5
The Geography of Pickpocketing at Bus Stops: An Analysis of Grid Cells

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Introduction

'Pickpocketing needs a crowd'

(Marcus Felson, ASC Conference, Atlanta, 2013)

Bus stops, as any other type of transport node, may be criminogenic places by nature. Evidence from North American and British studies has repeatedly shown that areas that 'contain' a bus stop are more criminogenic than those without (Levine and Wachs, 1986; Loukaitou-Sideris 1999; Loukaitou-Sideris et al., 2002; Newton and Bowers, 2007; Smith and Cornish 2006; Tsai et al., 2011). Yet despite such findings, the link between bus stops and crime has been controversial (Kooi, 2013) and highly dependent on North American and British evidence. If one randomly selects two areas, the first one containing a bus stop and the second not, is it more likely that the first area has more pickpocketing than the second one? Previous studies have attempted to isolate the effect of bus stops from that caused by the place's attributes (where bus stops are located) on crime. Surprisingly, the nature of bus stops is often neglected in the analysis. This article addresses this issue by assessing the potential impact of passenger flow and vehicle frequency on the geography of pickpocketing.

This is a relevant issue as bus stops are far from homogeneous entities (Levine et al., 1986). Some bus stops, particularly those in city centres, are busy settings, as passengers and potential offenders cluster around them, perhaps for short times because bus frequency may be high (see in this volume Uittenbogaard's article on the impact of the environment of transport nodes on the potential to exercise social control). On the one hand, crime may be facilitated by such fluid circumstances (passengers boarding/alighting buses), as people's willingness and ability to exercise social control is low in these circumstances. On the other hand, a high bus frequency may reduce passengers' waiting time and vulnerability to be victimized by thieves, while, at the same time, high frequency could mean that offenders may have an easy escape by taking the first bus after mugging a passenger. If buses do not arrive often, bus stops may suffer from inverse conditions. Thus, bus frequency and passenger flow at these transport nodes are suggested here to be an essential element for the understanding of the criminogenic conditions present at bus stops.

The aim of this chapter is to obtain a better understanding of the potential criminogenic effect bus stops have on their immediate vicinities. The study focuses on pickpocketing, a typical offence at transport nodes in Stockholm (Ceccato, 2013), which consists of purse snatching, wallet theft or other thefts, such as mobile phones or other personal belongings. This analysis is performed with two objectives in mind:

1. to assess whether pickpocketing is more likely to occur near bus stops
2. to investigate the distribution of pickpocketing incidents in relation to the respective flows of vehicles and passengers at bus stops

An important contribution of this article is methodological. The article is truly an example of multidisciplinary research as it brings data on passenger flow and bus frequency into crime analysis, which has so far been lacking in the international literature. Moreover, the study explores the use of equal-stratified sampling of grid cells generated from data using a geographical information system (GIS). Equal-stratified sampling of grid cells is commonly used in natural sciences (Hirzel and Guisan, 2002) but, to the best of the authors' knowledge, has not yet been employed in the context of understanding transit crime. The equal-stratified sampling was applied in combination with a Monte Carlo simulation to perform repeated random sampling of grid cells, an important step for hypotheses testing. This procedure was applied for an iterative sampling of grid cells that contain bus stops, and grid cells without any bus stop in order to compare the likelihood of pickpocketing incidents and their prevalence. Although safety at bus stops is recognized to be a multi-scale phenomenon (Loukaitou-Sideris et al., 2002; Ceccato, 2013), this article focuses primarily on the occurrence of pickpocketing at bus stop locations and their immediate vicinities represented by cells of 50 by 50 metres (similar to previous research, see Yu, 2009).

The structure of the chapter is as follows. A review of previous studies on crime and bus stops is first presented as basis for the hypotheses. Next, the study area is framed, followed by data, methods and then results. The chapter closes with a discussion of the findings and directions for future research.

Crime and bus stops: theory and hypotheses of study

Although crime in the transport system is a rare event, still the decision one takes to travel is often associated with a decrease in one's safety. A recent study in the United States demonstrated that the risk of victimization during travel between activities is more than eight times higher than staying at home and almost twice as high as any other activity outside the home. It is particularly high during commutes to and from school and work (Lemieux and Felson, 2012). International evidence shows that risk of crime varies by transport type (train, subway, tram and bus), within the system (large and small nodes) and by time (hourly, weekly and seasonally) (Levine and Wachs, 1986; La Vigne, 1997; Loukaitou-Sideris, 1999; Loukaitou-Sideris et al., 2002; Ceccato and Uittenbogaard, 2014).

Crime occurs at bus stops more often than inside buses (Levine et al., 1986; Loukaitou-Sideris, 1999). However, the condition and environmental settings of bus stops vary considerably. Some may be crowded spots in the city centre, others empty most of the time. They also differ in layout and location (Levine et al., 1986). Despite these differences, bus stops are often regarded as crime generators and/or crime attractors (Brantingham and Brantingham, 1995). They are often positioned in specific areas of the city that concentrate large flows of people, providing potential crime targets, or they themselves constitute a crime attractor, pulling motivated offenders, such as drug dealers, towards them. Bus stops are markedly different from train or subway stations, as train or subway stations form the urban landscape with tracks and large buildings, while bus stops often blend in with attributes of the landscape. Some bus stops only consist of a pole with a timetable located on the sidewalk, which marginally affects the urban landscape. Bus shelters that offer protection against rain, snow or sun are much more defined in space. These differences, although limited to a small area, are relevant for the way passengers wait for a bus and experience safety (Loukaitou-Sideris, 1999).

The level and types of crime that happen at a bus stop are determined by the characteristics of the bus stop and also by its context. In the United States, for instance, Loukaitou-Sideris et al. (2001) show that bus stops with high records of crime are associated with liquor stores, check cashing businesses, vacant buildings and general vandalism. Newton (2008) suggests that crime risk increases with greater concentrations of bus stop locations along a bus route. Yu (2009) shows that the geographies of both property and violent crimes are influenced by the concentration of bus stops, while Kooi (2013) finds that clusters of bus stops promoted increases in public-order offenses at the block level. It is therefore not surprising that the international literature has for decades shown evidence (sometimes contrasting) of the combined effect of bus stops and their contexts (Levine and Wachs, 1986; Loukaitou-Sideris et al., 2001; Yu, 2009; Kooi, 2013). However, Hart and Miethe (in this book) show that the bus stops alone are more likely to appear as determinants of robbery than any other environmental factor. These results suggest that the attention should turn from the *contexts* of bus stops to bus stops themselves as unique criminogenic settings, which implies analysis is required using a limited geographical unit.

Previous literature suggests the importance of passenger flow at bus stops. The seminal study of Levine and Wachs (1986: 20) suggests 'pedestrian crowding appeared to be critical in encouraging thefts'. Overcrowding was a major factor perceived as contributing to bus crime, a factor that was mentioned by victims and witnesses far more often than any other factor. Their findings indicate that, regardless, location factors contributing to crime differ among bus stops, which suggests that bus stops are far from homogenous. For example, during the evening rush hour, when there is disorganization on the sidewalks due to increased numbers of pedestrians given limited sidewalk space, petty thieves (specialized in purse snatching, pickpocketing and jewellery snatching) can operate easily in such a tangled environment.

Crowded bus stops offer crime targets and, in particular, pickpocketing targets if motivated offenders are around and if there is a lack of 'capable guardians' (Cohen and Felson, 1979), persons who, sometimes just by their presence, discourage crime from taking place. Individuals who usually function as capable guardians in their own neighbourhood often have no sense of ownership of bus stops and are thus unwilling to get involved if something happens there (Ceccato and Haining, 2004). Also, few passengers are ready to keep an 'eye on the street' and/or intervene (Jacobs, 1961). Newton (2004) suggests that it is not only crowding at a bus stop that affects vulnerability to crime but also the amount of time passengers have to wait for a bus. Thus, if a bus stop is frequently served, crime opportunities are constantly reset as passengers arrive and leave. However, if buses are infrequent, the bus stops may become crowded at certain times, promoting opportunities for thefts, or they may be constantly empty, allowing other types of criminal activities to occur as nobody is around. In this study, both bus frequency and passenger flow are taken into consideration when assessing the distribution of pickpocketing at bus stops.

Given the importance of the characteristics of bus stops for crime in North American and British cities, this study tests three hypotheses for the Swedish capital city of Stockholm, focusing primarily on the occurrence of pickpocketing at bus stop locations and their immediate vicinities (half a block) represented by cells of 50 by 50 metres:

Hypothesis 1 – Pickpocketing incidents are significantly higher in areas with bus stops than elsewhere in the city.

Hypothesis 2 – The flow of passengers at bus stops explains the variations of pickpocketing; more people, more potential victims and motivated offenders.

Hypothesis 3 – The higher the bus frequency at a bus stop, the lower the level of pickpocketing, as it lessens the passengers' time to wait for a bus.

The study area

The municipality of Stockholm (*Stockholms stad*) has a population of 881,235 (2012), spread over 188 square kilometres, while the Stockholm metropolitan area is home to approximately 22 per cent of Sweden's population (about 9.5 million in 2013). The central parts of the city consist of 14 islands, and a third of the city area is composed of waterways, while another third is made up of parks and green spaces. The whole archipelago (and county) is well connected by roads and an extensive and efficient public transportation system comprised of buses, trams, subway, regional and suburban rail, and archipelago boats. Every weekday, more than 700,000 people travel by public transport in Stockholm. In 2013, there were 2,065 bus stops located within the borders of Stockholm municipality (Figure 5.1). The main public transport interchange is located in the central business district (CBD) area in the central area of the inner city. This interchange, which includes the central station (the main railway station of the capital) also acts as the major hub for both the subway and bus networks, making this area a place through which many travellers and workers pass daily.

Crimes occurring near bus stops are more concentrated relative to the area taken up by the stops. For example, 95 per cent of all offences in Stockholm occur within 300 metres of a bus stop, whereas only 66 per cent of the city's area is within 300 metres of a bus stop. This means that many areas with bus

(a)

Figure 5.1 Continued

(b)

(c)

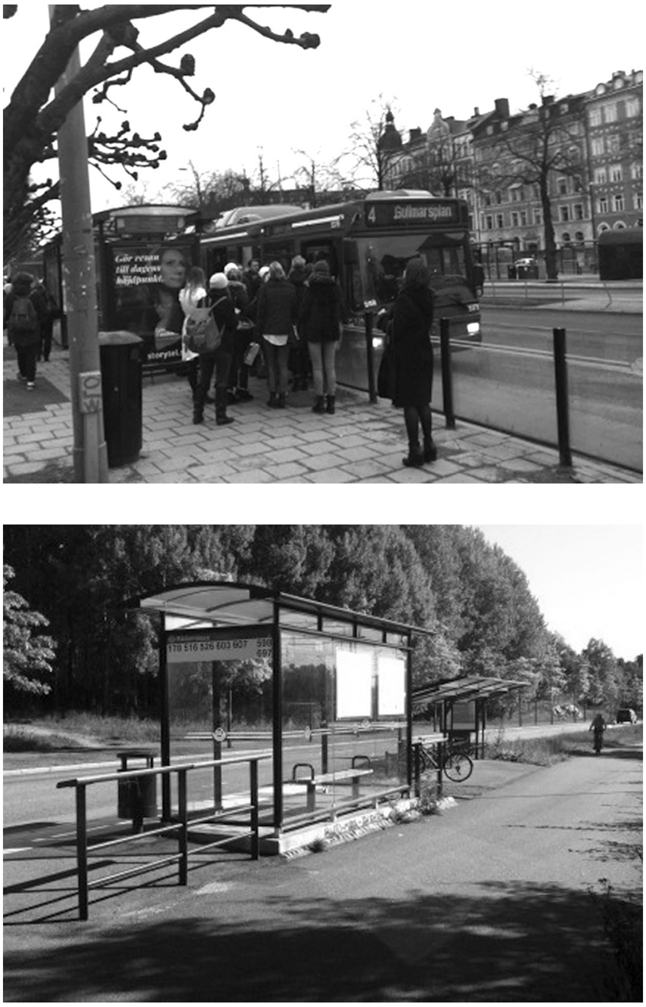

Figure 5.1 Examples of (a) bus stops located in transfer hubs (b), along an arterial street (c) and in peripheral outskirts

stops had no crimes. Pickpocketing is concentrated in the inner-city areas, particularly in Södermalm, Norrmalm and Östermalm (a large part of areas shown in Figure 5.4). Police statistics show a total of 7,260 pickpocketing records in 2008, with a sharp increase in 2011. During the summer, police estimate over 50 pickpocketing incidents per day in Stockholm County, and tourists are the thieves' primary targets.

Data and method

In this section, the main three elements of the analysis and their respective methods are briefly presented: (1) number of bus stops, (2) number of crimes committed near bus stops and (3) grid cells that have been overlaid on the study area to count both crimes and bus stops.

Police-recorded statistics of pickpocketing with *x,y* geographical coordinates for 2008 were obtained from the Stockholm Police Headquarters (7,260 incidents). Pickpocketing was mapped using a GIS. Bus stops' locations and their respective attributes were available from the Stockholm Public Transportation Agency (SL).

The dataset contained all bus stops located within Stockholm municipality borders (2,049 stops) along with their respective coordinates and attributes. Passenger flow is expressed as the number of boarding and alighting passengers per bus stop per bus line. Passenger flows fluctuate from day to day and are subject to seasonal variations. In the case of Stockholm, summer is characterized by significantly lower ridership levels. Therefore, the passenger flow is the average number of passengers during weekdays, from 22 August 2011 to 21 June 2012, excluding the summer holiday period. Vehicle flow is expressed as the number of buses serving a stop on a typical weekday (Wednesday). Vehicle flows are aggregated over lines, as bus stops are often served by more than one bus line. It is assumed that vehicle flows are symmetrical for both stop directions at the daily level. In addition to the attributes of bus services, two other variables indicating the activity level are also included in the model. One variable defines transport nodes which serve a high number of passengers as the 'transfer hub'. The other is an ordinal variable indicating the rank of distance to the centre, where activities concentrated. Details of the dataset are found in Appendix 5A.

To compare areas with and without bus stops, a grid pattern of 50 metres was created using GIS, with the boundaries of Stockholm municipality acting as the grid boundary (Figure 5.2). A total of 85,857 cells were created and overlaid with layers of location coordinates of bus stops, bodies of water, forests and parks, major vacant land and coordinates of pickpocketing. By using bus stop and pickpocketing locations as a reference, a selection of cells was performed with the objective of eliminating major areas that did not contribute to the analysis, such as lakes, forests/parks and non-built-up areas, resulting in the deletion of 36 per cent of the original 83,587 cells. The final study area was thereafter composed of 54,802 cells. Using SQL functions in GIS, data on bus stops and pickpocketing were associated with the grid cells to create a topology of pickpocketing by cell.

After data preparation, the study followed a two-stage approach (Figure 5.2). In part one, the objective was to assess whether the location of a bus stop increased the likelihood of having pickpocketing in a cell when the cells were randomly selected across the city. In order to answer this

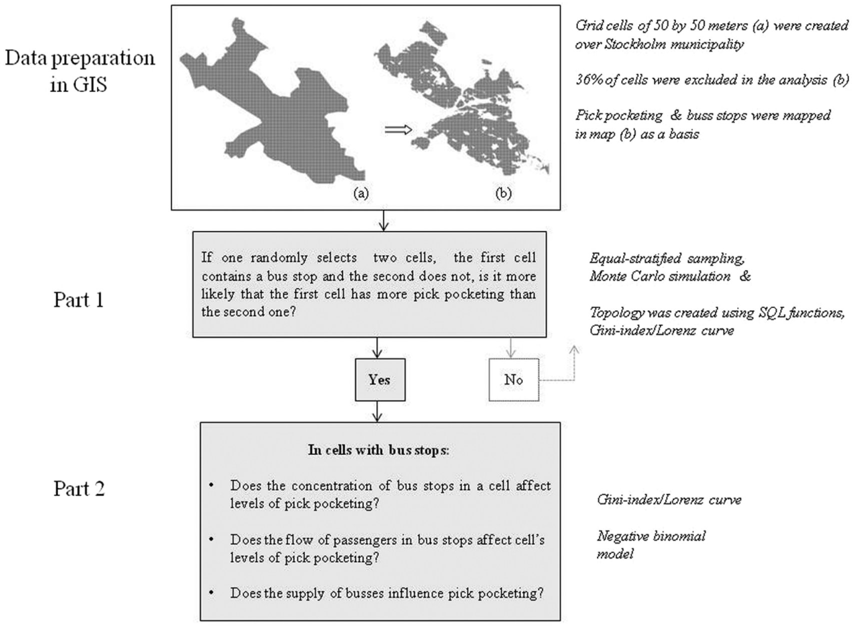

Figure 5.2 The impact of bus stops on the geography of pickpocketing: a two-stage approach

question, equal-stratified sampling, a Monte Carlo simulation and the Gini index are used, as explained in the following section. If the answer to this question was affirmative, then part two had to be performed with both exploratory and confirmatory analyses. Thus, the Gini index and negative binomial modelling would be used to examine whether the number of bus stops and the flows of passengers and buses impact the geography of pickpocketing in cells that have at least one bus stop. The steps taken in the analysis are described in more detail later in this chapter.

Analysis

Part 1: The distribution of pickpocketing and bus stops

Pickpocketing shows a concentrated geography in Stockholm and tends to be associated with the location of bus stops. The analysis shows that all recorded pickpocketing incidents were concentrated in only 2.5 per cent of the cells and that 50 per cent of all pickpocketing incidents occurred in less than 0.001 per cent of the grid cells. This is not unique for Stockholm. As the international literature of crime has long suggested, crime is often concentrated in a limited geographical area (Sherman et al., 1989; Weisburd et al., 2012). In

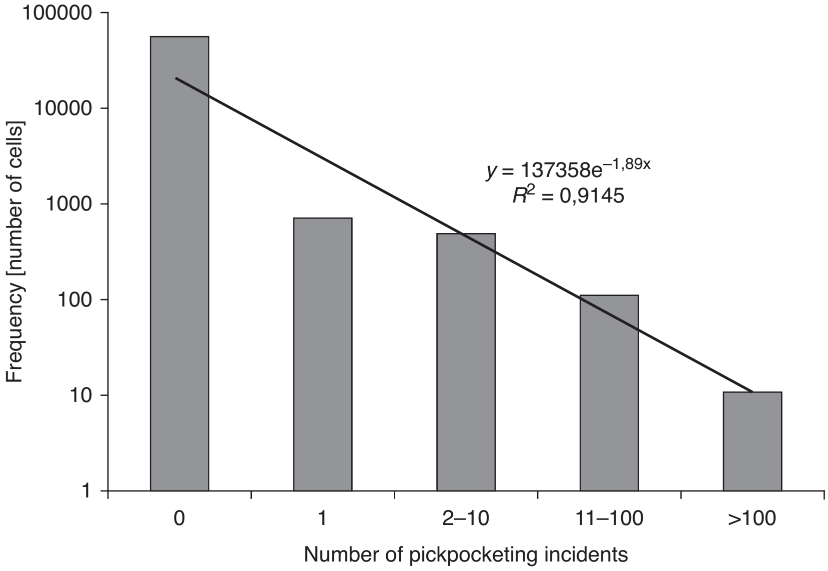

Figure 5.3 Distribution of number of pickpocketing incidents per grid cell

the case of Stockholm, a cell corresponds to a 50 by 50 metres square. This implies that 50 per cent of the incidents are limited to an area smaller than 0.15 square kilometres and that all pickpocketing incidents are constrained to 3.33 square kilometres. Figure 5.3 shows the histogram of pickpocketing incidents by cell. Note that for both axes, the number of incidents as well as the respective number of grid cells is in logarithmic scale. The histogram is characterized by a linear relationship with a high goodness-of-fit ($R^2 = 0.915$). A linear relationship between the logarithmic scales of two variables is the signature of a power law. The power law implies that the relation between the non-transformed variables can be expressed as follows: $f(x) \propto cx^{-\gamma}$, where γ is known as the scale factor, which determines how skewed the distribution is and the length of the tail. The scale factor of pickpocketing frequency in Stockholm is $\gamma = 1.89$ indicating that the vast majority of such incidents are concentrated in a fraction of the geographical cells.

Although the frequency of crime incidents by cell is illustrative of the overall distribution of pickpocketing, it neither says much about the nature of these cells nor why some attract pickpocketing and others do not. In order to assess the chances of having pickpocketing in a cell, cells were classified into two groups: cells that contain at least one bus stop within their boundaries ($N = 1750$), and the majority, those which do not include any bus stop ($N = 54{,}802$). Among the cells that contain at least one bus stop, the average number of stops is 1.18. The summary statistics of pickpocketing activity for cells with and without bus stops as well as for all

Tables 5.1 Summary statistics of pickpocketing activity by cell type

	N	**Pick-pocketing**	**Pick-pocketing per cell**	**Of which with pick-pocketing**	**Gini index of pick-pocketing**
Bus stop	1750 (3.1%)	1104	0.631	146 (8.3%)	0.977
Non-bus stop	54802 (96.9%)	6030	0.110	1182 (2.2%)	0.994
All	56552	7134	0.126	1328 (2.3%)	0.993

cells combined are presented in Table 5.1. Although most of the pickpocketing incidents (84.5 per cent) took place within non-bus stop cells, the average number of pickpocketing incidents per cell was significantly higher at bus stop cells compared with non-bus stop cells. More interestingly, the share of bus stop cells that had some pickpocketing was almost four times higher than non-bus stop cells – 8.3 per cent and 2.2 per cent, respectively. Note that a large share of the pickpocketing incidents in non-bus stop cells were concentrated within the touristic old town (Gamla Stan) and along the main pedestrian shopping streets (Drottninggatan and its immediate surrounding), in which there are large crowds of tourists and shoppers and no bus stops.

The level of spatial concentration of pickpocketing in cells with bus stops is confirmed by the Gini index, which is computed based on the difference between a perfectly even distribution and a Lorenz curve corresponding to the actual distribution. The Lorenz curve is constructed by matching the cumulative density function of the population with the cumulative density function of the variable of interest. The Gini index would take the value 1 if all pickpocketing incidents were concentrated in a single cell, and the value 0 if the incidents were distributed equally across the study area. The resulting Gini index is 0.993, which indicates an extremely uneven spatial distribution of pickpocketing, with very few cells accounting for the vast majority of incidents. Furthermore, this uneven pattern is observed for cells both with and without bus stops. As much as 90 per cent of the pickpocketing incidents that were committed within boundaries of bus stops cells took place at the top 60 cells regarded as generators/attractors, that is, in only 3.5 per cent of the bus stop cells. Some of the most important attractors are shown in Figure 5.4. The distribution of pickpocketing incidents at non-bus stop cells is even more skewed, with 90 per cent of all these observations attributed to 1 per cent of the cells.

A typology of the prevalence of pickpocketing at bus stops follows from the 60 attractors/generators. They are located in the inner-city areas with very few exceptions, such as cells in Vällingby, Liljeholmen and Älvsjö. The majority of them (46 cells) are composed of cells that have one bus

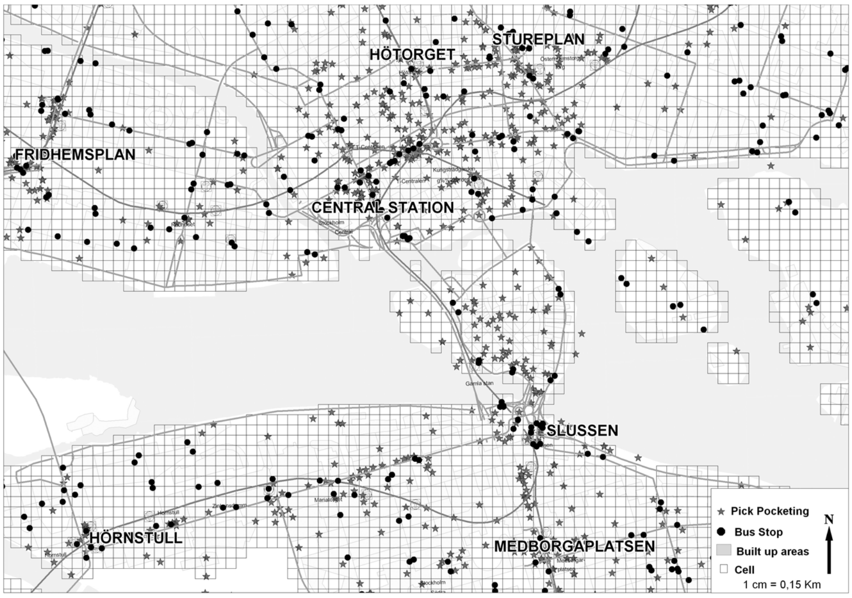

Figure 5.4 Pickpocketing and seven of the most important bus stops and crime generators/attractors

stop, with three or more cases of pickpocketing. Figure 5.4 shows the central area, in which most incidents occur. Examples are those located at Klarabergsvägen (T-centralen and Sergels torg), Linnégatan,, Hötorget, Kunsgatan, Blekholmsterrassen, Odenplan, Folkungatan (Medborgarplatsen), Katarinavägen (Slussen), Ringvägen (Skanstull), Oxtorgatan, Gullmarsplan, and Södertäljesvägen (Liljeholm). The second type are not mutually exclusive types as they are composed of those cells that have several bus stops (at least three) with a concentration of pickpocketing (max. = 111, mean = 17). Examples are those located at Katarinavägen (Slussen), Ringvägen (Skanstull), Central Station, St Eriksgatan/Drottningvägen (Fridhemsplan), Stureplan, Kungsträdsgården, Birger Jarlsgatan (Östermalmstorg), Vallhalavägen (KTH) and in the outskirts, Vällingby (subway station) and Älvsjö. Note that most of them act as transfer hubs providing connections to other types of public transportation such as subway and commuter trains.

In order to test the hypothesis that pickpocketing is more likely to occur in proximity to bus stops than elsewhere, an equal-stratified sampling of grid cells was conducted. This method is more often used in natural sciences and the study of ecological systems, and shows accurate and robust results when compared with similar sampling methods (e.g. see Hirzel and Guisan, 2002). The equal-stratified sampling strategy is systematic and requires a segmentation criterion for clustering the dataset, such as, in this study, the presence of bus stops within cells boundaries. Note that all cells within a certain set, either bus stop cells or non-bus stop cells, had the same probability of being included in the sample without controlling for other factors. In order to perform repeated random sampling of grid cells, the Monte Carlo method was applied. In order to guarantee a robust statistical analysis, ten samples were generated, each consisting of 200 observations. Sample size and the number of samples were selected based on the respective population size (i.e. number of cells per set) and the prevalence and variability of pickpocketing incidents.

Two indicators were calculated for each sample: (a) the share of cells that have at least one pickpocketing incident reported within their boundaries and (b) the total number of pickpocketing incidents occurring within these cells. A one-tailed *t*-test for two samples with unequal variance was used. The null hypothesis that the pickpocketing rate at bus stop cells is *not* larger than at non-bus stop cells was rejected ($t = 3.42$; $p < 0.01$). Moreover, the same statistical test also rejected the hypothesis that the share of bus stop cells at which pickpocketing occurred is *not* larger than the corresponding share among non-bus stop cells ($t = 8.24$; $p < 0.001$).

Both the share of cells with pickpocketing and the number of pickpocketing incidents were found to be significantly higher at bus stop cells than elsewhere, findings that are in line with hypothesis 1. Note that, although this does not imply a causal relationship between bus stop presence and pickpocketing, these findings provide strong evidence for the influence of bus stops on the geography of pickpocketing. First, these cells are relatively small geographical units (equivalent to a half a street block), which should therefore reflect the micro-landscape in which pickpocketing takes place. Second, different types of cells run the same likelihood to be drawn, therefore allowing for other factors, such as differences in land use, to be picked up by the equal-stratified sampling selection.

Part 2: Modelling pickpocketing in cells with bus stops: a grid analysis

In this analysis, the geography of pickpocketing has been associated with proximity to bus stops. Given that bus stops are heterogeneous in terms of flows of passengers and buses, the effects of these two factors on crime are further explored. In detail, does passenger flow at bus stops affect cells' levels of pickpocketing? Does the flow of buses influence pickpocketing?

In order to investigate these issues, a regression analysis is carried out using grid cell data. Original data of flows of passengers and buses are now transformed into numbers by cell. The sum of the attribute value is taken if there is more than one bus stop in a cell. Among 56,039 cells, there are 1,669 cells containing passenger and vehicle flow values.[1] The regression analysis uses these 1,669 observations, of which only 142 cells have a record of pickpocketing incidents. The aim of this regression analysis is not to find the best model, but rather to explore the explanatory power of vehicle and passenger flows with respect to variations in the number of pickpocketing incidents across the urban grid.

Poisson and negative binomial regression are commonly applied in modelling count data. Poisson regression assumes the mean and variance of the dependent variable to be equal, while negative binomial regression, which is used in this study, relaxes this restriction with a dispersion parameter α. The larger αi, the more disperse the variable. Table 5.2 shows that the standard deviation of the number of pickpocketing incidents is 5.6, much higher than its mean of 0.66. In other words, the distribution of the dependent variable is strongly skewed. Thus, it is assumed that the dependent variable follows a negative binomial probability distribution and that the expected value of the number of pickpocketing incidents E[yi] can be modelled as

$$E[y_i] = \lambda_i\, EXP(\beta_0 + \beta_1 * x_i^1 + \beta_2 * x_i^2 + \beta_3 * x_i^3 + \beta_4 * x_i^4 + \epsilon_i),$$

where EXP(ϵ_i) is a gamma-distributed error term with mean equal to 1 and variance α^2 to be estimated.

y_i : The number of pickpocketing incidents in cell *i*
λ_i : The expected number of pickpocketing incidents in cell *i*
x_i^1 : The passenger flow in cell i
x_i^2 : The rate of passenger flow divided by vehicle flow in cell *i*
x_i^3 : A dummy variable, where $x_i^3 = 1$ if cell i contains a transfer hub at which more than 10,000 passengers interchange daily; otherwise, 0.
x_i^4: An ordinal variable indicating the distance di between cell i and the centre cell of *Mälartorg*, which is located in the 'old town' (*Gamla stan*). $x_i^4 = 1$ *if* $d_i < 2$ *km*; $x_i^4 = 2$ *if* $2\ km < d_i \leq 4\ km$; $x_i^4 = 1$ *if* $d_i > 4\ km$. Therefore, the smaller the d_i, the higher the rank *i* (the highest rank is 1).

Table 5.2 Negative binomial regression, dependent variable (number of pickpocketing incidents), $N = 1669$

	Output	**Parameter**	**Std. error**	***Z* value**	**Pr(>|z|)**
Model A	β_0	1.167	0.337	3.159	0.001
	β_1	0.001	0.000	12.882	0.000
	β_3	2.377	6.046	3.932	0.000
	β_4	–1.529	1.556	–9.825	0.000
	α	13.7741			
	LL(β_0)	–842.648			
	LL(β)	–741.987			
Model B	β_0	1.011	0.392	2.576	0.010
	β_2	0.523	0.056	9.341	0.000
	β_3	2.817	0.615	4.584	0.000
	β_4	–1.497	0.157	–9.533	0.000
	α	15.244			
	LL(β_0)	–842.648			
	LL(β)	–753.117			

Parameter vector $\beta = [\beta_0, \beta_1, \beta_2, \beta_3, \beta_4]$ is the marginal utility of the corresponding variables.

Based on the hypothesis that the congregation of people creates a potential criminogenic effect, two variables, passenger flow x_i^1 and the rate between passenger flow and vehicle flow x_i^2, are respectively included in models A and B (see Table 5.2). The rate x_i^2 is used instead of vehicle flow per se, as the rate indicates the accumulated passengers because of the interval of bus services. The dummy variable x_i^3 for transfer hubs (e.g. a bus stop in the same cell as a subway station) is included for controlling the cells with extra passengers. Inner-city land uses may also be relevant for the geography of pickpocketing (e.g. ATMs, bars, public squares and tourist attractions), and the inclusion of variable x_i^4 reflects how close each cell is to the inner city. Variables x_i^3 and x_i^4 are included in both models A and B (for details, see Appendices 5B and 5C).

Note that, passenger flow varies throughout the day with morning and afternoon peaks. In order to test potential effects of the variations in the number of passengers and buses during the day on pickpocketing, a new set of models looking at peak and off-peak hours was tested. Disaggregated values of passenger and vehicle flows by time windows (peak and off-peak) were tested as explanatory variables, while the dependent variable was the daily count of pickpocketing. The results were inconclusive and will therefore not be included here. The effect of the varying number of passenger and buses is not consistent between morning peak and afternoon peak, or between off-peak windows. One reason could be that only 142 cells have a record of pickpocketing, out of 1,669 cells that contain some level of passenger and vehicle flow. That is, the incidence of pickpocketing is most likely to happen near certain bus stations, for example, stations in the city centre or a transfer hub. This indicates that stops located in the outskirts of the area, which contain a high number of bus passengers in the morning peak times, are not necessarily attracting pickpocketing. Another reason could be that the dependent variable is too aggregated to capture the corresponding time window that the independent variables have.

Parameter vector β is estimated via maximum likelihood using statistics package R. The results of two selected models are reported in Table 5.2, including parameter estimates, standard deviations, *Z*-values based on normal distribution and two-tailed *p*-values. All independent variables in the two models are statistically significant, supported by *Z*-values and *p*-values. The estimated α indicates how much the variance differs from the mean. The null Log-likelihood ($LL(\beta_0)$) of the model with only the intercept and the final Log-likelihood ($LL(\beta)$) with the explanatory variables are presented. The significance of the added covariates was tested by comparing $LL(\beta_0)$ and $LL(\beta)$.

The difference between the two models is that model A estimates β_1, the marginal value of passenger flow, while model B estimates β_2, the marginal value of rate of passenger flow divided by vehicle flow. Because the effect by the vehicle flow is included in model B, the rate variable is considered a better indication of the bus service. Parameters β_1 and β_2 are significantly different from 0, when controlling for the transfer hub and city centre effects. Positive β_1 in model A implies that the higher the passenger flow, the larger the number of pickpocketing incidents. Positive β_2 in model A indicates that the number of pickpocketing incidents increases with an increased rate of passenger flow divided by vehicle flow.

Positive β_3 suggests that a higher number of pickpocketing incidents happen in the cells with a transfer hub. This is expected because a large number of passengers using an interchange could create high numbers of pickpocketing incidents. It also makes sense that β_4 is negative since the city centre area is a crime attractor. The closer to the city centre, the higher the cell rank and number of pickpocketing incidents.

In summary, cells with both high passenger flow and high passenger rate per bus are associated with more pickpocketing. Overall, this means that cells that are poorly served by buses tend to generate overcrowded bus stops and are therefore more likely to be targeted by pickpockets. However, a deeper inspection of the data indicates that there are special cases to this general pattern of pickpocketing. For instance, incidents of pickpocketing are also concentrated in cells with low rates (passenger flow may be large, but because bus frequency is also high, the rate is low). These exceptions call for a detailed analysis of pickpocketing by passenger flow and rate of passengers per bus, as is explored in the following section.

Figures 5.5(a) and 5.5(b) show scatter plots with a logarithmic scale on the horizontal axis. Figure 5.5(a) depicts the number of pickpocketing incidents against passenger flow. Observations with the number of pickpocketing incidents larger than or equal to 10 are highlighted. The triangles are the cells with passenger flows larger than 1,000, and the squares are the cells with passenger flows less than or equal to 1,000. The observations marked with triangles tend to confirm the results shown in the general regression model A above. A further investigation revealed that these stops are major bus terminals. The observations marked with squares have relatively low passenger flows, yet high numbers of pickpocketing incidents. These cells are found to contain bus stops in proximity to subway stations. It is reasonable to believe that the high numbers of pickpocketing incidents associated with these bus stops is in fact affected by the high passenger flows generated by the nearby subway stations, commuter trains or the land use that characterizes these areas. Thus, pickpocketing by passenger flow is perhaps not a suitable indicator of the criminogenic conditions at these cells as they may only reveal the transportation hierarchy of the city (high pickpocketing and high passenger flows tend to be found in central areas or in the

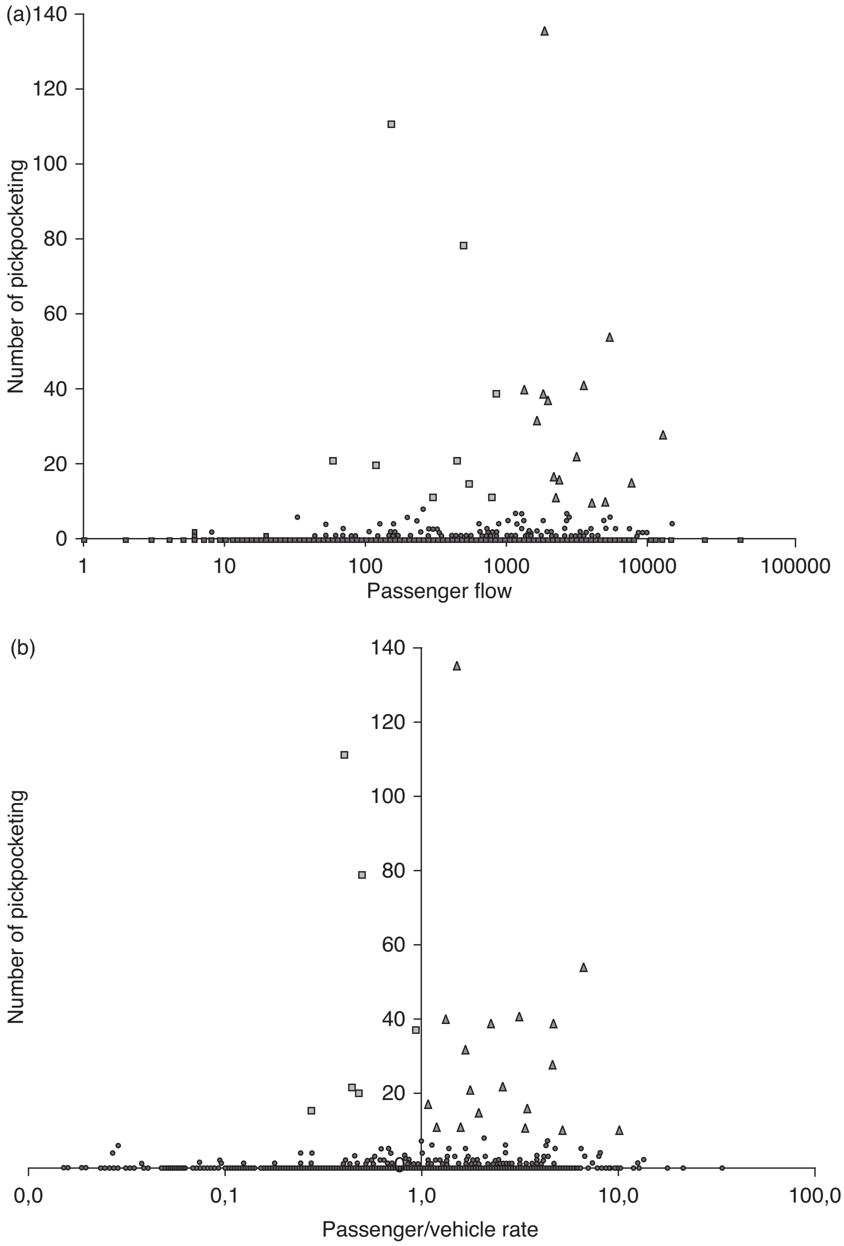

Figure 5.5 Relation between (a) pickpocketing and passenger flow by cell (b) and by rate of passenger by buses by cell

periphery locations) or the dynamics of other transportation modes (subway or commuter trains located nearby).

Figure 5.5(b) depicts the number of pickpocketing incidents against the rate of passengers per buses, where observations with numbers of pickpocketing incidents larger than or equal to 10 are highlighted. The triangles are the cells with vehicle flows less than passenger flows, and the squares are the cells with vehicle flows at least as large as passenger flows. Pickpocketing is more likely to occur in the triangle cells because bus stops are often overcrowded, offering good opportunities for thieves. Typical triangle cells contain areas such as those with bus stops around the central station's exits. In addition, there are 'overserved' cells, marked with squares. Stops in the square cells are characterized by large numbers of buses in relation to the recorded passenger flows because of their strategic locations, such as inner-city areas or major intersections of arterial roads connecting different parts of the city. In these areas, the high numbers of pickpocketing incidents could be related to other types of activities in the immediate surroundings.

There is another interesting finding that links the observations with extremely large rates of passenger per bus stop and no pickpocketing. They are mostly the start/end points of some bus lines, located relatively far away from the centre (e.g. Stora Skuggan, Kaknästorg and Minneberg). Although these stops are characterized by low bus frequencies and a comparatively high numbers of passengers, thieves are not attracted to commit pickpocketing in such areas, which are predominately residential. However, this does not mean that these bus stops are not attractors for other types of crime.

Summary and conclusions

This study examines whether pickpocketing is more likely to occur in proximity to bus stops by performing an equal-stratified sampling method on urban cells of 50 by 50 metres for Stockholm, the capital of Sweden. Findings show that both the share of cells with pickpocketing and the number of pickpocketing incidents were significantly higher in cells that contain bus stops than elsewhere, as initially hypothesized. These results are also consistent with previous research in North American and British cities. Moreover, data concerning vehicle and passenger flows were analysed in order to explore the relation between bus stop intensity and pickpocketing incidents. This study corroborates the hypotheses that both the total (boarding and alighting) passenger flow and the number of passengers per bus are significantly associated with higher levels of pickpocketing incidents. The dynamics of pickpocketing may be different based on where the bus stops are located. Some are extra targeted by pickpocketing because they are underserved by buses, while others have a protective effect against pickpocketing because of the high bus frequency.

These findings indicate that the overall passenger flow levels as well as crowding levels at bus stops partially explain the variations in pickpocketing levels by cell. This analysis captures the dynamics of particular settings within a 50-by-50-metre cell – a relatively small geographical area close to bus stops. A way to 'control' for the heterogeneity of these cells was to select areas using equal-stratified sampling in combination with a Monte Carlo simulation. The sampling method was carried out without controlling for variables other than bus stop presence. In future research, the importance of bus stop attributes to explain the geography of pickpocketing has to be reassessed, taking into account other covariates at bus stops (for instance, their design, whether the bus stop is located at street level, elevated or within a terminal) and variables that indicate the complexity of land use and socioeconomic contexts in which bus stops are embedded.

In this study, two variables helped flag for differences in the dynamics of city centre versus peripheral areas (a dummy for city centre and transfer hubs). The flow of passengers (model A) and the rate of passengers per bus (model B) are still significant after controlling for these variables. New modelling strategies could be tested by splitting the dataset into two models (centre and periphery) to test whether the models work differently in the inner areas versus the outer areas. Equally important in future analysis is to consider the temporary population. A measure of tourist and/or shopper distribution over Stockholm would be helpful to better assess the effect of bus stops on pickpocketing at cell level.

The results from this study contribute to the current research on relationships between crime and transport nodes by providing empirical evidence from bus stops in a Scandinavian capital. The analysis also combines different data sources that provide a comprehensive picture of what happens in terms of flows of passengers and buses at stops using grid cells. However, the study shares limitations with other analyses of this type, namely that the data utilized in this study are limited to buses – the presence of bus stops and the corresponding bus and passenger flows. While this enables a concentrated analysis on the impact of bus-related attributes, it also hinders the evaluation of risk. For example, it was found that most of the stops that experience high pickpocketing levels while having low passenger flows are located in direct proximity to subway stations within a common transfer hub. Risk assessment will therefore result in overestimation for passengers using these stops as, in reality, the risk is shared with users of other high-capacity services as well. Moreover, it is plausible that bus stops are likely to be positioned in locations which are characterized by high pedestrian flows (and not necessarily high passenger flows), which could also contribute to higher pickpocketing levels at these cells.

Another limitation is that the analysis is based on a one-year database, which is perhaps too short a time period for drawing final conclusions on the relationship between pickpocketing levels and passenger flows. Future studies should increase the sample size to cover for instance five years of data, or the dimensions of the cells could be increased in order to reduce their number (e.g. using 100-by-100-metre square cells rather than 50 metre). Another alternative is to use a Poisson-lognormal model to avoid the problem of low sample mean (Maher and Summersgill, 1996; Lord, 2006; Ma et al., 2008). Such a model could be tested as an alternative to the current negative binomial model, as it may become unstable with a low sample mean, which was the case in this study.

For future research, one of the main challenges is to elucidate the processes through which other land use and socio-economic variables interact and influence levels of pickpocketing in bus stop cells using a long-term data series, perhaps broken down by time. This study is regarded as only an initial step in identifying what makes bus stops vulnerable to pickpocketing, taking into account passenger and bus flows.

Compared to other analytic approaches, the utilized method avoids limitations imposed by irregular arbitrary administrative zones by creating small cells of 50 by 50 metres over the study area. Data permitting, future analysis should investigate the vulnerability of bus stops during peak and off-peak hours of the day. Although tests were performed in this study, the dataset was not appropriate for creating the same peak and off-peak time windows for both independent and dependent variables. It is important to check the peak and off-peak hours as changes in people's routine activities are expected to affect bus stops differently, for example, eating in different locations, at different hours of the day, the week and seasonally.

What are the implications of the results of this study for transport planners and safety experts?

For transport planners, the results suggest that bus stops with high volumes of waiting passengers and with high rates of waiting passengers per bus are especially prone to pickpocketing. Bus stops are often used by several bus lines, which provide greater transfer and connection possibilities, but which also may result in greater crowding among passengers waiting for different bus lines. An alternative is that bus lines could be split between several bus stops along the road segment in order to mitigate pickpocketing. However, in some cases, this solution goes against standards of public transport level of service. This is particularly true in cases in which the lines serving the bus stop have a considerable overlap between their downstream destinations, as many passengers will board the first arriving vehicle. Another alternative is the division of passenger flows, particularly at bus stops at transfer hubs, by creating queues using barriers. Queues may make crowding look less chaotic and also make passengers aware of what is happening when an individual behaves differently from everyone else, for instance, by walking in the wrong direction.

For safety experts, findings support the saying that 'pickpocketing needs a crowd'. Thus, an increase in the number of buses per passenger may not only improve level of service but also promote passengers' transit safety. Putting strategies into practice requires tight cooperation between public transportation authorities, police, security companies, other stakeholders and passengers themselves. Increased security should be focused in the places and time windows where and when most thefts take place. In these buses, the presence of service hosts, security guards or police raise the offender's risk of arrest. There is also a need to create opportunities for passengers and transients to strengthen the natural surveillance of bus stops. Moreover, it is important to advise passengers to be aware and keep track of their belongings along the trip. Simple warning messages are one of the easy solutions that make it more difficult for thieves to act. This is particularly relevant for Stockholm during the summertime, when the city attracts tourists who may be unfamiliar with the public transportation settings, and may be easy targets for thieves.

In this study, police-recorded data on pickpocketing do not reveal whether the offence happened inside the bus (when the bus was parked at the bus stop), at the bus stop or on the way to/from the bus stop (a few metres from the bus stop). This uncertainty in the exact location of crime calls for a shared responsibility for safety between transportation agencies and municipal authorities. Adopting 'a whole journey approach' to safety requires clearer roles in cooperation between transportation agencies, municipalities, police and other actors. Transportation agencies often dismiss any responsibility for passengers' safety at or near a bus stop. The municipal authorities may not feel responsible for what happens around bus stops either. Instead of putting the burden on only one actor, it would be better to adopt a model of shared responsibility for safety. This fits the picture of the city of tomorrow – a city that offers a safe public transportation system and also a more sustainable one.

Appendices 5A The Dataset

Data	Definition	Source
Pickpocketing incidents	Pickpocketing (*fickstöld*), 2008	Stockholm Police Authority
Bus stop	The location of bus stops, 2013	Stockholm Public Transportation Agency (SL)
Passenger flow	Average daily number of alighting and boarding passenger, 2013	Stockholm Public Transportation Agency (SL)
Vehicle flow	Bus frequency on a weekday, 2013	Stockholm Public Transportation Agency (SL)

Appendix 5B Variables of models A and B

Model A

y_i: The number of pickpocketing incidents in cell *i*
x_i^1: The passenger flow in cell *i*
x_i^3: A dummy variable. x_i^3, If cell *i* owns a transfer hub at which more than 10,000 passengers interchange yearly; otherwise 0
x_i^4: An ordinal variable indicating the distance d_i between cell *i* and the centre cell of *Mälartorg*, which is located at the old town (*Gamla stan*). $x_i^4 = 1$ *if* $d_i < 2km$; $x_i^4 = 2$ *if* $4km < d_i \leq 2km$; $x_i^4 = 3$ *if* $d_i > 4km$. So the smaller d_i is, the higher rank *i* is.

Model B

y_i: The number of pickpocketing incidents in cell *i*
x_i^2: The rate of passenger flow divided by vehicle flow in cell *i*
x_i^3: A dummy variable. $x_i^3 = 1$, if cell *i* owns a transfer hub at which more than 10,000 passengers interchange yearly; otherwise, 0.
x_i^4: An ordinal variable indicating the distance d_i between cell *i* and the centre cell of *Mälartorg*, which is located at the old town (*Gamla stan*). $x_i^4 = 1$ *if* $d_i < 2km$; $x_i^4 = 2$ *if* $4km < d_i \leq 2km$; $x_i^4 = 3$ *if* $d_i > 4km$. So the smaller d_i is, the higher rank *i* is.

Appendix 5c Pickpocketing, flow of passengers and passengers by buses by cell

	Variable	Maximum	Mean	Std. deviation
Dependent variable	Pickpocketing incidents	136	0.66	5.64
Independent variables	Passenger flow	41101	653.36	1703.02
	Vehicle flow	22128	451.48	931.04
	Passenger\vehicle rate	33.65	1.33	1.84
	Transfer hub dummy	1	0.026	0.004
	City centre	3	2.463	0.018

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Note

1. An articulated bus, common in Stockholm, is about 18 metres long; thus, two articulated buses cover almost one side of the cell, half a street block in Stockholm. Another innovative aspect of this study is the use of negative binomial regression models, instead of traditional ordinary least square models, to assess the importance of passenger flow and rate of passengers per bus stop to explain the variation in pickpocketing counts by grid cell.

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