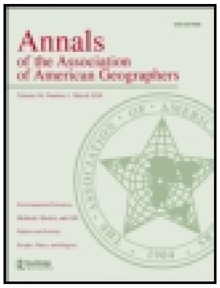

Annals of the Association of American Geographers
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/raag20

Space-Time Dynamics of Crime in Transport Nodes

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Published online: 20 Nov 2013.

To cite this article: Vania Ceccato & Adriaan Cornelis Uittenbogaard , Annals of the Association of American Geographers (2013): Space-Time Dynamics of Crime in Transport Nodes, Annals of the Association of American Geographers, DOI: 10.1080/00045608.2013.846150

To link to this article: http://dx.doi.org/10.1080/00045608.2013.846150

Space–Time Dynamics of Crime in Transport Nodes

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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, 00(00) 2013, pp. 1–20
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.

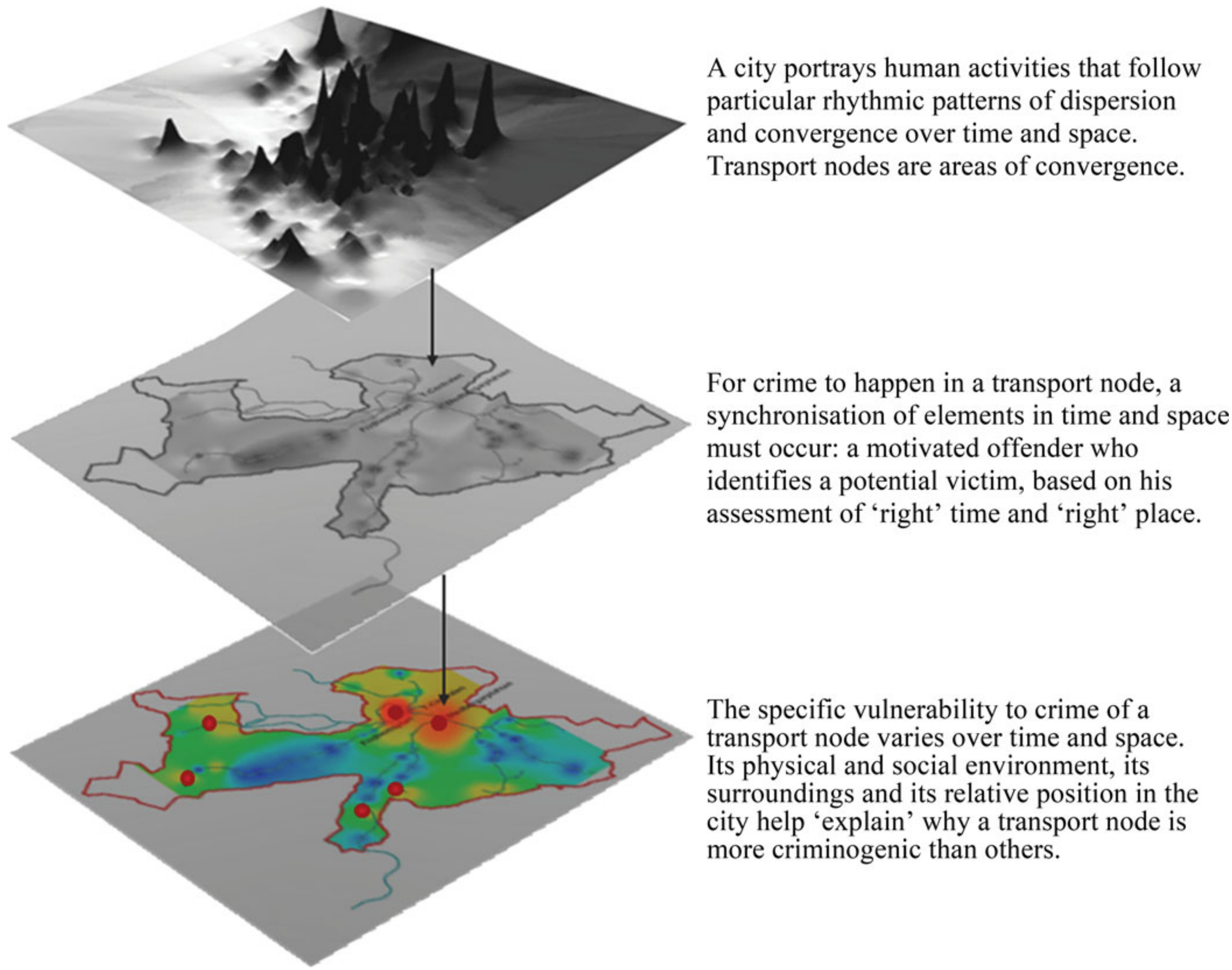

Figure 1. The conceptual framework: Mobility and crime at underground stations. (Color figure available online.)

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

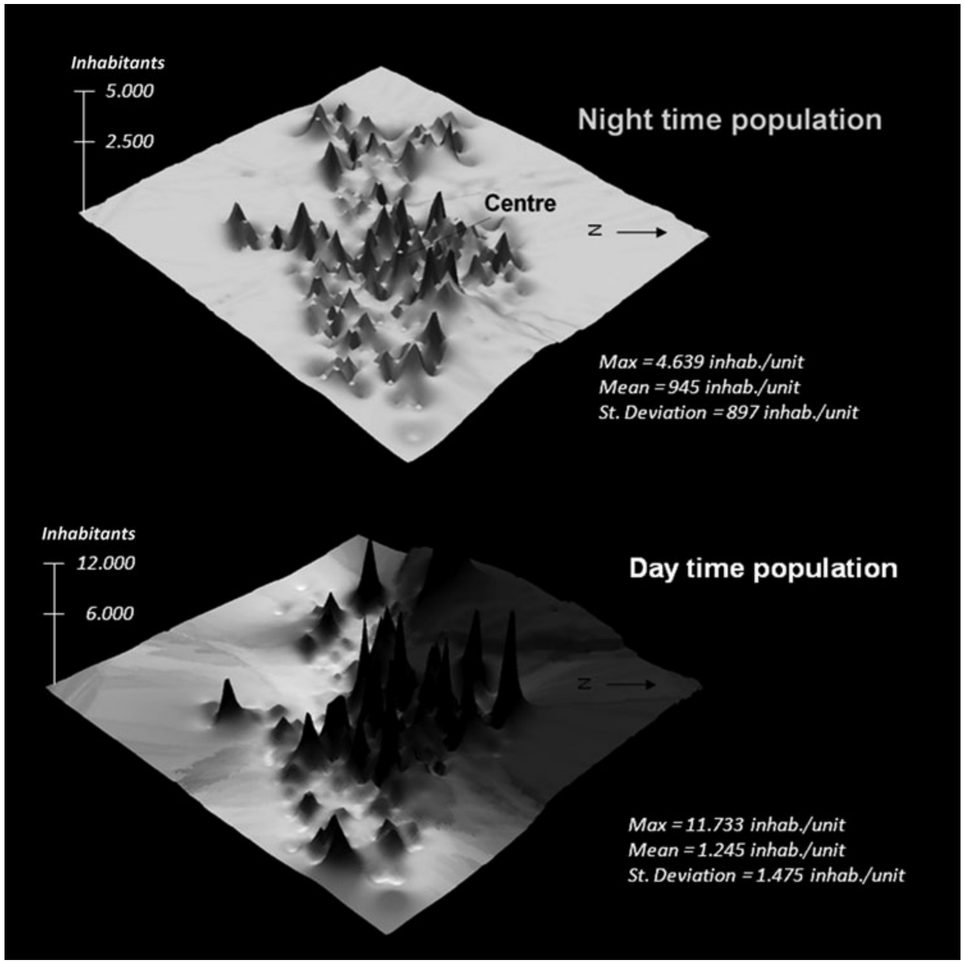

Figure 2. Night and daytime population in Stockholm municipality.

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.

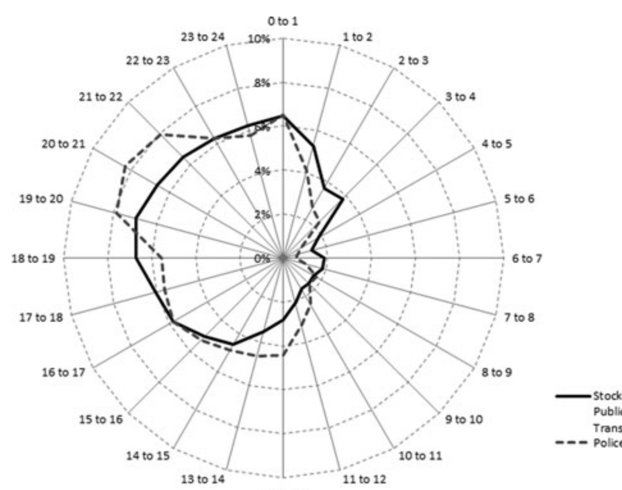

Figure 3. Distribution of crime and disorder by hour of the day and data source.

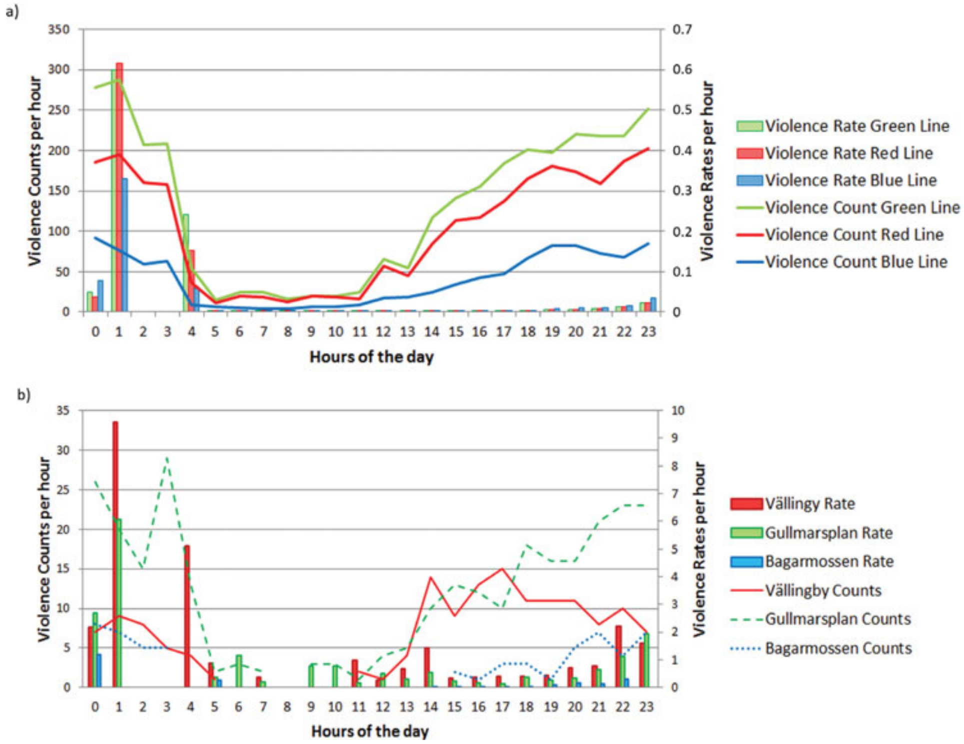

Figure 4. (A) Counts and rates of violence per hour of the day at all stations. (B) Counts and rates of violence per hour of the day in selected stations on the green line. (Color figure available online.)

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).

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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.