction.

Wilson, J. Q., and G. Kelling. 1982. The police and neighborhood safety: Broken windows. *Atlantic* 127:29–38.

Correspondence: CEFIN, School of Architecture and the Built Environment, Royal Institute of Technology, Drottning Kristinas väg 30, 10044 Stockholm, Sweden, e-mail: vania.ceccato@abe.kth.se (Ceccato); Department of Real Estate and Finance, School of Architecture and the Built Environment, Royal Institute of Technology, Drottning Kristinas väg 30, 10044 Stockholm, Sweden, e-mail: acui@kth.se (Uittenbogaard).

Appendix A: The Stockholm Underground System

Source: AB Storstockholms Lokaltrafik, 2013. (Color figure available online.)

Appendix B. Ordinary least squares regression results of violence and vandalism rates at underground stations (Log): daily variation, weekly variation, and seasonal variation models

	Peak hours (V1)		Off peak (V2)		Holidays (V3)		Weekdays (V4)		Winter (V5) December–February		Spring (V6) March–May	
	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values
Violence												
Distance city	0.049	1.825	0.096	4.509	0.055	2.105	0.088	2.384	0.062	2.045	0.073	2.328
No. CCTV	0.245	3.158	—	—	—	—	0.034	3.403	0.028	6.818	0.023	3.419
P_Corners	0.423	2.358	—	—	—	—	—	—	—	—	—	—
P_litter	0.447	2.448	—	—	—	—	0.556	1.856	—	—	—	—
P_Disturbance	1.259	3.157	—	—	—	—	—	—	—	—	—	—
E_Hiding	–0.416	–2.501	—	—	—	—	—	—	—	—	–0.376	–2.121
E_Sunlight	0.255	1.862	—	—	0.355	2.470	—	—	—	—	—	—
P_Drunken	—	—	–0.444	–2.299	—	—	—	—	—	—	—	—
P_Number	—	—	0.359	3.821	—	—	—	—	—	—	—	—
E_Longwalk	–0.414	–2.234	—	—	–0.497	–2.798	—	—	–0.545	–3.187	—	—
E_EscalatorU	—	—	–0.360	–2.689	—	—	—	—	—	—	—	—
No. ATM	—	—	—	—	0.377	4.394	0.430	3.956	0.335	3.640	0.405	4.336
L_Crowded	—	—	—	—	0.168	2.009	—	—	—	—	—	—
P_Overview	—	—	—	—	—	—	0.581	2.201	—	—	—	—
L_Visibility	—	—	—	—	—	—	0.404	2.337	—	—	—	—
L_Hiding	—	—	—	—	—	—	0.392	1.916	0.367	2.004	—	—
S_PopDensity	—	—	—	—	1.029	2.417	—	—	—	—	—	—
E_SocialDisord	—	—	—	—	0.804	2.259	—	—	—	—	—	—
P_CCTVvisible	—	—	—	—	—	—	—	—	—	—	—	—
T_Crowded	—	—	—	—	—	—	—	—	—	—	—	—
Systembolaget	—	—	—	—	—	—	—	—	—	—	0.426	1.832
L_OpenSpace	—	—	—	—	—	—	—	—	0.492	2.668	0.331	1.858
L_Underground	—	—	—	—	—	—	—	—	—	—	–0.523	–2.969
L_ElectroGates	—	—	—	—	—	—	—	—	0.328	2.203	—	—
W_Litter	—	—	—	—	—	—	—	—	0.254	1.758	—	—

(*Continued on next page*)

Appendix B. Ordinary least squares regression results of violence and vandalism rates at underground stations (Log): daily variation, weekly variation, and seasonal variation models (*Continued*)

	Peak hours (V1)		Off peak (V2)		Holidays (V3)		Weekdays (V4)		Winter (V5) December–February		Spring (V6) March–May	
	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values	Coefficient	*t* values
R^2	0.614		0.477		0.710		0.695		0.767		0.720	
Input variables	$n = 20$		$n = 4$		$n = 14$		$n = 17$		$n = 21$		$n = 17$	
Vandalism												
Distance City	0.116	3.746	0.106	2.110	0.111	4.115	0.074	2.616	0.063	2.242	—	—
No. CCTV					0.014	3.684	0.014	3.711	0.014	3.612	0.015	4.138
No. Schools	—	—	–0.458	–0.839	–0.290	–2.031	—	—	—	—	—	—
P_ Sunlight	0.424	2.531			—	—	0.333	2.109	—	—	0.374	1.739
P_Crowded	–0.270	–2.109	–0.356	–1.898	—	—	—	—	—	—	—	—
L_Cafe	0.419	1.932	—	—	—	—	0.386	1.950	—	—	—	—
L_Photobooth	–0.873	–2.699	—	—	—	—	—	—	—	—	—	—
L_Drunken	–0.836	–1.823	—	—	—	—	—	—	—	—	—	—
E_Longwalk	–0.709	–3.625	—	—	–0.384	–2.076	—	—	–0.336	–1.983	—	—
T_Surveillance	—	—	0.382	1.974	—	—	—	—	—	—	—	—
No. ATM	—	—	—	—	0.166	1.863	—	—	—	—	—	—
T_Crowded	—	—	—	—	0.200	2.181	—	—	—	—	—	—
E_Sunlight	—	—	—	—	0.348	2.438	—	—	—	—	—	—
E_Drunken	—	—	—	—	0.895	2.471	—	—	—	—	—	—
T_EscalatorU	—	—	—	—	—	—	—	—	—	—	0.548	2.951
E_RoughMaterial	—	—	—	—	—	—	—	—	—	—	–0.684	–2.427
P_Corners	—	—	—	—	—	—	—	—	0.536	2.933	—	—
E_Seats	—	—	—	—	—	—	—	—	0.304	1.851	—	—
W_Disorder	—	—	—	—	—	—	—	—	0.457	2.438	—	—
R^2	0.664		0.574		0.544		0.278		0.402		0.468	
Input variables	$n = 12$		$n = 14$		$n = 15$		$n = 9$		$n = 10$		$n = 13$	

Note: P = platform; L = lounge; T = transition area; E = exit area; W= winter (variable's conditions in the winter); No. ATM = presence of ATM inside the station; Cafe = presence of cafes; No. CCTV = number of CCTVs placed at a station; Distance City = distance from city center; Corners = presence of dark corners; Crowded = overall crowded at the station: low (0 – 5), med (6 – 10), high (11+); Disturbance = presence of social disturbance (loud speech, kids fooling around); Drunken = presence of drunk or homeless; EscalatorU = escalator(s) going up; ElectroGates = type of gates available at lounges (old = 1, new = 2, mix = 3); Hiding = hiding places; Litter = presence of any litter; Number = number of platforms at station; OpenSpace = layout is open without walls and roof; Overview = clear view from outside; Photobooth = presence of photo booth; PopDensity = population density; RoughMaterial = area (partly) built of rough material; Seats = presence of seats or benches; CCTVvisible = CCTVs are placed and visible; No. Schools = number of schools within 100 m; Disorder = presence of social disorder; SocialDisord = presence of social disorder; Sunlight = sunlight easily illuminates the covered places; Surveillance = possibility of surveillance by others; Systembolaget = number of alcohol selling premises within 100 m; Underground = located underground; Visibility = everything is visible at the place; Longwalk = long walking distance.

Eur J Crim Policy Res
DOI 10.1007/s10610-013-9212-8

Safety in Stockholm's Underground Stations: An Agenda for Action

Adriaan Uittenbogaard · Vania Ceccato

Abstract The objective of this article is to propose an agenda for interventions to prevent or reduce crime and disorder at underground stations in Stockholm, the capital of Sweden. The article first reports the nature, the levels, and the patterns of crime and disorder across time and space. Different types of crime are analyzed and specific conclusions are drawn for each type of crime which relate to the suggested interventions presented in this article. Findings lend weight to principles of situational crime prevention to improve security in transport nodes, with overlaps with routine activity and social disorganization theories. Intervention measures comprehend suggestions on both environmental design related changes and more complex social aspects regarding the reduction of crime at transport nodes. Suggestions for interventions at Stockholm's underground stations, as presented here, constitute an illustration of what can be achieved with situational crime prevention principles; however, they may not be regarded as a "one-size-fits-all" solution to the demands and challenges of safety in transport nodes elsewhere.

Keywords Crime prevention · Offences · Safety · Subway · Transport nodes

Introduction

Crimes cannot be properly explained, nor effectively prevented, without a deep understanding of the environments in which they occur. Nowhere is this more apparent than in urban public transport (Smith and Clarke 2000, p. 169). Transport nodes, such as underground stations, are often characterized as being crime generators and crime attractors (Brantingham and Brantingham 1995). Because transport nodes concentrate heavy flows of people, they may attract offenders searching for suitable targets and locations to commit planned crimes. A crowded station may be an attractive place for theft owing to the opportunities present. Transport nodes are also social spaces, dynamic environments that (unintentionally) generate

A. Uittenbogaard · V. Ceccato (✉)
CEFIN—School of Architeture and the Built Environment, Royal Institute of Technology,
Drottning Kristinas väg 30, 10044 Stockholm, Sweden
e-mail: vania.ceccato@abe.kth.se

A. Uittenbogaard
e-mail: acui@kth.se

Published online: 02 October 2013

crime situations (e.g., settings where arguments can turn into acts of violence). The dynamic situations at transport nodes also attract offenders and generate opportunities for crime less visible than in other public places. For instance, offenders may be attracted to specific stations because they offer known hiding places. Nevertheless, studies have also shown that some stations may be safer in comparison to other public spaces (e.g., LaVigne 1997). Good planning should involve crime prevention measures that can make underground stations safe for both passengers and personnel by taking into account their nature as crime generators and attractors.

The objective of this article is twofold. First, the goal is to present examples of the nature, the levels, and the patterns of crime and disorder at underground stations, taking into consideration variations across time and space. The work reported here draws on an earlier study by Ceccato et al. (2013), which showed that some stations are more exposed to crime and disorder than others. As discussed in the literature review in the theory section of this paper, the geographical distribution of crime events is related to the environmental attributes of these transport nodes and their geographical context. Then, the article makes suggestions for improving the safety through crime prevention. These suggestions are derived from situational crime prevention, social disorganization theory, rational choice theory, and routine activity principles, as well as from previous studies on transport nodes in the United Kingdom, the United States, and elsewhere (see literature review). Although safety conditions at stations are dependent on multiscale factors (involving the station, neighborhood, and city levels), our focus is mainly on the different environmental features at stations.

Stockholm is an interesting case because it contributes to the international literature on safety and public transport that is dominated by North American and British evidence (but see, e.g., Alm and Lindberg 2000, 2004; Stangeby and Nossum 2004). Moreover, contrary to North American or British cities, the capital of Sweden has been shaped to a large extent by infrastructure planning practices that were a result of the implementation of welfare policies from the 1950s onward. These areas are often lively places where people converge. For this reason, the criminogenic characteristics of these areas may be increased.

The structure of the article is as follows. Relevant literature is discussed in the theory section, followed by the case study of Stockholm. The methodology and results from the empirical analysis are presented in the Method section. The findings and suggestions for action to improve safety conditions at underground stations are presented in the final sections of the article.

Preventing Crime in Transport Nodes: Theory

Transport nodes are places of convergence. They are places that people pass through during their daily routines. They are a point of convergence for many different people who are en route to different destinations and planned activities. An underground station can also represent a place where offender and victim paths converge and, for this reason, where crime may occur. The vast majority of crime occurs within an offender's awareness and activity space (Brantingham and Brantingham 1995). Crime reflects individuals' activities and daily habits, which are rhythmic and consist of patterns that are constantly repeated. Crime opportunities for offenders are created from this repetition of routines and knowledge of daily patterns (Cohen and Felson 1979). Routine activity theory suggests that for crime to happen, there is a need to exist a suitable target, a motivated offender, and the absence of a capable guardian in the same place at the same time. Crime prevention can involve dealing with these preconditions so as to reduce crime opportunities for each of these three aspects. As suggested in crime pattern theory, these preconditions can be dealt with by identifying crime patterns and tracking offenders' movements and behaviors so as to define the most probable areas for crime events, as well as by analyzing offenders' understanding of spatial environments and crime opportunities (Brantingham and Brantingham 1981). Bernasco and Block (2011) showed that the location of offenders' anchor points is particularly important in defining these patterns and, in fact, relate to higher crime levels.

In short, "crime prevention entails any action designed to reduce the actual level of crime and/or the perceived fear of crime" (Lab 2007, p. 24). This type of action, referred to as *situational crime prevention* (SCP) (Clarke 1995), is grounded in one of the oldest crime prevention approaches—the blocking of crime opportunities. The basics of SCP methods are rooted in opportunities for crime by taking a place-based approach that influences an offender's decision about committing a crime in a specific place (Sherman et al. 1998). The focus of SCP is on suggesting specific, offense-related altering of the management and design of the local environment so as to decrease crime opportunities (Clarke 1997). According to SCP, crime opportunities can be altered by following 25 prevention techniques (Cornish and Clarke 2003). These techniques are based on decreasing opportunities (as outlined in routine activity theory), increasing risks for offenders (as presented in rational choice theory), and managing crime patterns and predicted movements of offenders (as suggested by crime pattern theory) (Brantingham and Brantingham 1981). The techniques used in SCP stem from five intervention possibilities (Cornish and Clarke 2003):

1. Increase the degree of effort for offenders; this includes target hardening, control of accessibility, specific screening of entrances and exits, deflecting of offenders, and security checks for tools and weapons.
2. Increase the risks of crime, which includes extending guardianship, enhancing natural surveillance opportunities, reducing anonymity, utilizing place managers, and strengthening formal surveillance measures.
3. Reduce the rewards for committing a crime, which includes concealing targets, removing targets, marking property, disrupting markets, and denying benefits.
4. Reduce provocations, such as stress and frustration factors, possible disputes, emotional arousal, negative peer influence, and harmful forms of imitation.
5. Remove excuses for crime by establishing clear rules, displaying clear signage and instructions, alerting the conscience of faults, making rule compliance easy, and controlling drugs and alcohol.

It is submitted here that these five intervention possibilities can be used to minimize opportunities for criminal acts at underground stations. The design and layout of a station affect its vulnerability to crime. For example, the design and layout affect a potential offender's likelihood of escaping without being detected (Clarke and Felson 1993). According to rational choice theory, potential offenders evaluate their own risk before making a decision to commit a crime (Clarke and Felson 1993). In this evaluation, the environment plays an important role. Thus, one strategy is to reduce the opportunity for crime by increasing the risk of being caught and decreasing the rewards of committing crime. Both are embedded in Clarke's (1997) SCP approach.

Increased visibility and natural surveillance are key elements of successful crime prevention. Cozens et al. (2003) found visibility to be the most crucial aspect of security at railway stations. A study of Green Line light-rail stations in Los Angeles (Loukaitou-Sideris et al. 2002) showed strong links between crime rates and stations with dark/hiding places or with poor visibility of the surroundings (the opposite was shown for stations with good visibility). Surveillance can involve, for instance, the installation of closed-circuit television (CCTV) cameras, which from research has shown to have some positive effects on the reduction of robberies and assaults in the London Underground (Webb and Laycock 1992) but produced inconclusive results in the Stockholm subway system (Priks 2009; Ceccato et al. 2013). One topic of discussion is whether the placement of CCTV cameras is not merely a follow-up product in places with known high crime levels. Analyzing the relationship between the use of CCTV and its effect on crime levels is a challenge because it is difficult to know if the cameras are monitored live and controlled, which implies real-time viewing, or computer directed and only used for playback purposes.

Safety relates directly or indirectly to the visibility of passengers—that is, the possibilities of being seen and seeing others (in other words, natural surveillance). Natural surveillance can be defined as the "capacity of physical design to provide surveillance opportunities for residents and their agents" (Newman 1972, p. 78), a central concept in defensible space theory (Newman 1992). Crime prevention through environmental design (CPTED) follows Newman's (1992) basic principles and involves a number of environmental strategies that not only deter offences but also allow individuals to feel in control of their environment. An open layout provides more opportunities for surveillance and control of a place. Orienting housing blocks with windows facing the street creates indirect social control. The creation of softer boundaries between public and private spaces so as to make users of both spaces more responsible for events happening outside their own private space also enhances indirect social control (Newman 1992).

Formal and informal social control play important roles in determining crime levels in transport nodes. Low social control may lead to disorder and physical deterioration. The mechanisms are not well known for underground stations but, according to the broken windows theory put forward by Wilson and Kelling (1982), unrepaired damage to property encourages further vandalism and other types of crimes. A study on the New York subway system showed that the enforcement of quick removal of graffiti also reduced other types of crime such as vandalism and theft (Weisel 2004). This development goes hand in hand with high levels of community social disorganization (Shaw and McKay 1942; Kornhauser 1978) and low collective efficacy (Sampson et al. 1997; Sampson and Raudenbush 1999), which may act as triggers for offenders to commit crimes.

Transport nodes are also influenced by their relative position in a city. Kinney et al. (2008) found that the greatest number of crime incidents is concentrated in and around commercial and civic/institutional land uses; for instance, assault rates in these areas are six times greater than those in residential areas. Research has also revealed that higher rates of violent offenses exist in areas with particular land uses, with high residential and commercial land-use patterns and busy roads being associated with increased crime rates (Stucky and Ottensmann 2009). By contrast, research has shown that a link exists between industrial zoning and decreased violent crime levels. Moreover, in areas with high levels of socioeconomic disadvantage, residential land use had a stronger effect on crime rates than other factors. A relationship seems to exist between the socioeconomic composition of a neighborhood and land-use patterns and their influence on crime levels (Stucky and Ottensmann 2009). Research has also revealed higher robbery levels in neighborhoods (and adjacent areas) accommodating land uses that attract offenders, such as bars and illegal activities (drugs and gambling), where offenders are often around, and that are easily accessible to offenders by, for instance, public transportation (Bernasco and Block 2011). High levels of crime at a station are often correlated with high levels of crime in the surrounding neighborhoods, which are sometimes triggered by the socioeconomic composition of the population or particular land uses (Pearlstein and Wachs 1982; Hirschfield et al. 1995; Loukaitou-Sideris 1999; Loukaitou-Sideris et al. 2002; Ihlanfeldt 2003; Newton et al. 2004); however, there are exceptions to this rule (e.g., LaVigne 1997). The location of a transport node can be an access point and an attractor for offenders, thereby raising crime levels in the surrounding areas. In particular, transport nodes located in neighborhoods with specific land uses also have higher crime rates in the surrounding areas (Robinson and Giliano 2012). Research has found that in Boston USA, crime incidents concentrate around transit stations in a relatively small area. When the land surrounding public transit stations is used to accommodate event areas (arenas), parking areas, liquor establishments, and residential and green areas, higher levels of different types of crime are found (Robinson and Giliano 2012).

Past and recent strands of Western research on crime geography and crime prevention are used as the basis for this study. It is expected that stations with environments that provide poor conditions for formal and informal social control will tend to be exposed to more crime and disorder than other stations. Moreover, crime follows human routine activities; therefore, significant variations are bound to exist at different times (of the day, week, and year) and stations. The context in which a station is located also plays a role in determining the levels of crime and disorder at the station (Ceccato et al. 2013). It is suggested that for crime prevention to be successful, it has to include a set of interventions that takes into account the surroundings and environmental conditions of the stations and the city context.

The Case of Stockholm's Underground Stations

Stockholm's underground system is composed of 100 stations, of which 47 are underground (mostly central) and 53 aboveground. There are three lines: Green, Red, and Blue (Appendix 1). The main public transport junction is in the central business district (CBD), which is located in the central area of the inner city. All underground lines pass through Central Station, which is the main railway station of the capital. Thus, many travelers and workers pass through this station daily. Central Station is the only station that is connected to all three lines.

To obtain a comprehensive picture of what happens at the stations and in the surrounding areas, three databases were used: Stockholm Public Transport's calls for service, Veolia's personnel register, and police-recorded crime data. The first is based on a reporting database of calls to the central alarm center of Stockholm Public Transport (SL), with most calls being made by passengers and passersby. The Veolia database is based on reports collected from staff (drivers, cleaners, guards, ticket issuers, etc.) working at the (former) contracted organization (Veolia) responsible for running the underground system. The police database is based on records from official police statistics of reported events in an area within 100 m of the underground stations. The uniqueness of using these three data sources is that they provide a view on crime and disorder events from different perspectives (official police reports, as well as personnel and passenger observations). Moreover, the police do not have a complete database of all events that occur (i.e., some events may not be reported to police), nor are all police-recorded events observed and reported by staff and passengers. Therefore, examining all three databases provides a more complete overview of events rather than relying on one database only. Furthermore, the databases represent the different areas analyzed in this paper: SL and Veolia capture events at the stations, whereas the police records are more likely to capture events at the stations and in the surrounding areas (based on 100-m radius buffers). The police mainly patrol outside the stations and are called in to help in more serious cases or to apprehend individuals who violate the law. Because the databases capture information from similar geographical areas, they are used as complementary sources—rather than as competing sources.

Public disorder is the most common type of event reported at stations, comprising about 80 % of all events. Public disorder at stations includes events that are reported as unlawful activities or anti-social behavior. Some typical examples of such reports are cases of drunkenness and sleeping on trains as well as unjustified use of emergency brakes, fire extinguishers, and fire hoses. Other examples of "irritating behavior" are public urination, littering, begging, drug use, and loitering. The other 20 % of all reported events at underground stations are more serious offenses, often involving violence (including threats), thefts, and vandalism. Most of these serious offenses at underground stations are fights (about 40 %), followed by vandalism and threats, and reports of other types of violence. Most reports of violence are against passengers and guards or other personnel. Threats against personnel are typical events, followed by threats against passengers and drivers. Property crimes at stations are more often recorded by official police statistics than by the databases of SL and Veolia. According to the SL and Veolia data on robbery, most reports are events of robbery of passengers at stations. The police robbery data also show a large number of reports at stations; however, the majority of all records is related to places such as shops and supermarkets located in stations. Theft at underground stations can generally be divided into two types: theft from individuals and of objects at stations. The latter includes theft of bikes and cars, which is not uncommon in the parking lots and streets around underground stations. Theft from individuals mainly involves the stealing of goods from transients and passengers using the underground system. According to the police database, these types of thefts primarily occur at crowded stations. Although police records do not show high numbers, they do record burglary and shoplifting at stations for shops. In this paper, robbery, burglary, and theft are aggregated into the same category of property crimes; otherwise, the number of cases would be too small to assess them individually. However, it would be desirable to work with separate categories for each of these crimes because they require different approaches for intervention. Vandalism is recorded in both databases; the records show events of vandalism, often graffiti and criminal damage to public property, to both stations and trains. The records of vandalism can be discussed in terms of the reliability of the reported time windows for the act as most occurrences are likely discovered at the end of a working day when personnel conduct checks or trains terminate their runs at maintenance areas. However, according to the databases, reports of vandalism on carriages are much less common. For the most part, the reported crimes are related to the stations themselves. Indeed, as with most types of crime, it is hard to define the exact time of the occurrences unless one receives the reports firsthand. Nevertheless, it is the visibility of vandalism, not the event itself, which has the strongest impact on offenders and other types of crime in terms of acting as a provocation and catalyst (see broken windows theory, Wilson and Kelling 1982).

Previous research analyzing the Stockholm underground system reported clear temporal and spatial variations in both crime and events of public disorder (Ceccato et al. 2013). Events tend to happen more often in the evenings/nights, during holidays and on weekends, and, at least for violence, in the cold months of the year. Specific types of crimes also show different patterns: property crimes peak during the afternoon (12:00 noon to 5:00 p.m.), vandalism occurs most often between 7:00 p.m. and 10:00 p.m., and events involving violence typically happen at night (11:00 p.m. to 3:00 a.m.). Public disorder events generally occur during the afternoon, with increased numbers from 3:00 p.m. to 12:00 midnight. Geographically, the distribution of crime differs according to the type of crime, with suburban stations having higher rates of violence and more central stations having higher rates of property crime (see Ceccato et al. 2013).

Method

Instead of using crude data of events by station from the databases of the police and the transport authorities, rates per 1000 passengers for the three databases and crime types were calculated: robbery, burglary, theft, graffiti, threat, violence, public disorder, and others. Central Station shows the highest number of events in Stockholm; however, after events are standardized by daily passenger flow, Central Station shows a medium-high rate in comparison to other stations. The number of events alone does not present an appropriate distribution because more events will obviously occur in places where more people are around and crime opportunities are higher. Therefore, in order to focus on identifying environmental features of influence on crime levels, standardization by number of passengers is needed. In this case, the so-called “end stations” often have higher rates of events (crime and public disorder) than stations located in the inner city areas, with a few exceptions. These end stations have higher numbers of events related mainly to public disorder; which, according to previous theory, may have in turn an effect on other types of crime. When trains complete their scheduled runs, the end stations often represent the final stop for drunken people on their way home or for disputes that started between passengers while traveling on the train. On a more technical note, it could be expected that passenger flows at end stations are relatively lower than at central stations. Crime and disorder events still occur at end stations, with the rate of event per passenger becoming relatively higher at those stations because of the low passengers flow.

The focus of the present study is on the underground station, which includes platforms, transition areas, lounge areas, and exits. The police crime rates are based on a representation of the station’s area that is within a radius of 100 m (roughly representing the size of the station from exit to exit). The “immediate surroundings” are based upon the field of view of about 25 m from each exit. The “surrounding neighborhood” is within a 100 m radius of the station.

The environments of underground stations share some common features (e.g., illumination, gates, real-time train arrival timetables, platform/lounge structures). However, these places are far from homogenous, which potentially affects the stations’ vulnerability to crime. To assess these differences, two researchers conducted a systematic and detailed inspection of all underground stations in the Stockholm underground system as well as a check of their surrounding areas over the course of 2 months, spending at least 1 hour at each station. This inspection was at first conducted during daytime hours, between 10:00 a.m. and 4:00 p.m., to avoid rush hour and the darker hours of the day so as to obtain a picture of the stations at “normal operation times.” A scaled-down version of the fieldwork was repeated in the winter to check for specific differences during the darker hours of the day (from 2:00 p.m. to 12:00 midnight in winter) and to determine whether winter climate conditions changed the characteristics of the stations’ environments.

The features examined by the researchers were selected based on current theories of urban criminology and SCP. The results of previous studies on transport crime have demonstrated that a number of environmental features, indicators of social control, and socioeconomic variables can influence levels of crime at stations (Table 1). Some examples include the examination of visibility at platforms, as suggested by Cozens et al. (2003); natural surveillance, as highlighted in SCP and rational choice theory; the presence of CCTV, as demonstrated by Webb and Laycock (1992); and mixed land use in surrounding areas, as measured by Loukaitou-Sideris et al. (2002). The attributes were assessed during the fieldwork with a yes/no scale (e.g., presence of dark corners, well illuminated, open layout, social disturbance) or a high/medium/low scale (e.g., crowdedness, visibility, littering). This assessment is, of course, prone to subjectivity; however, a comparison of the results of both researchers showed that the variance was minimal. For example, visibility and surveillance were each checked with a high/medium/low scale by assessing the situation and perception of space from a professional point of view, keeping in mind suggestions from previous studies. The possibility of surveillance at the place was defined as "how well others can see you," thereby taking into consideration a multitude of aspects such as direct view, number of people (guardianship), view from outside toward the place, mirror placement, illumination of the place, and objects disturbing direct view. This definition allowed for a comprehensive and uniform assessment of surveillance. By contrast, visibility was defined

Table 1 Attributes inspected during the fieldwork: a selection

Attributes	Theory
Visibility at the place	Newman 1992; Cozens et al. 2003
Surveillance opportunity	Newman 1992
Objects blocking the view	Cornish and Clarke 2003
Hiding corners	Clarke and Felson 1993
Well illuminated	Cornish and Clarke 2003; Cozens et al. 2003
Presence of guards	Cohen and Felson 1979
Crowded place	Newman 1992
Visibility of CCTVs	Cornish and Clarke 2003
Deterioration	Wilson and Kelling 1982
Presence of café	Cornish and Clarke 2003; Newman 1992
Surroundings	
Number of ATMs	Brantingham and Brantingham 1995
Number of state alcohol-selling outlets	Brantingham and Brantingham 1995; Kinney et al. 2008
Residential area	Kinney et al. 2008; Robinson and Giliano 2012
Commercial area	Kinney et al. 2008
Presence of bars	Brantingham and Brantingham 1995
Presence of guards	Cornish and Clarke 2003; Newman 1992
Presence of bus stops	Kinney et al. 2008
Presence of walking paths	Newman, 1992
Presence of social disorder	Shaw and McKay 1942; Wilson and Kelling 1982
Average income of area (100-m radius)	Shaw and McKay 1942; Kornhauser 1978; Bursik and Grasmick 1993
Population density (100-m radius)	Shaw and McKay 1942; Kornhauser 1978; Bursik and Grasmick 1993

Some features are used in all sections of the station, whereas others are more specific to a particular area (see Ceccato et al. 2013 for details) as “how well you can see others.” Although the definitions for surveillance and visibility are similar, they are not the same. For example, you may be able to notice someone else, but this other person may not be aware or have a direct view of what is happening to you (for additional examples, see Ceccato et al. 2013).

A station’s platform consists of the area where the trains arrive and passengers wait, and a transition area is the area between the platform and the gates/ticket window, which commonly includes stairs and elevators to the platform. The lounge is the area before the gates/ticket booth and extends to the exits or tunnels. The exits are entrance areas before the lounge area; they lead directly to a street or via a tunnel to a street. The surroundings include the immediate surroundings around each exit—that is, the field of view from a station’s exits. Data from the fieldwork inspection (checklists) were gathered in spreadsheets and then imported to a Geographic Information System (GIS) together with land-use data, crime data, and demographic and socioeconomic data of the population. Stations and crimes were mapped as point data, whereas the Stockholm demographics and socioeconomic data were linked to small unit statistics (*Basområde*) (Appendix 2). To assess the influence of surroundings on crime and disorder events at each station, a number of criminogenic land-use indicators were added to the analysis—the location of automated teller machines (ATMs), schools, police offices, and state alcohol-selling outlets (*Systembolaget*)—in Stockholm.

Bivariate correlation was performed to check for correlation between variables so as to reduce multicollinearity. Regression modeling ordinary least squares (OLS) was tested using 82 % of the Stockholm underground system (i.e., all stations covering the entire municipality of Stockholm) since crime and socio-economic data was available for the municipality only. OLS regression was used to assess how the environment of the stations and surrounding areas (independent variables) affected crime rates (dependent variables). Crime rates (crimes per 1000 passengers) underwent a natural logarithm transformation so as to fit the linear regression modeling assumptions (see Poole and O’Farrell 1971). By using a three-stage procedure, the models first identified variables that significantly (10 % significance level[1]) influenced crime levels at each part of a station (platform, transition, lounge, exits). These results were put together into the model for the whole station, from which the significant variables were combined with variables related to the surroundings. This procedure made it possible to assess the effect of all variables on crime levels, from small-scale environments at the station to the influence of the surroundings (for details, see Ceccato et al. 2013).

Results from the Analysis

In this subsection, some of the most important findings are discussed as a basis for developing suggestions on how to improve safety conditions at underground stations. Table 2 summarizes the results of the modeling for events involving crime and disorder, violence, property crime, and vandalism. However, different types of crime appear to be more specifically related to certain attributes. For violent crimes, the presence of corners was more significant in explaining variations in violence rates, whereas for vandalism, smaller, open layouts and the presence of rough materials were more significant.

Differences in the environment of underground stations has an impact on the stations’ vulnerability to crime and disorder. Evidence shows that features that indicate barriers to

[1] A significance level of 10 % is a common practice in criminology and used here to eliminate the variables that did not contribute to the model.

Table 2 Station features, neighborhood surroundings, and city context

Variables associated with higher crime rates	Variables associated with lower crime rates
More corners, hiding places	More people around the station
Peripheral stations	Good illumination (visibility)
More ATMs in the surroundings	More CCTV cameras
Presence of physical deterioration	More police stations
Higher population density	Lower housing instability

Source: Ceccato et al. 2013, p. 49

formal and informal social control, such as fewer people in the station, objects hindering visibility/surveillance, the presence of out-of-sight corners, and hiding places, are related to higher rates of offenses. Good illumination and a minimal presence of factors that relate to physical and social disturbances are often related to lower rates of crime and events. The context of the stations is also important to the stations' vulnerability; however, the environmental design of the stations remains the most important in explaining crime levels at the stations. The surroundings of some stations help explain some of the variation in addition to the stations' features. Stations with higher rates of crime and disorder are often located in more peripheral neighborhoods (here defined as suburban neighborhoods outside the central congestion tax zone, corresponding to distances of over 5 km from the CBD) as well as in those neighborhoods with higher housing instability, higher population density, and fewer police stations. However, these significant variables and the influence of surrounding environments may vary by the type of crime (Table 3). For crimes involving violence, the model shows mainly an effect of the stations' characteristics—that is, more crime and disorder are found where there are more dark corners in the platform area, more hiding places in transition areas, fewer CCTV cameras in place, transition areas with signs of deterioration, and poor informal surveillance in lounge and exit areas. For property crimes, the situation is the opposite; crime levels are better explained by models that include the surrounding environment. The rates based on police data, which also include events occurring in the immediate vicinity of the stations, perform much better than the ones from the database of SL (station-only events). Variables associated with station surroundings (e.g., open entrances, distance to city center, population density, and presence of villa housing) are all related to high rates of property crimes, according to police data.

Surprisingly, some of the variables depicting the surrounding areas turned out to be non-significant or to have an unexpected sign. For example, no effect was found for the presence of schools, nor for the presence of alcohol-selling premises in the surrounding area, as suggested in previous literature (e.g., Block and Block 1995; Loukaitou-Sideris et al. 2002). However, alcohol-selling premises in the present study included only state alcohol-selling outlets, not restaurants and pubs, which may explain the results. Only ATMs showed an effect related to increased violence. The presence of car parks near underground stations also did not show any effect on property crime rates; this finding is unexpected because car parks have a larger number of potential targets for property crime. (For a more extensive discussion of these results, see Ceccato et al. 2013).

Crime and Disorder Prevention at Underground Stations: An Agenda for Action

Because underground stations are an important aspect of everyday life, they should be safe and comfortable for all. Good planning can make daily trips safe for both passengers and

Table 3 Environmental factors affecting crime and disorder and suggested interventions

Problem	Theories	Attributes	Preventive actions
Vandalism	Defensible space	Bad illumination[a]	• Check the quality of illumination in all parts of station premises
	Routine activity	Covered platform**	• Improve visibility and surveillability
		Smaller stations**	• Strengthen formal surveillance
		CCTVs installed**	• Use of graffiti and damage resistant materials
		Rough material[a]	• Make bare walls less accessible
	Broken windows	Deterioration[a]	• Eliminate deterioration and litter
			• Limit graffiti in transport nodes
	Social disorganization	Peripheral location**	• Provide user information and clear rules
			• Improve information and create campaigns targeting specific groups
			• Provide alternatives for legal graffiti
Violence	Defensible space	Low surveillance**	• Improve surveillance possibilities
	Routine activity	Dark corners**	• Eliminate dark places and hiding spots
	Rational choice	Hiding corners**	• Improve winter conditions at stations
		Separate platforms**	
		Better illumination	
	Social disorganization	Peripheral location**	• Manage land use in surrounding areas
		ATMs in vicinity**	• Encourage preventive actions by locals and shopkeepers
		Foreign population in surroundings[a]	
	Rational choice	Less crowded platforms[a]	• Strengthen formal surveillance
		CCTV visible[a]	
		CCTVs installed[a]	
	Routine activity	Deterioration[a]	• Eliminate deterioration
	Broken windows	High visibility	• Separate flows of passengers
	Crime pattern theory		• Train personnel
			• Create safe places for vulnerable groups

Table 3 (continued)

Problem	Theories	Attributes	Preventive actions
Property crimes	Routine sctivity	High visibility**	• (robbery) Remove hiding spots
		Hiding places**	• (theft) Control access
		Open layout of entrance**	• (theft) Separate flows
		Views on platform from other parts[a]	• (theft/robbery) Strengthen formal surveillance
		Escalators**	• (theft) Make available real-time arrival information to reduce waiting times at platforms and dark/hidden places
	Rational choice	Fewer benches**	• (theft/robbery) Create advantage of seating (promote informal social control)
	Defensible space	Peripheral location**	• (theft/robbery) Eliminate signs that "nobody is in control"
		Villa housing area[a]	• (theft) Clear warnings of possible theft
		High population density	• (robbery) Take charge of 'your own safety' campaigns
Public disorder	Social disorganization	Peripheral location**	• Strengthen formal surveillance
	Routine activity	Bigger central stations**	
		Separate platforms**	
	Social disorganization	Social disorder[a]	• Warn and instruct children and teenagers about behavior and consequences when involved in disruptive acts
		Disturbance[a]	• Inform passengers about consequences of inappropriate behavior
			• Prevent urination on the stations premises by offering public toilets at stations
			• Post information at stations about drink restrictions and food-free carriages
			• Allow for legal performers or buskers on underground premises at pre-determined areas
	Crime pattern theory	ATMs in vicinity[a]	• Adopt a holistic approach to safety through intersectorial cooperation
		Few schools in vicinity[a]	• Have an inclusive approach to safety (avoid group stigmatization)

All variables significant influence (10 % level)

[a] Average significant influence (5 % level)

**Highly significant influence (1 % level)

(Source of "Attributes": Ceccato et al. 2013) personnel. Simply being aware of crime and disorder at these stations is not enough. The environment and context in which these events occur must be considered, and actions towards improving these environments must be taken. For these actions to be carried out, planners and practitioners should be aware of their role and the challenges involved when working with specific safety issues. They should strive to implement practices that are inclusive and fair (the focus should be on different target groups, and cooperation should be fostered between different actors responsible for different areas and services) and, as much as possible, to work on participatory frameworks. If well thought out, safety interventions and urban planning actions can serve to engage local communities, empower participants, and help facilitate public participation in the production of a safe and liveable built environment.

Suggestions on how to improve safety in transport nodes should not be considered a *one-size-fits-all solution* for the whole transport system or for other underground systems elsewhere. Identifying types of stations (i.e., "typologies") that are more vulnerable to crime (or are perceived as such), as well as considering the contexts in which they are embedded (neighborhood and city contexts), is crucial. Certain stations (e.g., end stations) require more specific surveillance actions against public disorder, whereas some stations require actions to improve environmental design (such as stations with high rates of violent crimes and property crimes). Other stations with high vandalism rates need to focus on establishing and maintaining an image of "in control" surrounding environment (as suggested by broken windows theory). Nevertheless, one station can be part of more than one typology, and one action can be included in several typologies. For example, a station can be included in programs for both surveillance actions and an "in control" environment, as suggested here.

Although transport agencies and other authorities responsible for public environments may not have the power to make structural changes that affect the long-term socioeconomic context of stations (e.g., population density, housing mobility, police patrol programs in neighborhoods), this study offers a number of indications of how environmental attributes (design and land use of stations) may be reconsidered so as to enhance the promotion of safety at underground stations. There are a number of strategies that can be developed to maximize the positive—and to minimize the negative—physical characteristics of particular settings, thereby contributing to greater safety for passengers. These interventions link environmental attributes to current criminological theory (Table 3).

These suggestions are not organized according to priority but rather are linked to the attributes in the third column of Table 3. In the following subsections suggestions for interventions that may help reduce and/or deter acts of vandalism, violence, property crime, and public disorder at underground are discussed in detail. A number of interventions apply to more than one type of crime; these are actions with a broader effect on crime prevention and may provide a different approach to a similar problem according to the type of crime.

Vandalism

Acts of vandalism occur frequently at Stockholm's underground stations (Fig. 1). Vandalism often involves graffiti and criminal damage to public property, both to stations and more rarely inside trains. Damage to trains and stations includes shattered windows, etching, wall graffiti, and other physical damage like damaged benches or burned furniture. It can also involve damage to public transportation properties, including vehicles, shops, and other

Fig. 1 Littering in carriages and transition areas on the weekend; graffiti is one of the most common types of vandalism at underground stations in Stockholm

structures. More than half of these events are related to underground stations themselves, followed by schools and parked private cars near the stations. As mentioned in the case study section, vandalism happens most often in the evenings, specifically between 7:00 p.m. and 10:00 p.m.

The case study in Stockholm indicates that poor illumination at public transport nodes is linked to higher rates of vandalism. Better illumination and see-through walls/windows make offenders feel more exposed, which, according to rational choice theory (Clarke and Felson 1993), negatively affects their decision to vandalize public property. Presented as one of the tools in SCP—that is, as something that enhances natural surveillance opportunities (Cornish and Clarke 2003)—better illumination would increase the risk of being seen while applying graffiti or damaging objects in these dark places. The increase in natural surveillance possibilities may also improve the potential for action by guardians and, according to routine activity principles (Cohen and Felson 1979), restrict the opportunities for offenders to commit crimes. In addition, SCP suggests strengthening formal surveillance (Cornish and Clarke 2003), this will make the risk of detection higher and should, therefore, affect offenders' behavior (Smith and Cornish 2006). Formal surveillance includes an increase in the presence of guards and police officers at stations vulnerable to vandalism at times when vandalism events are most likely to occur (between 7:00 p.m. and 10:00 p.m.).

Transition areas by themselves are vulnerable places for visibility is often low and bare walls/windows are ubiquitous and, thus, attractive for the application of graffiti. Visibility and surveillance in a place are key elements in crime prevention (Newman 1992). Improved opportunities for visibility need to be implemented in transition areas. An investment in design that allows good visibility from outside is desirable, for instance, improved lighting, sightlines and see-through walls/windows. Formal surveillance by CCTV is related to lower levels of recorded vandalism at stations (Ceccato et al. 2013). Smaller stations (with higher vandalism rates) often have fewer cameras installed, and stations with high vandalism rates show less of a CCTV presence. A careful audit should provide information as to where new CCTV cameras should be installed. Because visible CCTV cameras would both reassure passengers and deter potential offenders by increasing the potential risk, their installation should be encouraged in appropriate locations.

More vandalism occurs at stations in which the platform areas are covered by a rain shield and walls consist of rough materials. Rain shields do provide a target for the application of graffiti or other types of damage, and rough materials simply mean that the "work" is harder to remove and, thus, will be visible longer. As suggested by Smith and Cornish (2006), the application of smooth coatings and the use of specific materials, which make it possible to remove graffiti easily, may result in the "art" being visible for only a short period of time in stations. In this situation, the reward of a longer period of time in which the graffiti is displayed (what graffiti artists aim for) (Cornish and Clarke 2003) is reduced, which makes it less attractive to do at all and may discourage offenders from applying graffiti. Other studies suggest that smooth materials are often preferred by graffiti artists because they are easily workable objects for quickly tagging a place with a marker; however, the application of proper coatings allows the removal process to be quicker and less costly (Weisel 2004). Quick removal in turn slows the rate of general deterioration and has indirect effects on other types of crime. One example of how the quick removal of graffiti results in a reduction in vandalism is the New York subway system, where any graffiti is removed within 24 h (Geason and Wilson 1990). Rain shields should not be removed from stations because they protect passengers and serve their comfort; however, they could be made of damage-resistant material or glass with resistant coating. Another suggestion is the use of plants and thorny bushes in front of walls. By planting vegetation, walls will be less accessible and less attractive to graffiti sprayers. Vegetation also increases the pleasantness of a place, which in turn affects the overall atmosphere and people's moods (Morgan and Smith 2006a).

The deterioration of station environments should be addressed as quickly as possible because it may communicate poor social control at a station and incite offenders (Cornish and Clarke 2003). In accordance with the well-known broken windows theory (Wilson and Kelling 1982), places that are already trashed and littered may influence people to do the same. Preventive actions should be carried out on weekends when stations are plagued by acts of vandalism and littering. So far, SL has already implemented a rapid removal scheme for graffiti and vandalism, which should be intensively continued so as to discourage offenders and let them know that their "work" is not tolerated there and will not be on display long. The Stockholm County Council also keeps a detailed digital record of all reported vandalism in the Stockholm region (Brottsförebyggande rådet - BRÅ 2008). With this record system, graffiti and vandalism can be tracked, resulting in a reduction in the anonymity of graffiti artists, an increase in the risk of detection, and a decrease in rewards (Cornish and Clarke 2003).

Installing signs that clearly state the regulations and penalties in certain spots in stations may make individuals think twice about their actions. These signs should explain that vandalism and graffiti are forbidden at underground stations and that, when caught, one might be fined or have other legal actions follow. The rules for general use of the underground, as well as information about prohibited acts and criminal activities, should be made known to underground users. This displayed information will negate the excuses offenders may find to vandalize a place (Cornish and Clarke 2003).

One alternative way to decrease vandalism may be to provide legal graffiti sites. However, offenders perceive the display of their illegal graffiti in public places as the main reward. Therefore, this alternative action does require coordination with the previous action involving the rapid removal of graffiti and repair to areas of deterioration at other public places. These actions are needed to keep the rewards low and the effort high for illegal public graffiti, resulting in a more satisfying use of legal graffiti sites. For graffiti to become an accepted form of artistic expression requires the free use of walls or buildings for legal graffiti spraying. At present, Stockholm County has a zero tolerance policy toward graffiti. The only exception is "the legal graffiti wall" (*Den Lagliga Graffiti Väggen*) located in the town of Märsta in the municipality of Sigtuna, where graffiti artists can apply graffiti to a limited area/wall. The wall is popular, especially between March and November when young people queue for the right to paint on the wall. This area has maintenance rules for the environment near the wall so that it can be used by all (for more information, visit http://www.sigtuna.se). Some cities allow graffiti in certain areas (e.g., on the outskirts) but impose limits, such as defining zones that have to be graffiti-free.

In their list of possibilities for SCP, Cornish and Clarke (2003) also proposed alerting the conscience of acts of crime and public disorder, such as vandalism. Campaigns highlighting the responsibility of each individual in contributing to the pleasantness of public spaces should be implemented in schools, libraries, and youth leisure centers, as well as through daily media sources, with a focus on discouraging vandalism and littering. Campaigns of this type, however, require careful planning and a long-term commitment. According to Smith and Cornish (2006), there is a risk of using inappropriate language in these campaigns that may challenge young people to carry out acts of vandalism. The key ingredient for success in such campaigns, they suggested, is to rely on the involvement of multi-actor actions: the school, the municipality, police, other authorities, nongovernmental organizations, and individual citizens.

Violence

Most violent crimes are directed at passengers and are more often reported at stations than on trains. This finding may be an artefact of the recording method used by authorities, which often link events to stations. Violence involving assault (*misshandel*) is the most common event recorded by Stockholm police (70 % of violent acts at underground stations); only a few records are classified as “serious assault.” To a lesser extent, there are reports of violence against guards and ticket controllers. As suggested in interviews conducted during fieldwork for this study, ticket controllers at the gates have been insulted, yelled at, and verbally accosted more often recently than they were a couple of years ago. This may be related to the fact that the installation of new electronic gates has made fare dodging more difficult. Violent crime rates, standardized by passenger flow, are highest at stations along the Blue Line and at bigger stations and end stations of the Green Line and the Red Line. This finding may be related to their location in disadvantaged areas and dynamic activity spaces, such as regional centers. As presented in the case study section, violence is most common at night (see also Ceccato et al. 2013). Actions should thus be focused within the time window of 11:00 p.m. and 3:00 a.m.

Stations targeted by acts of violence are usually those with more than one platform and numerous hiding places. In accordance with the defensible space theory (Newman 1992) and SCP (Cornish and Clarke 2003), dark corners at platforms and hiding spots in transition areas need to be checked and, if possible, eliminated. Interventions can include improving sightlines, installing mirrors, and illuminating corners so as to minimize the number of hiding places. Better illumination should provide passengers with better visibility of their environment while waiting for their train to arrive. Transit areas devoid of people are places where passengers are the most fearful; therefore, priority should be given to installing better lighting and improving safety measures in desolated areas (Loukaitou-Sideris et al. 2009). Other measures include the installation of emergency buttons, intercoms, and help points staffed by station employees at targeted stations, which can decrease the time needed to respond to offenses and possibly prevent crimes.

Our findings from Stockholm indicate that natural surveillance, particularly in lounge and exit areas, decreases the possibilities for offenders to stay unnoticed while preparing for an assault and awaiting their next victim. With the creation or improvement of sightlines, passengers can see from afar what awaits them. This action increases the risks for the offender, one of the main tools in SCP (Cornish and Clarke 2003). Moreover, other passengers or passersby are more likely to notice an offense, and may respond by calling for help or, if unable to make a call, approaching the scene so as to help out immediately. Removing objects that block the view is one aspect of this action. For optimum natural surveillance, lounges and exits should not be covered or sectioned by concrete or brick walls. They should instead provide an open space with glass windows so that the view from the outside is good. Waiting areas at stations should be transparent shelters; the transparency of the shelters improves the natural surveillance in these waiting places. Equally important is the engagement of shopkeepers and locals living in areas surrounding the stations because doing so may increase the number of "eyes on the station," to paraphrase Jacobs (1961).

Our results also showed that increasing formal surveillance—for example, by installing CCTV and having security officers, guards, and police patrolling stations—improved safety. This finding is in line with increasing the risks of crime (Cornish and Clarke 2003) and improving the guardianship role as described in routine activity theory (Cohen and Felson 1979). The implementation of formal surveillance patrols means that immediate action can be taken when a crime occurs and that victims are not left without help when something happens. The presence of guards and ticket controllers makes it difficult for fare dodgers to board a train without valid tickets. Violence may erupt when fare dodgers come face-to-face with ticket controllers. The installation of electronic gates may make it more difficult for a motivated offender to enter a station's platforms without a valid ticket and, thus, serve to protect ticket controllers. Yet, the results of our Stockholm analysis did not show any effect of electronic gates on crime rates compared with older gates at stations (of which a certain amount are still left to date). Nevertheless, in addition to CCTV cameras, the presence of guards and ticket controllers increases natural surveillance opportunities by diminishing anonymity as well as creating a feeling for passengers of always being over watched.

The degree of illumination at underground stations during winter should be investigated and revised. This is particularly important in Scandinavian countries, where daylight may be limited in early mornings and late afternoons (Fig. 2). Improved illumination will aid in enhancing surveillance possibilities and visibility (Newman 1992), thereby increasing risks for offenders (Cornish and Clarke 2003). The conditions of waiting areas are also important. Improved illumination provides better visibility and conditions for surveillance during the dark days of winter. The overall safety and comfort of passengers can be improved with the provision of more comfortable waiting areas; this action in turn makes crowded indoor places seem more welcoming.

Another way in which to help deter violence at stations and in carriages is to provide personnel with clearly defined roles and adequate training. In Stockholm,

Fig. 2 Artificial illumination plays an important role in the perception of places on short winter days with limited exposure to natural light in Scandinavian countries

ticket issuers are not encouraged to intervene in cases of violence because it is the responsibility of security or police to act. In recent years, SL has improved safety for its employees by placing CCTV cameras in the ticket booths at the gates. When we were conducting fieldwork for the present study, we learned from the personnel themselves that the installation of these cameras has substantially decreased harassment and conflicts at the gates. A ticket issuer at a station also remarked during our fieldwork that the emergency courses provided by the transportation agency, which are designed to teach employees how to react and what procedures to follow when harassment and violent events occur, do not always work (personal communication 2010).

The location of ATMs in the areas surrounding underground stations should be reconsidered in Stockholm. According to previous findings, the presence of ATMs in the immediate surroundings of a station increases the chances of violent encounters (Ceccato et al. 2013). Offenders searching for easy targets to rob are often attracted to areas with ATMs because they can easily identify who has withdrawn cash from the ATMs; for this reason, stress levels and the possibility of violent disputes may rise in these areas (Smith and Cornish 2006, p. 97). Installing ATMs inside stations, close to ticket booths, may increase visibility of the palace and indirect surveillance from passengers and ticket issuers. Removing evidence of deterioration will make the atmosphere more pleasant and is especially important for reducing rates of violent crimes in transition areas. According to the broken windows theory, eliminating signs of deterioration will reduce not only the influence on violence and other types of crime (Wilson and Kelling 1982) but also provocations.

Property Crimes

Property crimes are theft, robbery, and burglary. Shoplifting accounts for one-fifth of crimes in the theft category. Robbery includes the robbery of passengers at stations. There are also cases of serious robbery involving the use of weapons; these cases are often associated with the theft of items like cell phones, motorbikes, and clothes. A violent robbery is also classified as an event of violence in the databases if the crime involves serious violent behavior and personal damage; thus, it is recorded as both a robbery and a violent crime. Burglary includes break-ins of shops, cars, and surrounding buildings. Property crimes in the Stockholm underground occur most frequently at stations with larger passenger flows and at those situated in denser and more affluent areas. Intervention measures should be concentrated within the time window when property crimes occur most often—that is, from 12:00 noon to 5:00 p.m. (see case study section).

Strengthening formal surveillance is fundamental to preventing property crimes. Thieves may be less likely to commit theft, robbery, or burglary when they know they are being watched, guards are visible, and cameras are in place. One way to make it more difficult for offenders is to remove hiding spots in transition areas and platforms. The removal of hiding spots will also provide passengers with a more secure feeling. Another way involves installing seats and benches, thus allowing passengers to sit down and easily observe their environment and what is happening around them. This “natural surveillance from a bench” may also increase the effort required to commit theft because potential offenders are probably being watched. Moreover, the increased presence of guards or police elevates the risks of possible arrest, which helps dissuade offenders from committing theft.

Piza and Kennedy (2003) suggested that the accessibility of entrances and exits of subway stations, on the one hand, and the unfamiliarity of passengers with underground stations, on the other hand, tend to increase the opportunity for offenders to commit crime. One way to deal with these vulnerabilities is the separation of flows. Separating passenger flows may make situations less chaotic and less crowded, thus decreasing possibilities for theft. In this type of environment, passengers will be more relaxed and focused on their surroundings, and fewer targets will be available for theft. When an offender behaves differently—for example, by walking in the wrong direction—in this type of environment, passengers are more likely to notice this “strange sight.” Moreover, the installation of electronic gates in underground stations means that a motivated offender needs to pay to enter the premises, which in turn increases the costs/effort for committing theft (Cornish and Clarke 2003).

Furthermore, providing real-time information about train arrivals means that passengers do not need to wait unnecessarily in “dangerous” areas, thus diminishing the chances of theft or robbery; in Stockholm, all stations have this feature available. While waiting for a train, passengers should try to stand in well-lit, highly visible places near other people. The provision of real-time information about train arrivals also controls for unneeded loitering on platforms. In general, passengers should keep to well-lit, busy areas around, on the way to/from, and at underground stations. While at a station, passengers should be encouraged to “look alert and act confidently.” On busy trains, passengers should keep their belongings nearby and secured. Carrying out these preventive measures may increase the sense of unease that offenders may have about committing crime and in turn decrease their motivation to do so.

As Morgan and Smith (2006b) suggested, providing passengers with useful information about the risks of crime at highly targeted stations makes these stations less attractive to offenders to commit crimes and increases the feeling of safety among passengers. For passengers who wish to park their cars close to underground stations, they should try to park in approved car parks and places that offer opportunities for surveillance. Passengers should avoid deserted places. They should also not leave any items, such as clothes, electronics, and loose change, inside the vehicle which could encourage a break-in. If they have a bike, they should always lock it. When leaving the bike for a period of time, they should try to lock it to something secure (Johnson et al. 2008). People should not leave items such as helmets and other possessions with the bike.

Public Disorder

Public disorder at stations includes events that are classified as unlawful activities or irritating behavior rather than crimes per se. Implementing interventions for public disorder is complex because these actions may not be crimes per se; they are types of behavior that make passengers feel uncomfortable or offended. Nevertheless, there are actions available to control public disorder. These actions should be carried out within the specified time window from 3:00 p.m. to 12:00 midnight at larger stations, particularly at central stations and stations where several transport links (buses, trains) come together as well as end stations. Larger central stations require increased formal surveillance because people frequent there during weekend nights when heading to or from a night out. The presence of extra security elevates the risk of being sanctioned for disorder, as one of the SCP techniques suggests (Cornish and Clarke 2003). When trains complete their scheduled runs, the end stations are often the final stop for passengers who have become intoxicated and/or fallen asleep. Increased attention at these stations is required for dealing with such passengers. Providing proper care is important because drunkenness can complicate matters, leading to irritation, arguments, and, in some cases, violence. Moreover, implementing formal direct actions, interventions, and mediation of offenders creates a safer atmosphere and reduces provocations (Cornish and Clarke 2003). Reducing the existing potential for acts of disorder and disturbance, which affects public disorder at stations (Table 3), may also lead to a decrease in the levels of disorder as an indirect effect. In the following paragraphs, we put forward some suggestions for reducing actual levels of public disorder.

Clearly posting the rules for underground stations and/or on trips is also important. For instance, rules of what is acceptable in terms of food consumption and drinking in carriages and at stations should also be made known. Regarding alcohol consumption, SL has a zero tolerance policy. Security guards have the authority to confiscate any alcohol being consumed at underground stations. The placement of trash bins in convenient and noticeable locations and the posting of signs encouraging passengers to put trash in trash bins should help prevent littering. Other actions, such as giving seating priority to senior citizens and to pregnant women, discouraging the habit of putting shoes on seats, and enforcing no-smoking bans, should be advertised more often and clearly.

Allowing performers and buskers to work legally on the premises of underground stations and providing them with designated areas inside stations will create a more comfortable and pleasant atmosphere. The passengers will be put at ease with the knowledge that the performers are legally authorized to work there (i.e., the passengers know that they will not be harassed or accosted by the performers). The presence of the performers may also provide natural surveillance. The performers can be provided with instructions on what to do when crime or disorder events occur, thus making quick intervention possible.

A common problem in elevators and exit areas at underground stations is urination. Although not an offense, it affects passengers' sense of safety and well-being. Posting signs of where to find public toilets in underground stations and surrounding areas seems to be more effective than signs prohibiting urination in public places. The installation of free-of-charge toilets, which are accessible to passengers only, at stations along the transport system should decrease urination in elevators and at entrances to underground stations. Although urination may be mainly an act of drunken people, stricter legal actions and higher fines when a person is caught urinating may help in decreasing the problem.

Implementing safety interventions requires cooperation between transportation and security authorities of the City of Stockholm and nongovernmental organizations. By working together, they can tackle issues that are rooted in structural and long-term socioeconomic and land-use problems. A holistic approach involving safety through cooperation must be adopted. In this framework, actions that promote safety must be inclusive because safety is a human right that should be experienced by all. In Stockholm, about half of all reports from underground stations are linked to drinkers/sleeping drinkers. Both the police and partner agencies should continue working together to offer support and amenities to street drinkers.

Although not a new phenomenon, homeless people make use of many public spaces, including transport nodes and surrounding areas. Of the total estimated homeless population population (2892 people) in Stockholm, young people comprise 17 %, and this particular group seems to be increasing (Stockholm stad 2010). The homeless youth population in Stockholm mainly comprises males who have some sort of psychiatric disorder and/or addiction problems (Stockholm stad 2010).

Station personnel, station guards, and police officers should work in partnership with homeless shelters and social care services in Stockholm to provide better possibilities for the homeless. Outreach teams should further encourage the homeless to take advantage of the help and support offered by nongovernmental organizations, such as *Stadsmissionen*, and from governmental organizations in cooperation with social care services in Stockholm Municipality. Through cooperation, these authorities should endeavor to achieve long-term goals involving better integration of land uses in the areas surrounding underground stations that may become detached from neighborhoods and attract unwanted activities.

Conclusions and Looking Ahead

Underground stations are criminogenic places, but certain stations experience more crime and disorder than others. Previous research has shown that the vulnerability of underground stations to crime varies across space and time as well as type of crime (Ceccato et al. 2013). The present study suggests several actions to improve the safety of stations at specific times for types of crime that occur the most. The study is based on comprehensive fieldwork combined with secondary data sources, regression models, and a GIS. Events tend to happen in the evenings – nights, holidays, and weekends – and, at least for theft, in the hotter months of the year (Ceccato et al. 2013). Results from the modeling show that opportunities for crime are dependent on stations' environmental attributes, type of neighborhood in which they are located, and city context, thus demonstrating the need for a comprehensive, all-inclusive approach. Although these different scales all affect crime levels at underground stations, the environmental features at the stations explain most of the variations in crime types. Features that indicate barriers to formal and informal social control (such as low numbers of people in the station, objects hindering visibility/surveillance, corners, and hiding places) are related to higher rates of offenses. Good illumination and a reduced presence of physical and social disturbance are often related to lower rates of crime and disorder events. As previous studies have demonstrated (e.g., Bernasco and Block 2011; Robinson and Giliano 2012), the context of the stations is also important to the stations' vulnerability. Stations located in more peripheral neighborhoods with higher housing instability and population density and fewer police stations are often targeted to a greater extent by crime and disorder than other stations. However, the significant variables may vary by crime type. Property crimes tend to be concentrated in more central stations as well as stations at the end of the lines. Our results lend support to the principles of traditional urban criminology theory such as routine activity and social disorganization in transport nodes, which define the meeting of a motivated offender and a suitable target in the absence of a guardian (routine activity) and the influence of social provocations and backgrounds (social disorganization) as a basis for criminal behavior. These findings also indicate the potential use of SCP principles in improving safety in these transport nodes with the adoption of techniques that increase risks and effort for the offender, reduce rewards and provocations, and remove excuses for crime (Cornish and Clarke 2003).

The most important message from this study is that safety at underground stations is a function not only of the local conditions at stations but also the surroundings in which these transport nodes are located. Previous studies had already shown links between higher crime rates in underground stations and specific environmental attributes (Table 3). Thus, authorities should adopt a "whole journey approach" to ensuring the safety of passengers in underground stations. This type of approach was presented by the Department of Transport in the United Kingdom in one of its studies on passenger safety. A whole route approach (i.e., from door to door) was established as a basic requirement for ensuring safe travel when dealing with issues of crime (Department of Environment, Transport and the Regions [DETR] 1999). Authorities' adoption of a whole journey approach may lead to a decrease in crime displacement as the intervention actions have to take into account not only the station but also the surrounding areas.

Thus, implementing prevention measures at stations also involves carrying out prevention measures in the surrounding areas.

Actions should also be based on all stations included in the underground system (i.e., they should not be restricted to the City of Stockholm). Hence, the success of implementing safety interventions will depend to some extent on how well municipalities in Stockholm County cooperate with each other and make surrounding areas safer. This requires better coordination between transport agencies and other institutions responsible for safety in public environments (e.g., the municipality, police districts) not only within the City of Stockholm but also with other municipalities in the region.

Based on her research on the transportation system in Los Angeles, Loukaitou-Sideris (2012, p. 106) suggested that actors should "adopt a multipronged approach to safety" and that the right mix of strategies should depend on the particularity of each setting, the passengers' expressed needs, and available resources. Environmental design interventions should be complemented by policing and neighborhood watch efforts, the use of security technology on transportation premises, the dissemination of information, and the launch of media campaigns. For example, the problems of begging and sleeping at underground stations in Stockholm require actions that are a result of cooperation between social care services in the City of Stockholm and other nongovernmental organizations that specialize in searching for homes (e.g., *Stadsmissionen*) and providing alternatives for shelter, particularly in winter. Another example is the problem of vandalism at underground stations, particularly littering. Actions could be supported by no-littering campaigns driven by schools; this no-littering message could be reinforced in public places, such as libraries and shopping malls, which are often connected to transport nodes in Stockholm.

Are criminologists, urban planners, and practitioners able to ensure a safe journey for all? If so, how can it be done? What can be learned from the international experience and, particularly, from the situation in Stockholm presented here? In the following paragraphs, a number of actions aimed at improving safety conditions at underground stations in Stockholm is suggested. These actions range from easy-to-implement solutions that have a direct effect to long-term structural changes in the area so as to decrease crime levels. The actions that can be implemented quickly and easily mostly involve changes to the environmental design of stations, direct surveillance improvements, and ways to control tidy public spaces.

Adjust Small-Scale Environmental Attributes Priority should be given to the attributes that most substantially influence crime levels (see Table 3). To decrease vandalism, the focus should be on improved surveillance through the installation of CCTV cameras, strengthened formal surveillance at smaller stations, and increased visibility at covered platforms. Efforts to curb violence should concentrate on improving surveillance possibilities and management of land uses in the areas surrounding underground stations through improved illumination; detection and adjustment of dark spots and corners in stations will also improve surveillance. Improving the location and accessibility of cash machines (e.g., installing ATMs in stations instead of in areas surrounding stations) may help reduce crime. In addition, understanding the surrounding social environment can help in identifying local issues that need to be addressed in the long term. In the beginning, efforts to decrease property crime rates should involve enhancing visibility and informal surveillance. Public disorder prevention strategies should focus on prioritizing issues in the areas surrounding stations and improving visibility at the stations themselves. There is also a need to improve platform sightlines and overviews and the ability to create sightlines onto separate platforms from elsewhere and outside the stations.

Improve Visibility and Natural Surveillance at Underground Stations and Surrounding Areas It is important to identify the features of underground stations that negatively influence visibility and surveillance. Measures should then be taken to eliminate these features or to diminish their negative effects. These features include hiding places, dark corners, and poor illumination, particularly in transition areas, lounges, and platforms. Equally important is the presence of people in the stations and in the surrounding areas. Empty streets and desolate public spaces generate opportunities for criminal acts to go unnoticed. Experiences in the United Kingdom and the United States have demonstrated that adequate lighting of streets, parks, bus shelters, and stations can decrease the risk of assaults and the perception of danger (see, e.g., Atkins et al. 1991; Farrington and Welsh 2002; Loukaitou-Sideris et al. 2002). The design orientation of buildings with windows facing the street can increase natural surveillance by neighbors. One design aspect that can improve opportunities for surveillanceis the construction of storefronts that face the sidewalk (Loukaitou-Sideris 1999, 2006).

Eliminate Signs that "Nobody is in Control" and Enhance Pleasantness in Underground Stations Our findings show that physical deterioration is often associated with high rates of crime at stations, which may indicate that the area lacks social control. The elevators of some central stations reek of urine and vomit after weekends and holidays. Creating better signs explaining where to find public toilets at stations or in surrounding areas should be a must in Stockholm underground stations. Incidents of vandalism in transport systems can be reduced through the use of graffiti- and vandal-resistant materials. Equally important is to provide alternatives to public places that can be used for graffiti. Previous research has shown that good maintenance and cleanliness of the public environment at station areas convey reassurance to transport users. City agencies should keep walls, sidewalks, and bus shelters free of graffiti and litter; this action demonstrates that residents are in control of neighborhood public settings and transport nodes.

Long term actions that are carried out in response to the influence of social structures and the surrounding environment on crime levels at stations need to be more societally rooted. Initially, it is important to identify those stations and neighborhoods that are in need of the quickest interventions, thereby setting up a typology of stations. Dealing with these types of situations requires more than a one-time effort; it requires a commitment by authorities to work continually on solving problems as they arise. Furthermore, when making decisions about underground stations, authorities need to take into consideration how these decisions will affect the safety and quality of living of all groups of society, including those citizens who are the most vulnerable (e.g., the elderly and the disabled).

Identify Underground Stations in Need of Intervention Some transportation settings are less safe than others (or, at least, perceived as such), and crime tends to be concentrated in these places. Although end stations are more vulnerable to crime than others, our results show that this pattern may vary by crime type and time (day/week/year). For example, thefts tend to be more concentrated in the hot months of the year, whereas acts of violence occur more often in winter. Targeted interventions should focus on the worst first – that is, the locations with the highest incidence of crime or risk of crime. Detailed monitoring of incident reports – along with regular safety audits by personnel, transport agencies, or other municipal agencies – could provide insight into which stations are most in need of intervention and prevention measures. Checking the social environment can help in identifying local problems that need to be dealt with in the longer term. This can be partly achieved through the establishment of neighborhood activity programs, particularly those directed at youth.

Adapt Safety Initiatives to Particular Needs of Communities and Groups of Individuals Different groups have different needs and run different risks of falling victim to crime while on the move. Interventions should be tailored to the needs of particular subgroups, as well as to the characteristics of neighborhoods and their various transportation settings. It is also important to evaluate whether proposed interventions are reaching the populations who seem to be more susceptible to being victimized or threatened, or may have fewer transport options, such as senior citizens, females, and individuals with disabilities. These populations may include not only passengers at underground stations but also station personnel (e.g., ticket booth workers, guards). Previous research has shown that poor accessibility on the premises of underground stations makes travel for women and for individuals with mobility issues less comfortable and, consequently, less safe (Loukaitou-Sideris et al. 2009). The possibility of adding more elevators for easy access to underground stations—particularly for individuals carrying heavy objects or pushing strollers or traveling with young children—should be investigated in Stockholm. It is a common sight to see parents carrying strollers and/or children while riding escalators; this type of practice poses a danger not only to themselves but also to other passengers, while at the same time it may be the cause of irritation for others. Providing separate spaces for vulnerable groups with mobility disabilities, in particular while waiting for trains, may provide an extra hurdle for offenders.

Based on the analysis of Stockholm's underground stations, several suggestions for safety improvements were put forward. These specific suggestions are thought to be efficient in this particular case for the following reasons:

First, these suggestions are particularly relevant for Stockholm because they are based on empirical results from the Stockholm network itself. Thus, suggestions may not be suitable for other underground network elsewhere. In Stockholm, visibility and surveillance opportunities are of high importance. Since Stockholm is a Scandinavian city, passengers experience extreme differences in weather conditions across the seasons, both in terms of temperature (cold versus warm) and length of daylight (long versus short), which are bound to have an effect on people's routine activity and crime opportunities. Therefore, improving illumination, as suggested here, could potentially have a substantial impact on safety level, particularly during dark, cold winters.

Second, the importance of formal social control may be of particular relevance for the Stockholm case. Guards are already employed at Stockholm's underground stations but not in large numbers. The current presence of safety hosts (*trygghetsvärdar*) and security personnel at underground stations suggests a willingness by authorities to improve surveillance and safety for passengers. The fieldwork showed, during short interviews, that passengers approved and appreciated their presence.

Third, suggestions for well-being in public transportation are generally welcomed by passengers and personnel, which increase the chances of successful interventions. Swedish society generally has a high degree of trust in authorities, thus, information provided by authority personnel is taken seriously and followed up. For example, a large campaign driven by SL was launched in 2012 as a way to thank passengers for their help and to the well being of other passengers while traveling (see http://sl.se/sv/Om-SL/Nyheter/700-tusen-tack/).

Fourth, cooperation between authorities is rooted in the Swedish social welfare system, which is built on policies driven by agencies and local and regional authorities. For the time being, a framework for cooperation does exist. However, the questions that needs to be answered is how to make it run more effectively to improve the conditions of underground stations and promote a safe public transportation for all.

Further Research

The interpretation of findings should take into consideration that the analysis and suggestions are based on offense data only. Future studies should investigate links between crime and disorder levels and perceived safety so that interventions can also take into account people's perception of the environment at underground stations. In the present study, aspects of visibility and surveillance proved to be important for explaining crime levels. Future research should investigate how these features relate to possibilities of guardianship and to improvements in the capability of guardians at underground stations based on routine activity theory. There is a need to investigate the nature of guardianship when several "guardians" are in place (e.g., passengers, safety hosts, personnel, security guards, and police) and how the possibilities for guardianship are affected by the environment at transport nodes. In addition, the suggested listing of typologies to identify stations that are more vulnerable to crime requires a further elaboration of how to define types of stations in accordance with particular criteria. These criteria can be based on the type of crime or on environmental attributes of importance for those particular stations. Regarding the use of data, a more detailed examination of crime reports is recommended. For example, property crimes could be disaggregated into specific offenses (theft, robbery, burglary) as a way in which to establish specific crime prevention measures for each of these offenses. Despite this limitation, the article contributes to the knowledge base in this area by providing information about the underground system of a Scandinavian city, a research area dominated thus far by North American and British examples.

Acknowledgments The authors would like to thank the Swedish Transport Administration (Traffikverket), Stockholm Public Transport (SL), and Stockholm Municipality for financing this research project. Thanks also to Ulla Wittrock (Stockholm County Police Department), Stefan Liljevall (Stockholm Statistics), Mats Pergel (SL), and Peter Assor (Veolia) for providing data for the analysis.

Appendix 1

The Stockholm Underground System

Stockholm is part of an archipelago. The islands are well connected by roads and an efficient public transportation system, comprising buses, the Stockholm underground system, rail systems, and commuter trains. The Stockholm underground system is composed of three lines: Green, Blue, and Red. The Green Line has 49 stations (39 of these are aboveground); it is used by 451,000 passengers per workday, and it is the biggest line in terms of the numbers of passengers and stations. The Red Line, which includes 36 stations (15 of these are aboveground), transports 394,000 passengers per workday. The Blue Line consists of 20 stations (only 1 station aboveground) and transports 171,000 passengers per workday. The trains are operated from 0500 h to 0100 h. All lines have trains running every 10 min during daytime hours. It is limited to every 15 min during the early morning and the late evening, and every 30 min during the night. During peak hours, additional trains operate every 5 to 6 min in suburb stations, with 2 to 3 min between trains in the central parts of the network (Stockholm Public Transport Annual Report 2006). The underground system is owned by the Stockholm County Council through Stockholm Public Transport (SL), which has contracted operators.

Appendix 2

Table 4 Characteristics of the databases of crime and perceived safety

Databases	Veolia	SL	Police	City of Stockholm	Fieldwork
Time	• 2005–2008 aggregated data by station • 2005 detailed database on hour and date by station	March 2006 to February 2009 detailed database by time and station	2008 police-recorded data by crime type and time	• 2008 socio-economic and land-use data	• 2010 summer and winter (selected variables)
Space	Stockholm underground network (at stations)	• Stockholm underground network (at stations)	• Stockholm City x,y coordinates and buffers	• Data per small unit area (*Basområde*)	• Stockholm underground stations

References

Alm, C., & Lindberg, E. (2000). *Perceived risk, feelings of safety and worry associated with different travel modes: Pilot study*. KFB-meddelande 2000:7. Stockholm: KFB.

Alm, C., & Lindberg, E. (2004). *Betydelsen av upplevda risker och känslor av otrygghet vid resor med kollektivtrafik: En undersökning i Göteborg samt jämförelse med resultat från Norrköping och Stockholm* [The meaning of experienced risks and unsafe feelings while traveling by public transport: A investigation in Gothenburg in comparison with results from Norrköping and Stockholm]. (VTI meddelande 962). Linköping, Sweden: Swedish National Road and Transport Research Institute.

Atkins, S., Husain, S., & Storey, A. (1991). *The influence of street lighting on crime and the fear of crime*. Crime Prevention Unit Paper 28. London: Home Office.

Bernasco, W., & Block, R. (2011). Robberies in Chicago: a block-level analysis of the influence of crime generators, crime attractors, and offender anchor points. *Journal of Research in Crime and Delinquency, 48*(1), 33–57.

Block, R. L., & Block, C. R. (1995). Space, place, and crime: Hot spot areas and hot places of liquor-related crime. In J. Eck & D. Weisburd (Eds.), *Crime and place* (pp. 145–183). Monsey: Criminal Justice Press.

Brantingham, P., & Brantingham, P. (Eds.). (1981). *Environmental criminology*. Beverly Hills: Sage.

Brantingham, P., & Brantingham, P. (1995). Criminality of place: crime generators and crime attractors. *European Journal on Criminal Policy and Research, 3*(3), 1–26.

Brottsforebygganderadet, B. R. Å. (2008). *Brottsutvecklingen i Sverige fram till ar 2007 [Crime developments in Sweden until 2007]*. Stockholm: Brottsforebygganderadet.

Bursik, R. J., Jr., & Grasmick, H. G. (1993). *Neighborhoods and crime: The dimensions of effective community control*. New York: Lexington Books.

Ceccato, V., Uittenbogaard, A., & Bamzar, R. (2013). Security in Stockholm's underground stations: the importance of environmental attributes and context. *Security Journal, 26*, 33–59.

Clarke, R. V. (1995). Situational crime prevention. In M. Tonry & D. Farrington (Eds.), *Building a safer society: Strategic approaches to crime prevention* (pp. 91–150). Chicago: University of Chicago Press.

Clarke, R. V. (1997). Introduction. In R. V. Clarke (Ed.), *Situational crime prevention: Successful case studies* (2nd ed., pp. 1–43). Monsey: Criminal Justice Press.

Clarke, R. V., & Felson, M. (Eds.). (1993). *Routine activity and rational choice: Vol. 5. Advances in criminological theory*. New Brunswick: Transaction Books.

Cohen, L. E., & Felson, M. (1979). Social change and crime rate trends: a routine activity approach. *American Sociological Review, 44*(4), 588–605.

Cornish, D. B., & Clarke, R. V. (2003). Opportunities, precipitators and criminal decisions: A reply to Wortley's critique of situational crime prevention. In M. Smith & D. Cornish (Eds.), *Theory for situational crime prevention* (Crime prevention studies, Vol. 16, pp. 41–96). Monsey: Criminal Justice Press.

Cozens, P., Neale, R., Whitaker, J., & Hillier, D. (2003). Managing crime and the fear of crime at railway stations—a case study in South Wales (UK). *International Journal of Transport Management, 1*(3), 121–132.

Department of Environment, Transport and the Regions (DETR). (1999). *Personal security issues in pedestrian journeys*. London: DETR.

Farrington, D. P., & Welsh, B. C. (2002). *Effects of improved street lighting on crime: A systematic review (Home Office Research Study 251)*. London: Home Office Research.

Geason, S., & Wilson, P. (1990). *Preventing graffiti and vandalism. Crime prevention series*. Canberra: Australian Institute of Criminology.

Hirschfield, A. F. G., Brown, P. J. B., & Bowers, K. J. (1995). Exploring relations between crime and disadvantage on Merseyside. *European Journal on Criminal Policy and Research, 3*(3), 93–112.

Ihlanfeldt, K. R. (2003). Rail transit and neighborhood crime: the case of Atlanta, Georgia. *Southern Economic Journal, 70*(2), 273–294.

Jacobs, J. (1961). *The death and life of great American cities*. New York: Random House.

Johnson, S. D., Sidebottom, A., & Thorpe, A. (2008). Bicycle theft (Problem-oriented Guides for Police, Problem-specific Guides Series Guide No. 52). Department of Justice, Office of Community Oriented Policing Services. http://www.popcenter.org/problems/bicycle_theft/. Accessed 27 May 2013.

Kinney, J. B., Brantingham, P. L., Wuschke, K., Kirk, M. G., & Brantingham, P. J. (2008). Crime attractors, generators and detractors: Land use and urban crime opportunities. *Built Environment, 34*(1), 62–74.

Kornhauser, R. (1978). *Social sources of delinquency*. Chicago: University of Chicago Press.

Lab, S. P. (2007). *Crime prevention: Approaches, practices and evaluations* (6th ed.). Cincinnati: Anderson Publishing.

Loukaitou-Sideris, A. (1999). Hot spots of bus stop crime: the importance of environmental attributes. *Journal of the American Planning Association, 65*(4), 395–411.

Loukaitou-Sideris, A. (2006). Is it safe to walk? Neighborhood safety and security considerations and their effects on walking. *Journal of Planning Literature, 20*(3), 219–232.

Loukaitou-Sideris, A. (2012). Safe on the move: The importance of the built environment. In V. Ceccato (Ed.), *The urban fabric of crime and fear* (pp. 85–110). London: Springer.
Loukaitou-Sideris, A., Liggett, R., & Iseki, H. (2002). The geography of transit crime: documentation and evaluation of crime incidence on and around the Green Line Stations in Los Angeles. *Journal of Planning Education and Research, 22*(2), 135–151.
Loukaitou-Sideris, A., Bornstein, A., Fink, C., Samuels, L., & Germai, S. (2009). *How to ease women's fear of transportation environments*: *Case studies and best practices* (MTI Report 09–01). San José, CA: San José State University, Mineta Transportation Institute.
LaVigne, N. G. (1997). *Visibility and vigilance: Metro's situational approach to preventing subway crime (National Institute of Justice–Research in Brief)*. Washington, DC: U.S. Department of Justice.
Morgan, R., & Smith, M. J. (2006a). Vandalism and graffiti. In M. J. Smith & D. B. Cornish (Eds.), *Secure and tranquil travel: Preventing crime and disorder on public transport* (pp. 126–151). London: University College London (UCL) Jill Dando Institute of Crime Science.
Morgan, R., & Smith, M. J. (2006b). Crimes against passengers – theft, robbery, assault and indecent assault. In M. Smith & D. B. Cornish (Eds.), *Secure and tranquil travel: Preventing crime and disorder on public transport* (pp. 77–102). London: UCL Jill Dando Institute of Crime Science.
Newman, O. (1972). *Defensible space: Crime prevention through urban design*. New York: Macmillan.
Newman, O. (1992). *Improving the viability of two Dayton communities: Five Oaks and Dunbar Manor*. Great Neck: Institute for Community Design Analysis.
Newton, A., Johnson, S. D., & Bowers, K. J. (2004). Crime on bus routes: an evaluation of a safer travel initiative. *International Journal of Police Strategies & Management, 27*(3), 302–319.
Pearlstein, A., & Wachs, M. (1982). Crime in public transit systems: an environmental design perspective. *Transportation, 11*(3), 277–297.
Piza, E., & Kennedy, D. (2003). Transit stops, robbery, and routine activities: Examining street robbery in the Newark, NJ subway environment. http://proceedings.esri.com/library/userconf/proc04/docs/pap1303.pdf. Accessed 28 May 2013.
Poole, M. A., & O'Farrell, P. N. (1971). The assumptions of the linear regression model. *Transactions of the Institute of British Geographers, 52*, 145–158.
Priks, M. (2009). *The effect of surveillance cameras on crime*: *Evidence from the Stockholm subway*. CESifo Working Paper Series No. 2905. Available at SSRN: http://ssrn.com/abstract=1536432.
Robinson, J., & Giliano, L. (2012). Spatial interplay: Interaction of land uses in relation to crime incidents around transit stations. In M. A. Andresen & J. B. Kinney (Eds.), *Patterns, prevention, and geometry of crime* (pp. 137–147). New York: Routledge.
Sampson, R. J., & Raudenbush, S. W. (1999). Systematic social observation of public spaces: a new look at disorder in urban neighborhoods. *The American Journal of Sociology, 105*(3), 603–651.
Sampson, R. J., Raundenbush, S. W., & Earls, F. (1997). Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science, 277*(5328), 918–924.
Shaw, C. R., & McKay, H. D. (1942). *Juvenile delinquency and urban areas*. Chicago: University of Chicago Press.
Sherman, L. W., Gottfredson, D., MacKenzie, D., Eck, J., Reuter, P., & Bushway, S. (Eds.). (1998). *Preventing crime: What works, what doesn't, what's promising*. Washington, DC: National Institute of Justice.
Smith, M., & Clarke, R. (2000). Crime and public transport. In M. Tonry & N. Morris (Eds.), *Crime and justice: A review of research, Vol. 27* (pp. 169–233). Chicago: University of Chicago Press.
Smith, M. J., & Cornish, D. B. (Eds.). (2006). *Secure and tranquil travel: Preventing crime and disorder on public transport*. London: UCL Jill Dando Institute of Crime Science.
Stangeby, I., & Nossum, Å. (2004). Tryggkollektiv trafik: trafikanters upplevelse av kollektiv trafik resor och återgärder för att öka tryggheten [Safe public transport: passengers' experience of public transport journeys and measures for increased safety]. Transport ekonomisk institut. https://www.toi.no/getfile.php/Publikasjoner/T%C3%98I%20rapporter/2004/704a-2004/704a-2004-el.pdf. Accessed 20 June 2013.
Stockholm Public Transport Annual Report. (2006). Storstockholms Lokaltrafik. 2007-06-21. pp. 17.
Stockholm stad. (2010). Hemlösa i Stockholms stad 15 april 2010, tabeller och kommentarer. Socialtjänst- och arbetsmarknadsförvaltningen.
Stockholm stad. (2013). http://www.stockholm.se/Fristaende-webbplatser/Fackforvaltningssajter/Socialtjanstforvaltningen/Utvecklingsenheten/Utvecklingsprojekt/Sociala-insatsgrupper/. Accessed 28 May 2013.
Stucky, T. D., & Ottensmann, J. R. (2009). Land use and violent crime. *Criminology, 47*(4), 1223–1264.
Webb, B., & Laycock, G. (1992). *Reducing crime on the London underground*: *An evaluation of three pilot projects* (Crime Prevention Unit Series Paper No. 30). London: Home Office Police Department.
Weisel, D. L. (2004). Graffiti (Problem-oriented Guides for Police Series No. 9). U.S. Department of Justice, Office of Community Oriented Policing Services. http://www.popcenter.org/problems/graffiti/3/. Accessed 27 May 2013.
Wilson, J. Q., & Kelling, G. (1982). The police and neighbourhood safety: broken windows. *Atlantic Monthly, 127*, 29–38.