EXPLORING OFFENCE STATISTICS IN STOCKHOLM CITY USING SPATIAL ANALYSIS TOOLS[1]

Vânia Ceccato
Division of Regional Planning
Department of Infrastructure and Planning
Royal Institute of Technology
Sweden

Robert Haining
Department of Geography
University of Cambridge
Cambridge CB2 3EN
United Kingdom

Paola Signoretta
Sheffield Centre for Geographic Information and Spatial Analysis
Sheffield University
Sheffield S10 2TN
United Kingdom

ABSTRACT The objective of this paper is to investigate changes since the early 1980's in offence patterns for residential burglary, theft of and from cars, and vandalism in Stockholm City using methods from spatial statistics. The findings of previous Swedish studies on crime patterns and the insights provided by different theories notably one propounded by Wikström(1991) provide a background for this study and are briefly reviewed. The analytical elements of the paper are in two main parts. The first is a brief description of methodological procedures to obtain robust estimates of small area standardised offence ratios. Attention is paid to both the spatial framework as well as the method of calculating rates. Standardised offence ratios (SORs), are calculated and mapped using GIS and the Getis-Ord statistic is used to identify areas of raised incidence. The variation in a relative risk is modelled as a function of socio-economic variables using the linear regression model whilst recognising the complications raised by the spatial nature of the data. Results suggest that whilst there have been no dramatic changes in the geographies of these offences in Stockholm City during the last decade, there have been some shifts both in terms of geographical patterns and in their association with underlying socio-economic conditions.

KEYWORDS: Offence rates, region-building, Getis-Ord statistic, spatial regression, relative risk, Bayes adjustment.

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1.INTRODUCTION

In the early 1980's, data on offences for Stockholm showed a rather strong concentration in the inner city for some but not all offences (Wikström, 1991). Vandalism in public areas and theft of and from cars showed a marked concentration in the inner city, or at least in certain parts of the inner city. Although residential burglaries tended to have the highest rates in some outer city wards, half of all residential burglaries still happened in inner-city wards. Similar findings were revealed in studies in the United Kingdom and the United States and these have been reviewed in Bottoms and Wiles (1997). The question is: to what extent has this offences' pattern changed during the last ten to fifteen years and what are the socio-economic variables that underlie current geographies of crime in Stockholm?

It is time to look again at the geography of these offences for two reasons. First, many cities are undergoing quite fundamental economic and social change associated with the shift from modernity (the social formations which emerged out of industrialisation) to 'late modernity' (Giddens, 1990, 1991) or the emergence of 'the informational society' (Castells, 1989), the 'network society' (Castells, 1996) what Hall (1999) calls in general terms, the 'forces shaping contemporary urban Europe'. These changes take the form of changes to the built form and land use within a city as well as to its demography and socio-economic composition. These changes and in particular the geography of these changes will affect crime patterns by their impact on the routine activities of offenders and victims. They generate new opportunities for offenders in the form of new targets where offences may be committed as well as new patterns of interaction between motivated offenders and their victims. However, there is still a lack of knowledge on how these changes are affecting the geography of offences in cities and "there are surprisingly few studies of crime in the city that can be used for comparative purposes" (Bottom and Wiles, 1995:44).

The second reason is the advent of new technologies for data storage and analysis. The advent of computerised mapping systems as part of police command and control systems has led to the creation of systems for visualising the growing amounts of geocoded crime data. These are already in use in many police forces in Sweden, the UK, the USA and elsewhere for both operational and strategic purposes (Goldsmith et al 2000). In addition, geographic information systems (GIS) are making geographical analyses of crime data more penetrating than in the past. GIS facilitates the integration of many types of data onto a common spatial framework and opens up the possibility for fine-gained spatial analysis (Heywood, et al. 1992; Hirschfield et al. 1995; Harries, 1995; Lewin and Morison, 1995; Block, 1995(a); Ceccato, 1998; Wiles and Costello, 1999). The value of GIS for analysing crime patterns becomes even greater when enhanced with spatial statistical techniques (Canter, 1995; Block, 1995(b); Craglia et al. 2000; Messner et al (1999)).

The contribution of this paper is to investigate actual changes in offence patterns in Stockholm City, and in so doing, demonstrate the application of spatial statistics to problems in environmental criminology. Data on three types of offences, residential

burglary, theft of and from cars and vandalism are analysed. These offences have been chosen for the following reasons. First, more than 50 per cent of police records for Stockholm County are composed of thefts and vandalism. Vandalism accounted for 14 per cent of all recorded offences in 1998 and has almost doubled between 1990 and 1998 (Jacobson, 1999). Second, data on car theft and residential burglary are quite accurate in Sweden since insurance companies require police records before paying compensation. Finally, residential burglary, theft of and from cars and vandalism are offences for which there is a broad and rich literature about their spatial patterns in different countries and contexts. Some changes in the geographies of these patterns might be expected as a consequence of the wider societal changes noted above.

The spatial analysis of offence data in this study is undertaken with the following objectives in mind. The first is to propose a methodology for constructing reliable maps of relative risk for the three offences and to implement it in the case of the Stockholm offence data. Relative risk provides a measure of the excess risk of being a victim of an offence in an area. In this paper 'relativity' is defined with respect to the city-wide average so that the maps only provide evidence on geographical variation within Stockholm City. The second is to locate statistically significant clusters for the three types of offences. The identification of local offence clusters can shed light on the correlates of crime and perhaps even the reasons why certain areas become targets for crime, information that may not be apparent from "global" or "whole map" statistics (Anselin, 1995). The third is to investigate the extent to which socio-economic variables can explain overall patterns of the three offences for Stockholm City. A final objective is to make a comparative assessment of the findings reported here with earlier results on crime geographies in Stockholm particularly those described by Wikström (1991). Any comparison with the findings of previous research must be viewed with caution however because the spatial framework used and the crime classifications are not exactly the same. In this analysis vandalism included all types of vandalism against private property and also vandalism in public spaces. In Wikström (1991) only vandalism in public spaces was taken into account. The author also separated burglary in cellars and attics from burglaries in residences. Furthermore, there have been changes in the organisation of the police authority and changes in the law that have also influenced the statistics (Jacobson, 1999).

The structure of this paper is as follows. Section two contains a brief review of the relevant criminology literature that includes an examination of how changing urban geographies can induce changes to crime patterns. Section three describes the methodology and presents results on relative risk rates and the presence of significant clusters for the three types of offences. The relationship between crime patterns and socio-economic variables are analysed and results reported in section 4. Findings are compared with those obtained by Wikström (1991). Section five discusses directions for future work.

2. LOCAL GEOGRAPHIES OF CRIME AND PROCESSES OF CHANGE

Section 2.1 identifies the macro scale processes of economic and social change that are believed to have impacted on the geography of crime at the end of the 20th Century. Sections 2.2 to 2.4 review findings from studies mainly in the 1980's on the geography of the three offences with an emphasis on studies of Stockholm. Section 2.5 discusses how the playing out of macro scale processes in Stockholm might be expected to have affected its offence patterns. The last section therefore attempts to identify a broad set of expectations regarding offence patterns in Stockholm and how they might be expected to differ from those in the 1980's.

2.1 Local geographies of crime: macro processes of change

The theoretical framework for this study of offence patterns is provided by Wikström (1991) and is represented by Figure 1. Wikström's model provides a basis for understanding the geographical distribution of offences at any given time. The starting point for the model is the distribution of land use within a city. Land use determines both the activities found in an area and the composition of the population at any given time. The land use of an area of the city affects the number of interactions that take place between offenders and potential victims in that area. Spatial variation in land use, affects spatial variation in the number of interactions that are criminologically relevant in the sense that they could lead to offences. The identification of criminologically relevant interactions rests on specifying the routine activities of offenders and victims that generate 'suitable targets' (Cohen and Felson 1979) and the spatial awareness of offenders - in particular their cognitive awareness of criminal opportunities (Brantingham and Brantingham (1981)). In brief, offences occur where criminal opportunities intersect with areas that are cognitively known by the offender and these are in turn influenced by land use patterns. Bottoms and Wiles (1997) provide a review and critique of Wikström's model.
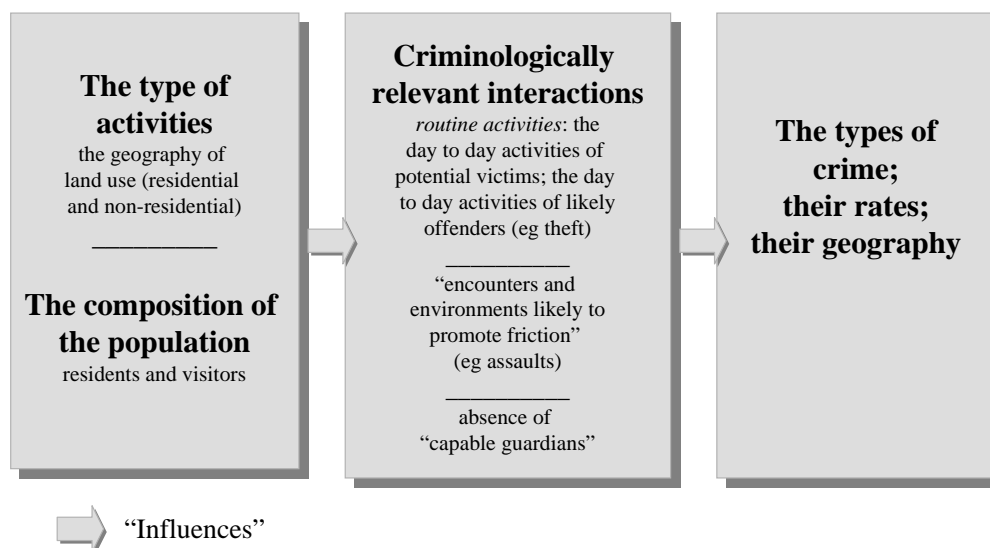

Figure 1 Wikström's model.

The analysis of crime patterns at any one point in time takes land use as a given but over time land use patterns may change and within the framework provided by Wikström land use change provides an important underpinning to any explanation of how offence patterns might change. Similarly, over time, perhaps partly as a consequence of land use change inducing new patterns of movement, but also as a consequence of wider changes within society, there may be shifts in the routine activities of the general population as well as shifts in offenders' cognitive awareness of different places. We now consider therefore the wider changes that are associated with the societal transition to late modernity and which may induce changes in the intra-urban geography of offences. We focus on the effects of economic and social change.

Economic change is bringing about changes in cities in terms of land use, demography and socio-economic conditions. This is often associated with increasing levels of insecurity that legitimise the creation of 'security bubbles' such as well-protected leisure centres and gated residential areas (Bottoms and Wiles, 1997). These sites are deliberate attempts to restore the sense of security that it is claimed has been lost. Another example is the increase in the number of large outlets or shopping areas on the outskirts of cities. Although shopping malls with their own security systems provide a protected and defended locale for work, consumption and leisure activities they also create new sites for offences. People who are mobile may prefer the service outlet, which is most convenient to their workplace instead of using the services near where they live. This then leads to the decline of small local shops and hence to the elimination of these locales as sites for offences. Economic change therefore not only eliminates certain sites where offences might occur but produces new sites (albeit well protected in some cases), new opportunities and hence new patterns of offences. In addition, economic change produces new patterns of mobility associated with changes in land use patterns both of would-be offenders and potential victims. Increasing affluence amongst certain groups leads to new patterns of routine activity.   Both of these in turn will create new opportunities for crime and hence new geographies of crime in the context of Wikström's model.

Social change has seen the emergence of a new geography of social differentiation linked to an increased economic polarisation that contrasts for example those with relatively secure well paid jobs with those affected by the decline of traditional manufacturing employment or by the consequences of technological change. These effects may be compounded by the operation of public and private sector housing markets that effectively concentrate the latter group of people in certain areas of the city. This in turn may lead to the emergence of areas that compound social exclusion with a particular local culture and social organisation that may lead to high levels of crime within those neighbourhoods. The loss of social cohesion and other forms of social capital in certain working class neighbourhoods can have a significant effect on crime levels and the types of crime committed (Hirschfield and Bowers, 1997). Such social and economic polarisation is apparent in so-called 'global cities' (Sassen, 1991) and, in other types of urban areas such as the 'dual city' (Mollenkopf and Castells, 1991; Van Kempen, 1994, Dangschat,

1994), the 'quartered city' (Marcuse, 1993) or the 'city of the coming Golden Age' (Hall, 1999).

There are other macro-scale changes that are impacting on local geographies of crime. Two of these comprise *two contrasting processes. The first* relates to the increasing demand for and production of a homogenised culture. Evidence of a homogenisation of space is found, for example, in standardised forms of architecture across Europe, in airports, entertainment centres and shopping areas. The functionality of some forms of architecture tends to suppress local cultural codes. It contributes to the creation of a 'space of flows', (Castells, 1996) which attends to the needs of mobile social groups that must travel as part of their work and have leisure time to travel and to consume more than ever before. Among European Community member countries, investments in infrastructure, especially in international transportation links, has been one of the priorities during the 1990's to promote social cohesion, diminish the economic disparities between countries (EC, 1997, EC 1998) and improve the connections between European capitals. This increase in accessibility makes cities, regions and countries more vulnerable to crime since new patterns of mobility may induce new offence patterns. At the intra-urban level, these macro-scale changes may generate new patterns of offences by creating new sites for offending and new transient groups unfamiliar with the levels and types of risks in particular areas. Another example of this macro-scale change relates to new life styles imposed by recent technological developments. People become less attached to, less committed to, local areas and communities. This may lead to a decrease in "capable guardians" at the local level, and thus, increase the areas vulnerability to crime. On the other hand, telecommuting may induce behaviours that go in the opposite direction, resulting in fewer trips to the workplace and more time spent in the residential areas, resulting in potentially more "capable guardians" and therefore less crime.

The second process on the other hand envisages the re-emergence of local cultures, as a counter reaction to such homogenisation, 'global disorder and uncontrollable, fast-paced changes' (Castells, 1997:64). There is simultaneously an embracing of the new and traditional. According to Featherstone (1993), globalisation does not produce homogeneity but familiarises us with greater diversity. Ethnic festivals (e.g., Rinkeby in Stockholm, Notting Hill in London), 'multicultural tourism' (Bergsrud, 1999) and tourism directed towards local consumers (e.g., carnivals that promote the urban cultural heritage) are examples of the activities that are emerging as a result of this search for local identity and self-worth. This leads to a new market for local cultures that produces 'new consumption landscapes' (Sýkora, 1994). This in turn, impacts on the level, structure and geography of crime through the creation of new sites for offending, new patterns of interaction, new environments that might engender friction and new groups of potential victims. These processes of economic and social change and other examples of their implications for the study of crime patterns at the local level are discussed in Bottoms and Wiles (1995, 1997).

Since the work of the Chicago School, many explanations have been offered for particular offence geographies. The British and American traditions of spatial analysis of crime data

have continued to reveal strong associations between characteristics of urban areas and the locations of certain types of offences. In the following sections we consider the three offences under investigation here.

2.2 Local geographies of vandalism

Roos (1986) explored the reasons behind reported vandalism comparing two urban areas in Sweden: a small town (Arvika) and a large city (Malmö). The differences recorded in this study between large city vandalism and small town vandalism showed among other things, that segregation in the housing market, form of tenancy and demographic structure are not significant in explaining vandalism in small urban areas. In Malmö, levels of vandalism showed a positive correlation with high population turnover, a high percentage of multi-family houses (flats in multi-storey buildings), a high percentage of unemployed people, a high percentage of households receiving social benefits, a high percentage of foreigners and low income workers.
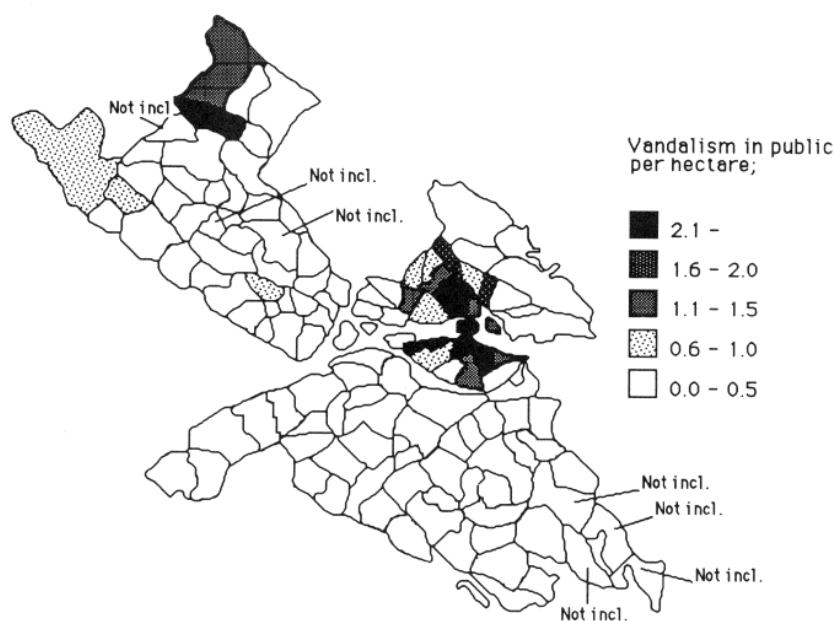
Figure 2 Vandalism in public per hectare in Stockholm 1982.
Source: Wikström (1991), p. 204.

Wikström (1991) analysed the occurrence of vandalism in public places in Stockholm, which means illegal destruction of property in streets, squares, and on public transport (Figure 2). Multiple regression analysis was used to explain patterns of offences. Wikström showed that variation within the inner city in rates of vandalism were closely associated with area variation in the location of places of public entertainment. For the outer city Wikström (1991) found a significant proportion of the spatial variation in vandalism was related to social problems or disorganisation. Results for Stockholm City have shown that stores in areas with a low degree of social stability were more exposed to various kinds of offences (including vandalism) than stores in other areas (Torstensson, 1994).

The Swedish experience may differ from that of other countries. Evans (1992) reviewed UK research that showed correlations between housing ownership, income and vandalism. The Islington Crime Survey (MacLean et al., 1986), for instance, showed the highest rates of vandalism were experienced by the highest income earners. In other studies cited by Evans, the areas of highest risk were those with high levels of owner-occupied housing, irrespective of whether they were inner city areas or not.

2.3 Local geographies of theft of and from cars

In Sweden, most car-related thefts occur when cars are parked on the street, usually near to the owners' home. In Stockholm, Wikström (1991) found area variation in thefts of and from cars to be strongly related to area variation in violence and vandalism in public. The highest rates were found in the city centre of Stockholm or areas near the city centre (Figure 3).
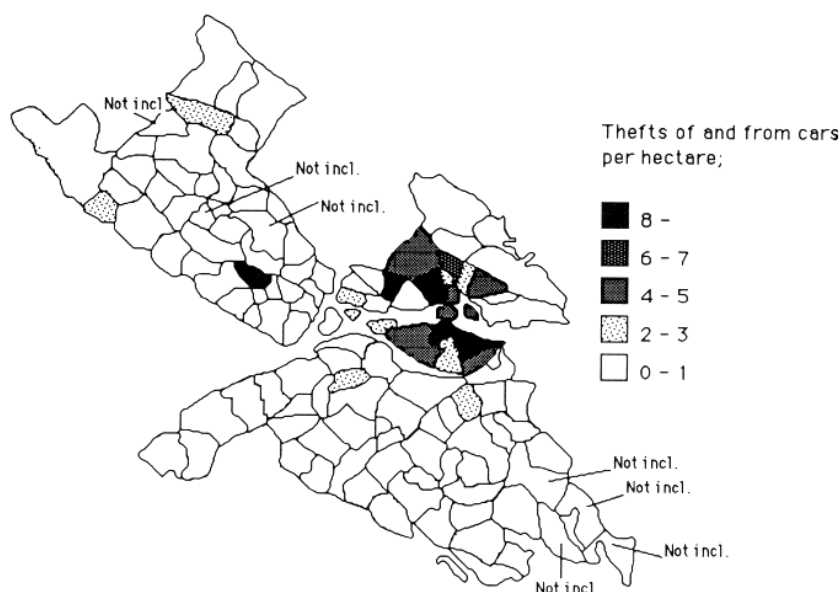

Figure 3 Thefts of and from cars per hectare in Stockholm 1982.
Source: Wikström (1991), p.206.

The distribution for the suburban areas separately showed that rates of thefts of and from cars tended to be highest in areas with social problems and predominantly in areas with flats in multi-storey houses. These may be the areas where the offenders reside or tend to spend time. This finding in Stockholm corresponds with findings elsewhere. Evans (1992) reported empirical findings that indicated a relationship between car related thefts and low-economic status. Residents of inner cities, flats and maisonettes and council tenants are most at risk from theft of and from cars in British cities.

2.4 Local geographies of residential burglary

Wikström (1991) showed that residential burglaries (excluding burglaries in attics and cellars) in Stockholm tend to occur mostly in some outer city wards of high socio-

economic status (with single family houses), and especially in districts where there are nearby high offender-rate areas (Figure 4). This finding is consistent with the observation that most offenders are from socially disadvantaged areas and that they tend to commit crimes close to home and which lie within their routine activity paths.
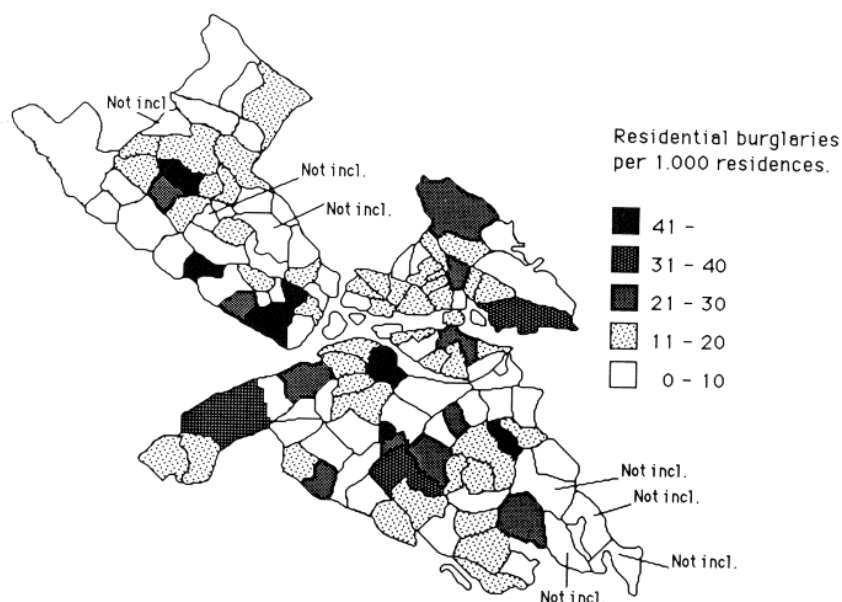

Figure 4 Residential burglaries per 1000 residences in Stockholm 1982.
Source: Wikström (1991), p.205.

This finding while not unique in the literature is suggestive of a different geography for the crime of burglary in Sweden than in other countries. Evans (1992) pointed out that poor households are more at risk from residential burglary, although within poor areas, higher value properties may be more at risk from residential burglary, since these constitute a more attractive target than nearby houses. Maguire and Bennet (1982) in their study of residential burglary in Great Britain indicated that within sizeable towns, those living in poorer housing areas, especially if these are situated close to the town centre, are the most vulnerable. Pockets of particularly affluent middle-class housing on the outskirts of towns sometimes receive a disproportionate amount of attention from burglars and middle-class housing located on or very close to main roads is also more likely to be burgled than similar housing which is less directly accessible to passers-by. Their findings also indicated some relationship between housing type and vulnerability to burglary. Both small and large detached houses are generally more vulnerable than semi-detached or terraced houses. Herbert's (1982) study of residential crime (residential burglary and thefts from dwellings) in West Swansea, showed that the vulnerable areas were in the heterogeneous inner city or in some of the large public sector estates, not in wealthier suburbs.

In the case of Sheffield, Wiles and Costello (1999) showed that domestic burglary and criminal damage is a very concentrated phenomenon. They showed that the residential

areas with high offence and victimisation rates are generally found on poorer housing estates, and some socially mixed city areas. This pattern holds because, first even poor areas contain plenty of suitable targets such as videos, televisions and cars. Second, offenders tend to live in these areas and on the whole, tend to offend close to home rather than conduct long range instrumental searches across a city. Third, if offending is carried out away from home it is often in areas where offenders have contacts, not unknown middle-class parts of the city.

2.5 Macro-scale processes and changes to the geography of offence patterns in Stockholm
There is an evident lack of specificity as to how the macro scale processes of late modernity impact on crime patterns (section 2.1). However, using the framework provided by Wikström's model, we now discuss how the geographical patterns for the three studied offences for Stockholm might be **expected** to have changed since the early 1980s. We start by briefly discussing aspects of the changing socio-economic urban geography of Stockholm.

Stockholm is the capital and biggest city of Sweden. The city of Stockholm had over 720 000 inhabitants in 1998, while the Greater Stockholm area had over 1.6 million inhabitants. The case-study area is limited to the city of Stockholm, which means the inner-city area and those suburbs belonging to the city of Stockholm.

Stockholm City has, compared to other Swedish cities, a very high population density of 1300 inhabitants/km^2. Only a few areas of the inner city are densely populated. During 1950 to 1985, the inner city area lost nearly 200,000 inhabitants. The decrease in population within the city of Stockholm is partly explained by the conversion of building space into offices at the same time as the population moved out towards new residential areas in the neighbouring municipalities. However, the demand for apartments within Stockholm City has created during the last decade a need for building companies to make available as many apartments as possible by renewing old residential areas and building new ones, mostly in vacant or old industrial zones. In Stockholm City, about 90 per cent of dwellings are composed of multi-family houses, the rest are single family houses. Two out of three dwellings are rented; almost all the rest is tenant owned housing. In contrast to many British and North American cities, there are no residential slums or run-down residential areas in the inner city or elsewhere in Stockholm.

The city's centre, because of its particular characteristics, is highly vulnerable to acts of vandalism. The CBD is located in the southern area of the inner city and is characterised by many office buildings and a number of large department stores. Not only the governmental and ministerial buildings are located in this area but also the major shopping area of the city, as well as theatres, museums, restaurants, bars and cinemas. The main public transport junction is located in the CBD area. All underground lines pass through the Central Station, which is the main railway station of the capital, making this area a place where many travellers and workers pass everyday. Segerls torg, a central

square and one of the main meeting points of the city, concentrates a lot of people during the whole day, including youths and drug addicts who frequent the square and the surrounding streets.

As with many other European capital-cities, Stockholm has been undergoing fundamental economic and social changes. Anjou (1998) points out that during 1990-1997 the total population of Stockholm City increased at the same time as the total number of jobs decreased. Traditionally, the region has had a net in-migration of young people aged between 20 and 30 and foreign citizens. About 20 per cent of the city's population were born abroad, from which 50 per cent became Swedish citizens. The unemployment rate shifted from 1 to 7.3 per cent in the same period. An increase in dependence on social benefits among single person households, young people and foreign households has also been noted (SOU 1999:46).

In Stockholm, as in other large cities, immigrants are mainly concentrated in areas with low socio-economic status and where rental tenancy is dominant. Thus, there is a clear connection between socio-economic conditions, type of tenancy, housing type and ethnic composition (Vogel, 1992; USK, 1996; Bevelander et al., 1997). Geographic, ethnic and socio-economic segregation has increased during the last decade in Stockholm (RTK, 2000) as a result of, amongst other things, a decrease in income and income mobility (SOU 1998:25, Sandström, 1997). In Stockholm City, there is evidence of changes in the geography of income levels between the 1980's and 1990's (Figure 5).

Figure 5 Average income levels (active population age 16-64) Stockholm City in 1982 and 1996. The darkest patterns indicate the highest-income levels.
Source: Based on maps by USK (1999).

Whilst there has been an impoverishment of certain areas, especially in southern areas, some residential areas, mostly close to the city centre, have increased their average income levels. There are indications that a gentrification process is taking place near the city centre, of which Söderlmalm is a good example. In Stockholm, as in other European cities like Rome and Madrid, the exclusive residential areas tend, as already pointed out by Castells (1996), to appropriate urban culture and history, and be located in refurbished or well-preserved areas of the central city. Vogel (1992:154) pointed out that 'the wave of rebuilding in the central areas of the metropolitan areas in Sweden reinforced residential segregation'. It is also worth noting that areas like Skärholmen, Sätra, Rinkeby, Tensta are examples of low-income areas in the 1980's that still remain as low-income areas in the 1990's. The same can be said about other parts of the city that were characterised by having high income levels and still continue as such, for example, Västerled and the traditional areas in the city core. This strong tendency for economic polarisation among social groups between the 1980's and 1990's is also confirmed by RTK (2000) for the whole Stockholm County.

Despite these socio-economic changes, the total number of recorded offences is not higher in 1998 than in 1990 but people feel less safe than before (Jacobson, 1999). According to Ivarsson (1997) it is estimated that one-fourth of Stockholm's population is often or always afraid of going out by themselves in the neighbourhood where they live when it is dark. This may indicate that there have been changes in offence type, with significant increases in violent offences (e.g., assault, rape) and vandalism. The latter has almost doubled between 1990 and 1998 for Stockholm County (Figure 6).
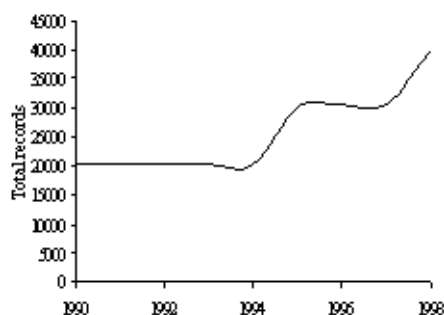

Figure 6 Recorded vandalism in Stockholm County 1990-1998.
Source: Based on Jacobson (1999), p. 27.

It is expected that certain types of offences will have changed their geography more than other types. The geography for vandalism and car-related thefts is expected to continue to show high levels in the inner city area. This is because these offences seem to be still dependent on the sorts of activities found in the CBD, such as office employment and public entertainment. These activities have not changed their location within Stockholm a great deal since the 1980's, on the contrary, there is some evidence of additional

concentration in the inner city (e.g. the locations of the headquarters of new IT firms). However new areas of high crime incidence are expected to appear on the outskirts of the City. These are, associated firstly with the increasing number of deprived areas or so-called problem-areas (Problem områden) during the 1990's and, secondly, to the fact that people are more mobile, which creates new opportunities for offenders.

The increasing process of economic polarisation, followed by a spatial and economic fragmentation of the city is expected to impact also on the geography of residential burglaries. Wealthy areas are tending to become more geographically and physically isolated from the rest of the city, and in doing so, they become more attractive targets for burglary. In Stockholm, the Hammarby sjöstad's project is a good example of such a development. This building project, with 8,000 apartments in Southern Stockholm, is planned to be completed by the year 2001 and will test urban planning's role in preventing urban crime. The creation of such safety redoubts reinforces segregation patterns since not everyone can afford to live in these safe areas. Whilst the creation of such buildings might displace some crime to other areas, their presence could represent for the offender an attractive target irrespective of the level of surveillance. Finally, increasing levels of geographical segregation may increase the likelihood that certain groups will offend and this may result in greater inter-area variation in offending rates. Liljeholm (1999) describes the geography of teenage offending in Stockholm by city parish.

Linking these local changes to the key elements of Wikström's model leads to the expectation of a generally more scattered spatial pattern for all three offences with less concentration in the inner city area in the mid/late 1990's compared to the early 1980s. This general trend is associated mostly with an increasing geographical and economic segregation of the population combined with changes in land use in the most peripheral areas. This includes the emergence of large out-of-centre shopping areas and other types of retail outlets. Increasing levels of population mobility of both potential victims and motivated offenders may also contribute to this dispersal by tending to increase the number of criminologically relevant interactions in a larger number of areas of the city.

3. METHODOLOGICAL PROCEDURES AND ANALYSIS OF RATES

The statistical data set of offences used in this study of Stockholm City were extracted from the Police Authority of Stockholm County's database. The data refer to 1998 and were initially divided by offence type and geographical unit, *Basområde*, varying in population size, from less than 300 to 8536 inhabitants. Each of Stockholm's *basområde* have in general a common housing type, which reflect different stages in the city's expansion.

The socio-economic data were obtained from Stockholm Statistics (USK - Utrednings- och Statistik Kontoret) using the same geographical units. Unfortunately these statistics were not all available for the same years. The statistics for households are from the beginning of

the 1990's. Statistics for unemployment among the population are for 1998. Table 1 shows a description of the data set used in the study. For further detail on the dataset, see appendix 1.

Table 1 Characteristics of the dataset

Type of data		Description	Year	Source
Offence	Residential burglary	Theft and theft followed by burglary (codes[2] 0824, 0825, 0826, 0858 and 0859) It includes attic and cellar.	1998	Policy Authority
	Theft of and from cars	Theft of and from cars (codes 0801, 0802 and 0840)	1998	
	Vandalism	Damages, disturbance and graffiti (1201, 1202, 1205, 1203, 1207)	1998	
Socio-economic	Population	Total number of inhabitants	1997	USK
	Born abroad	Total number of inhabitants born abroad	1997	
	Unemployment	Total number of unemployed inhabitants by age 18-64.	1998	
	Income	Average income (age 16-64) by geographical unity	1996	
	Residential turnover	Total number of inhabitants who move into and out by geographical unity	1996-7	
	Total households	Total number of households	1990	
	Housing by type	Total number of single and multi-family houses	1990	
	Dependent of social benefits	Number of households with dependants of social benefits	1995	

3.1 Creating reliable maps of standardized offence ratios

The methodology adopted here involved two stages: first the creation of a spatial framework which merged spatial units with small populations into larger aggregations; second the manipulation of the rates themselves using a Bayesian methodology. The aim is to construct reliable maps of the variation in relative risk for different types of offences across Stockholm City.

3.1.1 Constructing a new regional framework

A common problem with area-based analysis is that the results of analysis are sensitive to the choice of spatial unit (Wise et al., 1997). There are several reasons why it is often beneficial to group the basic spatial units to form larger regions as the framework for the analysis. The first reason is to increase the base population in each area so that offence

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[2] SCB - Statistiska Centralbyràn (Statistics Sweden) 1994.

rates will be computed from a larger denominator. Aggregating small regions or merging them into larger units results in rates that are more robust to within-area variation in the number of cases that may arise from random variation in the occurrence of crime events. The second reason is to reduce the effect of suspected inaccuracies in the data. Especially with small areas, an error of one or two in the count of offences could have a large effect on the calculated rates, whereas such errors may have less effect for larger areas. Trying to reduce the effect of suspected inaccuracies in the location of offences is the third reason for grouping spatial units. Using larger units essentially means that a smaller proportion of the cases are near boundaries, and hence a smaller proportion are likely to be assigned to the wrong unit as a result of geocoding errors. This is particularly important for crime statistics because there are problems of reliability not only regarding when the offence occurred but also where the offence took place. The location of an offence may be incompletely registered in Sweden, which adds to the difficulty of creating reliable maps.

The method used was a region building module implemented in the SAGE software system (Wise et al., 1997; Haining et al., 1996; Haining et al., 2000), Appendix 2. The region building module classifies N objects (areas) into K groups (regions) using the K-means method. The method requires two basic elements: an initial partition with K groups from N objects and a combined objective function that measures whether one partition is better than another. Up to three criteria can be introduced into the objective function to construct regions: homogeneity, compactness and equality.

Stockholm is an archipelago but no major statistical problems are expected from the lack of contiguity of the zones of the study area. First, only a small part of the central area is physically disconnected from the rest of the city (central islands are separated by water bodies). Second, the central unit functions like adjacent zones and these areas are easily accessible from the rest of the city by modern transportation links, mostly because they are part of the inner city.

One hundred and nineteen new spatial units were created for Stockholm City from the original 350. Only the equality criterion, of the three available in the SAGE module, was invoked to build the new spatial units. Population size was used as the criterion. This criterion ensures that the population in the new spatial units is as similar as possible. The number of regions was chosen based on a subjective assessment of what the minimum population ought to be to try to ensure reliable rates. As a result of using the region building module in SAGE a new set of regions was created where the minimum population size was 3,651, the maximum was 10,168, the mean was 6,517 and the standard deviation was 1,547. As Figure 8 shows, 10 areas were excluded from the crime analysis because they had extremely low residential populations (so the socio-economic data for these areas were missing) and because their locations were at the city's borders.

Re-running the region building module yields different outcomes, so it is possible to compare the effects of different runs. Histograms are provided in SAGE in order to assess the success of the method in achieving its objective. Several runs were performed and the

partition that came closest to generating truly equal population counts chosen. The final stage of the process was to create a new set of boundaries by removing the boundaries between zones in the same region and merging their values together using ArcView[3]. Figure 7 illustrates the final set of regions containing the 119 new spatial units.
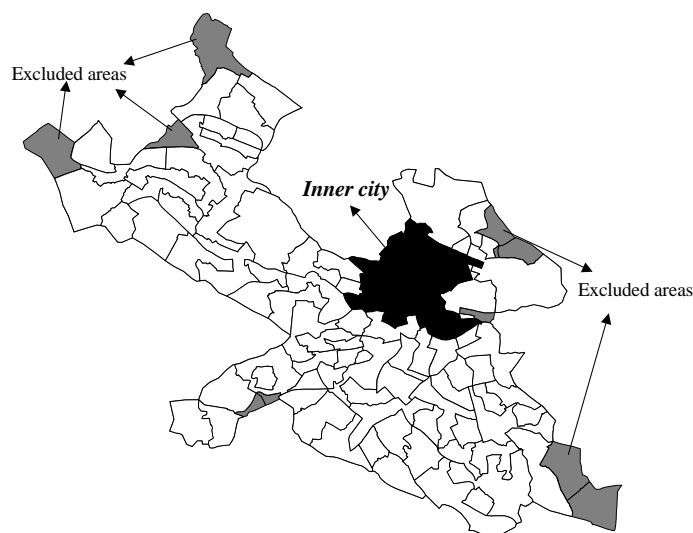

Figure 7 The new spatial units produced using the regionalisation process in SAGE. The units that compose the inner city are in black.

3.1.2 Bayes adjusted standardized offence ratios
In order to have a measure of relative risk of the offences for each the 119 regions of Stockholm City, a standardised offence ratio (SOR) was calculated using arithmetic functions in SAGE. This type of standardisation is a useful way of representing data for a set of areas where the areas differ in size (absolute values would tend to over-emphasise large areal units) and where it is necessary to allow for differences in population characteristics between areas (Haining, 1990). The SOR for region i is given by (1):

$$SOR(i) = [O(i) \diagup E(i)] \times 100 \qquad (1)$$

Where O(i) is the observed number of offences of a given type and E(i) is the expected number of offences of a given type.

With sufficiently disaggregated offence data that indicates say, the housing type where a burglary was committed, the calculation of the expected count could be undertaken in a similar way to that used for example in the calculation of standardised mortality ratios in disease mapping (Kahn, 1989). There, it is usual to control for the confounding effects of age and sex in estimating area specific relative risks. Age of house or housing type could be confounding factors in relation to burglary rates if the aim is to obtain an area specific measure of relative risk. In this work, however, we simply obtained an average rate for

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[3] ArcView GIS, software developed by ESRI – Environmental Systems Research Institute.

Stockholm City by dividing the total number of offences of a given type by the total size of the chosen denominator. For each area i, this average rate is multiplied by the size of the chosen denominator in area i to yield E(i). For this reason the maps of relative risk are in fact rate maps (as produced by Wikstrom) divided by a constant which is the average rate for Stockholm City and then multiplied by 100.

It is important to choose a suitable denominator for calculating E(i). Wikström (1991) pointed out the difficulty of defining plausible denominators, which is particularly problematic for mobile targets like cars. He suggested a list composed of best denominators and those which are practicable (that is, available) for the calculation of city crime rates. For instance, for thefts of and from cars, the best denominator should be the number of cars in an area while the often-used denominator is the area of the unit. Table 2 shows the denominators used in this study for calculating SORs. The use of area as the denominator could result in higher rates in the inner area. This is because there is likely to be a higher density of roads per unit area in the inner area and therefore more opportunities for car related crime and also vandalism than in an equivalent sized area in the outer parts of Stockholm.

Table 2 Chosen denominators for SOR

Crime	Chosen denominator
Vandalism	Area unit(hectare, e.g.)
Theft of and from cars	Area unit(hectare, e.g.)
Residential burglary	Number of households

In mapping relative risks of diseases it is becoming increasingly the practice to compute Bayes (or empirical Bayes) adjusted rates to adjust for the effects of population size variability across the map (for details, see for example, Clayton and Kaldor, 1987, Mollie, 1996). The Bayesian approach is a model-based approach to map smoothing. It involves specifying the distribution from which the area specific relative risks have been drawn. In the case of offence data the same adjustment process should improve the SOR as a measure of risk variability across the map.

The observed number of offences in area i is assumed to be the realisation of a Poisson model with parameter $\lambda(i)= E(i)R(i)$ where R(i) denotes the true (but unobservable) relative risk. The Poisson model is assumed since the risk of any offence is sufficiently rare. The selected model for the population of relative risks (called the prior distribution) is the gamma distribution. The effect of using the gamma distribution for the prior ensures that SORs based on large populations are largely left unadjusted whilst the SORs based on small populations are shrunk towards the mean for Stockholm City (Clayton and Kaldor 1987). The Bayes adjusted rates are not strictly standardised offence ratios but are the posterior means of the relative risks. However, they will be called here Bayes adjusted SORs.

The gamma distribution is often used for the prior because compared to other choices of prior distribution (such as for example the log-normal) it does not pull extreme values severely towards the area mean. Since the aim is to identify extreme rates the gamma distribution appears to represent an appropriate compromise. Selecting the gamma prior means that no allowance is made for spatial correlation in the relative risks $\{R(i)\}$. Other models for the prior, such as the log-normal model, could be specified instead in ways that incorporate spatial structure (Mollie, 1996). There are at least two reasons why this extension of the Bayesian approach is not appropriate in the present context. First, the introduction of spatial smoothing is most appropriate when the analyst is looking for trends or large scale patterns in the relative risks. The objective here is not to look for broad trends but to identify areas of raised relative risk. The introduction of a spatial prior would tend to smooth out such areas particularly if they are geographically isolated. Indeed the adoption of the Bayesian methodology in the form presented here already means areas with extreme rates but small populations will probably not be detected. Second, Basområde are small and given the heterogeneity of urban space, adjacent areas need not be similar in terms of housing type or other factors that underlie spatial variation in offence rates. It is therefore not necessarily the case that we should expect strong similarity in relative risks between adjacent spatial units.

In the present analysis there is quite a close similarity between SORs and Bayes adjusted SORs, because the process of constructing the new spatial framework has eliminated much of the inter-regional variation in population. Nonetheless in the remainder of this paper, the Bayes adjusted SORs are used. The argument is that by constructing regions of sufficient population size and using a Bayesian adjustment or borrowing strength methodology we obtain maps of spatial variation in SORs that are more reliable than if only one or neither of these operations had been performed.

Figures 8, 9 and 10 show the maps of relative risk for the three offences. The first of the two maps in each figure identifies all areas where after Bayes adjustment $O(I)>E(I)$. The second of the two maps attempts to follow the mapping scheme of Wikstrom (1991) by creating intervals that contain the same proportions of areas as found in the corresponding intervals of the Wikstrom maps.
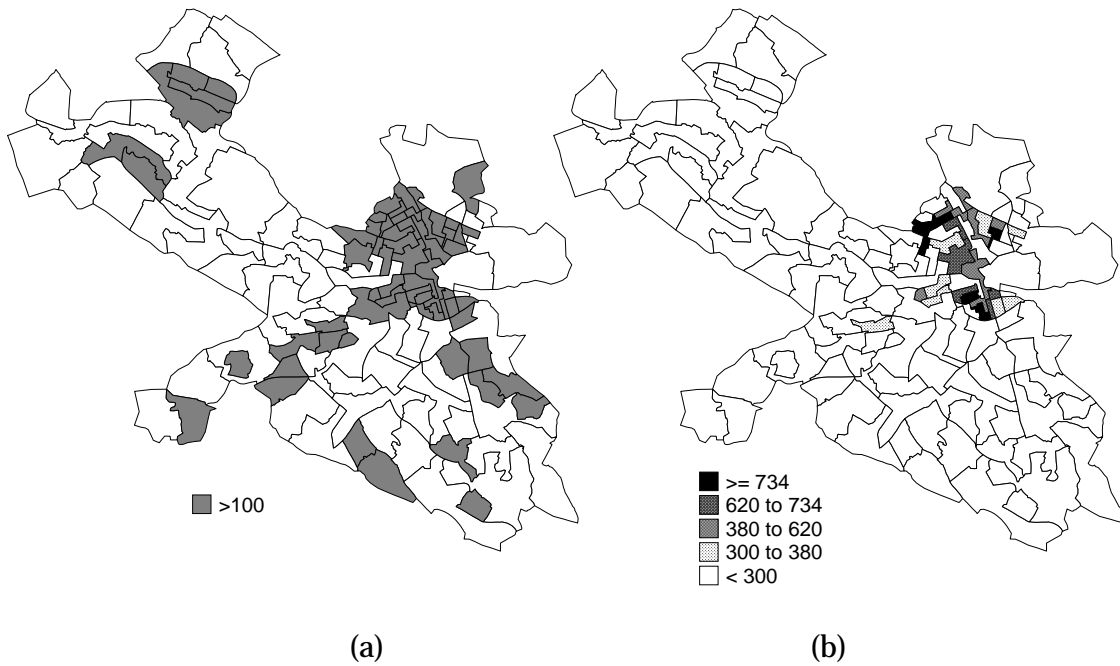
(a)   (b)

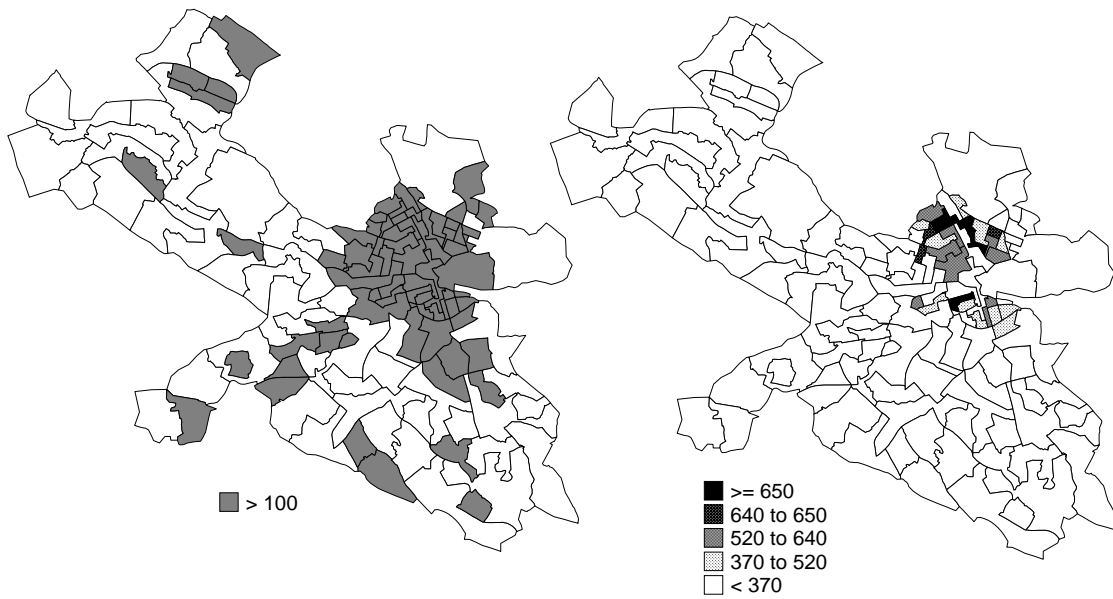Figure 8 (a) Vandalism - areas with higher risk–Stockholm 1998.

Figure 8 (b) Vandalism – Bayes adjusted SOR-Stockholm 1998.

(a)   (b)

Figure 9 (a) Theft of and from cars – areas with higher risk–Stockholm 1998.

Figure 9 (b) Theft of and from cars – Bayes adjusted SOR- Stockholm 1998.

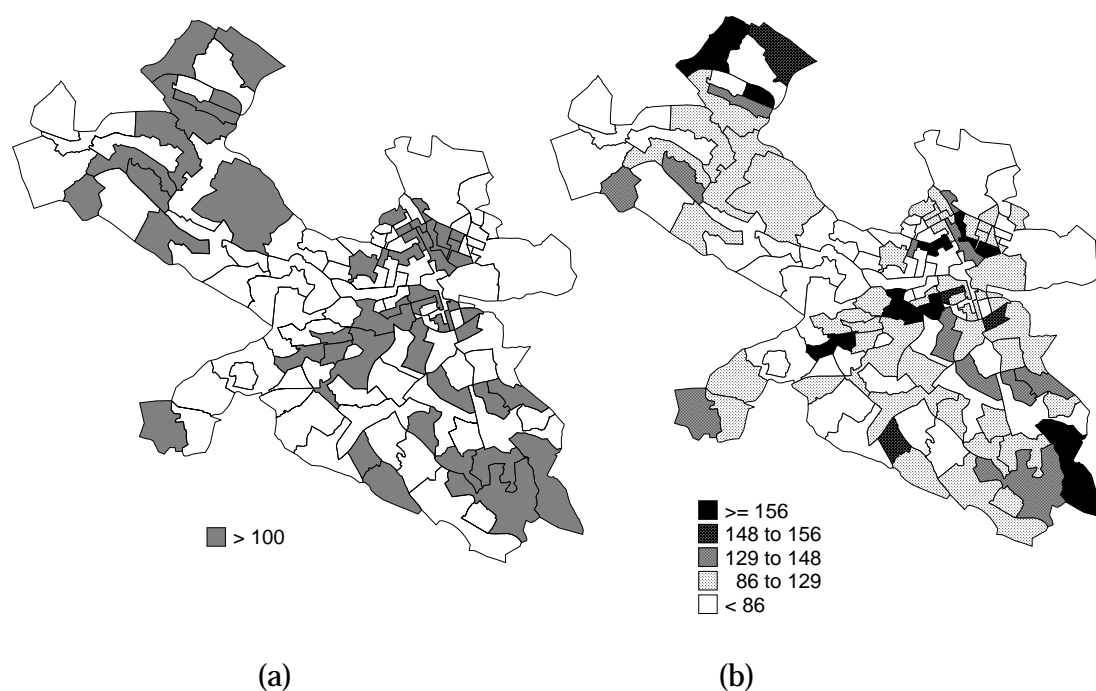(a)   (b)

Figure 10 (a) Residential burglary – areas with higher risk–Stockholm 1998.
Figure 10 (b) Residential burglary – Bayes adjusted SOR- Stockholm 1998.

3.2 Detecting spatial clusters of high SORs
3.2.1 The Getis-Ord statistic
The objective now is to analyse the spatial variation of offences across the study area in order to detect statistically significant clusters of high Bayes adjusted SORs . Clusters of high values are detected using a local Getis-Ord statistic of spatial concentration $G(i)^*$ (Getis and Ord, 1992). Inference is based on a standardised z-value computed by subtracting the empirical $G(i)^*$ from the expected mean and dividing the result by the expected standard deviation under the null hypothesis of a random distribution of SORs. The local Getis-Ord statistic provides a criterion for identifying clusters of high SORs, indicating the presence of significant local spatial clusters.

The local Getis-Ord statistic, $G(i)^*$, is given by the following formula (2):

$$G(i)^* = \sum_j w_{ij} (d) x_j / \sum_k x_k;$$ (2)

w_{ij} (d) = 1, if the distance between case *j* and case *i* is less than or equal to d;
        0, if the distance between case *j* and case *i* is greater than d.
w_{ii} (d) = 1

The radius d is topological distance or lag. Lag 1 means the calculation takes the areas which have first order adjacency with any selected area; lag 2 means that the calculation

takes not only the first adjacent areas but also those which are adjacent to the lag one areas; and so on for lags 3, 4, etc. If a cluster is small and exists only when taking first nearest neighbour areas, the cluster should disappear (in the sense of no longer being statistically significant) when the lag order is increased. The furthest lag used in this study was the third order. Undertaking analysis at different lags amounts to testing for different spatial scales of clustering.

A positive and significant z-value indicates spatial clustering of high SORs, whereas a negative z-value indicates spatial clustering of low SORs. It is important to note that the inference theory for the local Getis-Ord test is only strictly valid if there is no global tendency to spatial concentration or autocorrelation. Results for the global Getis-Ord statistic (see appendix 3) show that this assumption does not hold for any of these offences. The effect of global clustering on the performance of the Getis-Ord statistic has been noted and whilst it does not invalidate the technique, the results reported here should be interpreted with caution.

A conservative Bonferroni bound procedure was used to assess significance in order to take account of the effect of multiple testing. It is a conservative test criterion (that is there is an increased risk of a type II error) because the 119 tests, one per area, are not independent since they use overlapping subsets of the data. Notwithstanding these circumstances and using an overall α significance level of 0.05, the significance level for each individual test score was set to 0.05/119 or 0.00042. Maps were created showing areas with clusters of high SORs, which are statistically significant (p $\leq$ 0.00042) for the study area. The resulting clusters are discussed below.

3.2.2 Discussion of maps and tests for clustering

The following discussion of the results has two levels of analysis. The first level refers to results on the spatial variation in the (Bayes adjusted) standardised offence ratios as discussed in section 3.1.2 (Figures 8 to 10). These results are compared with Wikström's findings (1991). The second level refers to results based on the Getis-Ord test (3.2.1), which describes larger scale patterns in the data, namely geographical clusters of areas with high Bayes adjusted standardised offence ratios. In contrasting standardized ratio maps it is usual to pivot the shading on 100, where E(i) = O(i). In this case the Bayes adjusted SOR maps also need to be comparable to Wikstrom's rate maps. To achieve this, two maps for each offence are shown in figures 8, 9 and 10.

VANIA: we shall need to revise this again when you have had a chance to respond to my email about revising the maps.

Was the increase in vandalism that occurred during the 1990's associated with a change in its geography? Did it continue to be mostly concentrated in the inner city? Comparing Figures 2 and 8, it appears that the geography of vandalism may have changed to some degree since the 1980's. Wikström (1991) noted the marked concentration of this type of offence in the inner city but also in the area to the Northwest of Stockholm City and in parts of Spånga-Tensta (Figure 2). It appears that in the 1990's the spatial pattern as

revealed by Figure 8(a) has become more scattered, extending to other peripheral areas such as those in the South, Southwest and Western areas of Stockholm (such as, Hagsätra-Rågsved, Hammarby and Vällingby). However, the evidence of Figure 8(b) displays close correspondence with Figure 2 and the geographical concentration of areas with high SORs of vandalism is still in the inner city (Figure 11). Figure 11 shows the statistically significant clusters of vandalism using the different scales of cluster detection. Note that at the third lag, no cluster appears which indicates the spatially concentrated character of the

(a)
Gi* 1 Lag
P = <.00042
5 regions

(b)
Gi* 2 Lags
P = <.00042
17 regions
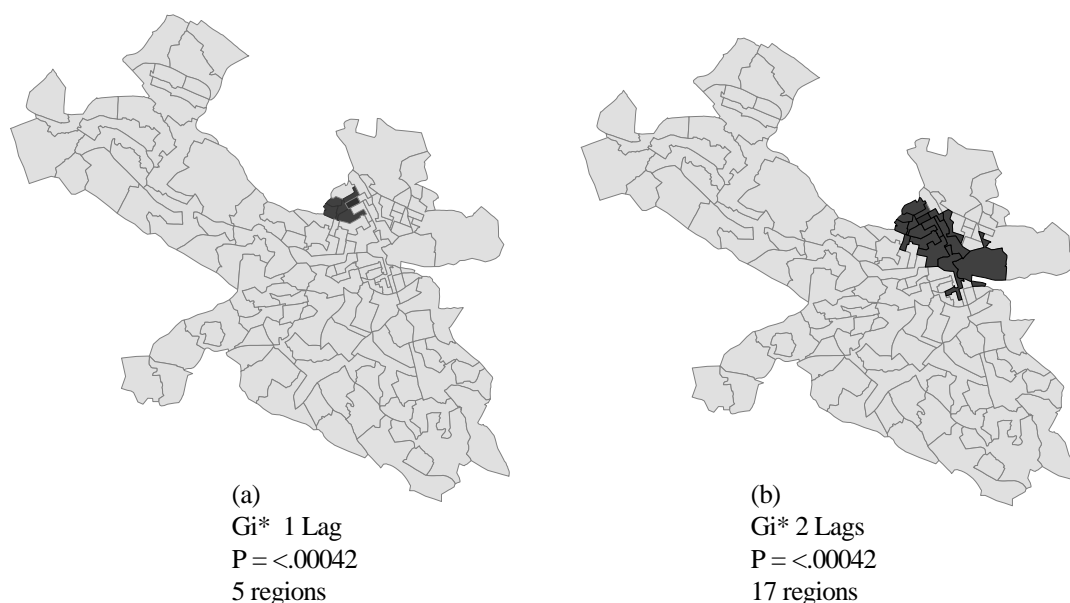
clusters.

Figure 11 Clusters of vandalism using G(i)*
Stockholm 1998

Theft of and from cars also showed a marked concentration in the inner city in the 1980's (Wikström, 1991). Comparing Figures 3 and 9, it appears that the inner city area with a high relative risk of car related thefts in the 1980's (Figure 3) still has a high level in the 1990's (Figure 9). The evidence of Figure 9(a) suggests that some new areas with high levels of relative risk may have emerged in the 1990s especially in Southern Stockholm (e.g., parts of Hammarby and Årsta).
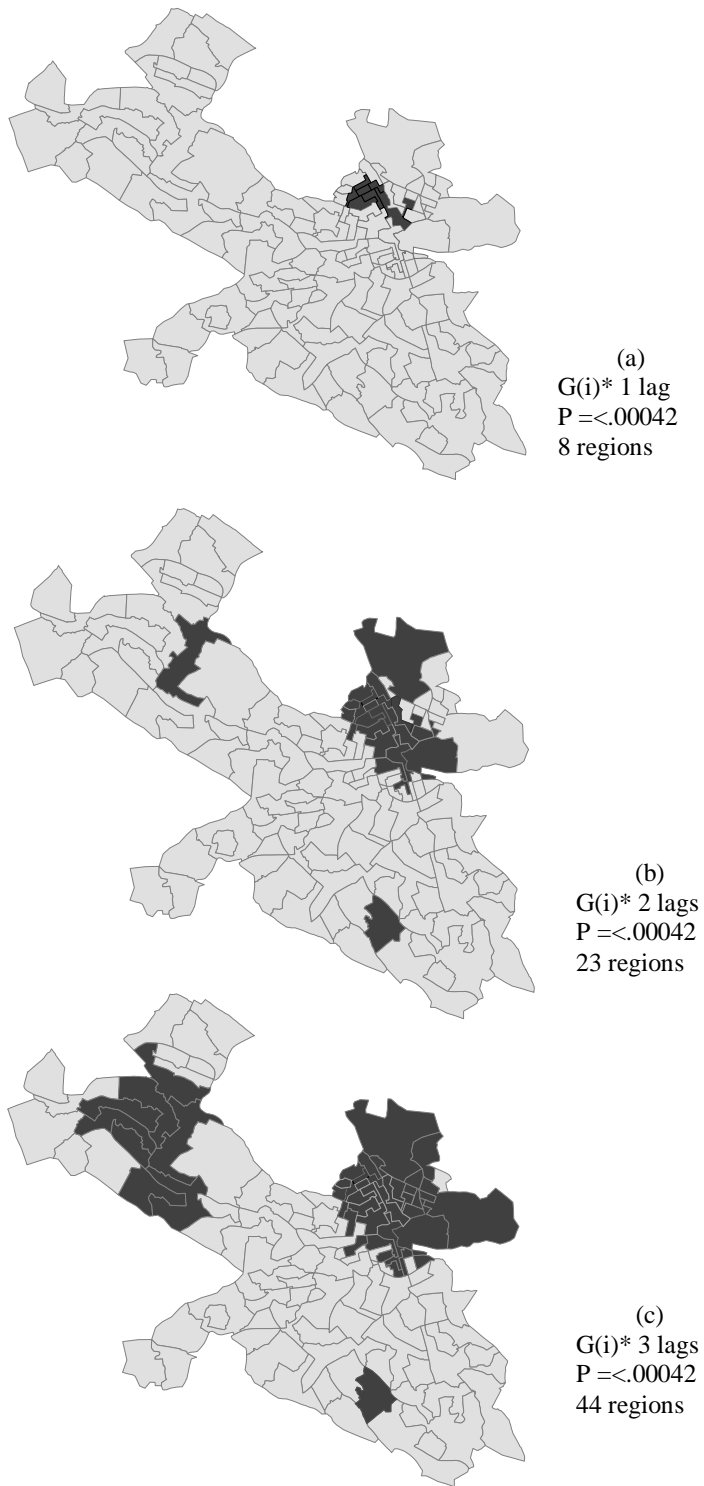
(a)
G(i)* 1 lag
P =<.00042
8 regions

(b)
G(i)* 2 lags
P =<.00042
23 regions

(c)
G(i)* 3 lags
P =<.00042
44 regions

Figure 12 Clusters of theft of and from cars using G(i)*

Stockholm 1998.

Figure 12 shows the areas with a geographical concentration of high relative risks of car related thefts in Stockholm City based on the different cluster criteria. Using first order adjacency, Figure 12(a) shows that only a small area of the city centre, mostly the commercial area, has a statistically significant concentration. In Figures 12(b) and 12(c), almost the whole inner city, comprises a statistically significant cluster of car related thefts followed by two other small clusters appearing in the Southern and Western parts of the city. There is some evidence that in the 1990's of a weaker association between the geography of vandalism and the geography of car related crime than that found in the 1980's. New clusters of car crime (unrelated to clusters of vandalism) are appearing away from the city centre.

Residential burglary has the most scattered pattern of high relative risk. As Figures 4 and 10 reveal several areas remained into the 1990's with a high relative risk of residential burglary (mostly in the Southern areas, e.g., parts of Farsta, Enskede). Some other areas have seen their risk increase (e.g., Akalla) while other areas appear to have become less vulnerable (e.g., parts of Bromma). No statistically significant clusters were identified for residential burglary, indicating that areas with high rates of residential burglary are more scattered over Stockholm City than the other two types of offences.

4. MODELLING OFFENCE RATES

To what extent can socio-economic variables explain the variation in relative risk for Stockholm City? The ordinary linear regression model has been used to try to explain the relationship between these variables. The ordinary linear regression model is given by (3):

$$Y = X\beta + \varepsilon \tag{3}$$

Where Y is the dependent variable (Nx1 vector); X is an Nxp matrix with N (= 119) cases on p explanatory (including the constant term) variables. β is a px1 vector of regression coefficients, and ε is random error with mean 0 and variance $\sigma^2 I$.

The dependent variables in this study are the three Bayes adjusted standardised offence ratios. A set of variables has been chosen as possible explanatory variables drawing on the existing literature. For a further description of the variables, see appendix 1). The explanatory variables are:

1. percentage of inhabitants born abroad
2. percentage of unemployed inhabitants aged 18-24
3. percentage of unemployed inhabitants aged 25-64
4. average income per economically active member of the population (16-64)
5. percentage of inhabitants who moved into the area in the last year
6. percentage of inhabitants who moved out of the area in the last year

7. percentage of multifamily houses
8. percentage of single family houses
9. percentage dependent on social benefits

Findings from previous Swedish studies on crime patterns and also from North American and British case studies (e.g., Wikström, 1991; Maguire and Benet, 1982; Costello, 1999; Evans 1992; Roos, 1986) were used as a background for the choice of explanatory variables. The above socio-economic variables have been chosen since they are indicators of the key variables underlying the variation in offence levels: community change, social instability and economic deprivation.

Two additional variables were included in the model in order to estimate regional effects. The first was a dummy variable which indicated whether an area (i) was part of the inner city D(i)=1 or not D(i)=0. The inner city boundaries were established based on the official spatial definition of the inner city (Regionplane- och traffikkontoret, 1994) which was then related to the spatial units produced by the region building process (3.1.1). This part of the city is composed of office buildings and a number of big department stores. It is the major shopping area of the city. The cultural centre is also concentrated in this area as well as other places of public entertainment. The governmental and ministerial buildings are also located in this area as well as the main public transport junction (underground and railway). Figure 6 shows the inner city defined in terms of the spatial units used in this analysis. The second additional variable was the distance from the centre of Stockholm's CBD to every other area as defined by each area's centroid. These variables were inserted as extra columns in the database:

10. Dummy variable to distinguish between inner city and outer city areas
11. Distance between each area's centroid and Stockholm's CBD.

The regression analysis was also implemented in SAGE because SAGE has regression modelling capabilities that are appropriate for spatial analysis. (For more detail about regression models in SAGE, see Ma et al., 1997, Haining et al. 2000). Other software packages such as SpaceStat can also be used for this form of modelling (Anselin, 1988).

4.1 Vandalism
Model results show that only the percentage of unemployed people (age 25-64) together with the dummy variable identifying the inner city were statistically significant in explaining the pattern of relative risk for Stockholm City. In both cases, the signs of the regression coefficients are as expected. The model explains just over 40 percent of variation in the rate of vandalism and Figure 13 shows the map of the large positive residuals.

The more central the region the higher the relative risk of vandalism. Most vandalism and violence occurs in and around public entertainment areas, such as restaurants, discos, pubs, theatres and museums (compare with Figure 5). In the case of Stockholm, these sites

are heavily concentrated in the inner city. Outer city areas with a high percentage of unemployed people also have a high risk of vandalism. This may be indicative of a lack of social stability or a high level of social disorganisation (Shaw and McKay, 1931; 1942). These findings correspond with those found by Wikström (1991) and described in section 2.2.

Y = Vandalism

$Y = 12.060 + 22.046x_3{}^* + 275.707x_{10}{}^{**}$
      (0.290)   (2.331)   (8.973)
(*t*-values in brackets)

*   Significant at the 5% level
** Significant at the 1% level

R^2 X 100 = 41.2%
R^2 (adjusted) X 100 = 40.2%

Shapiro-Wilks normality test 0.903 Prob 0.000
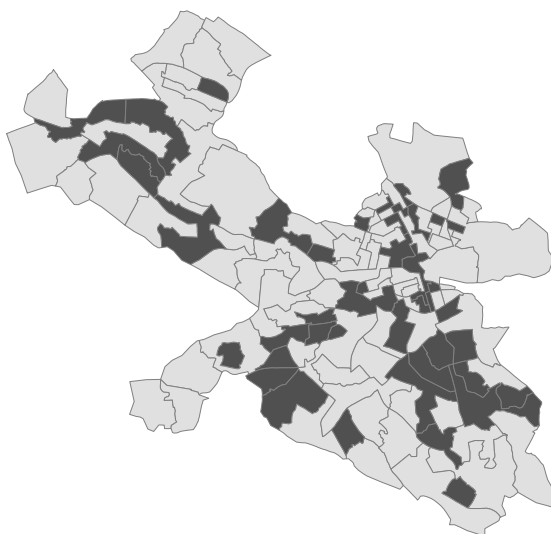Moran I on residuals: -0.010 Prob 0.861205

Figure 13 Positive residuals of the Multiple Ordinary Linear Regression Vandalism.

4.2 Theft of and from cars

The findings of this study show that the relative risk of car related thefts are explained by housing type and location (Figure 14) and correspond closely with those found by Wikström (1991) as described in section 2.3. The inner city has higher levels of car related thefts than the rest of Stockholm. TWOC - Taking without the owner's consent - is a

common offence committed by youths and it seems to have a particularly high relative risk in the inner city. Thefts from cars in the inner city can also be associated with other types of small offences committed by drug addicts.

The model suggests that the more multi-family housing (flats), the higher the relative risk of car theft and theft from cars (Figure 14). According to Wikström (1991:231-2) who found similar results, 'the differences in guardianship between multi-family and single-family houses may explain the pattern of such offences in Stockholm. The guardianship of cars parked in single family houses, often at the house lot or in a garage, may be considered to be higher than in other areas where cars are mostly parked in public spaces'. The lowest relative risk of thefts of and from cars tend to be found in areas where either formal or informal surveillance is greatest, that is, in areas with single family houses.

Figure 14 shows the positive residuals that indicate the areas where the offence pattern is under-predicted by the regression model. If the map of residuals is compared with Figure 6, several of the areas that show positive residuals are high-income areas such as Västerled, Lånsjö-Alvsjö, Hässelby villa strand and parts of the inner city. This may be an indication of the emergence of a new element in the geography of car related theft since the 1980's, namely increased rates of car crime in relatively affluent areas.

Y = Car theft and theft of cars

$$Y = -33.998 + 1.718x_7{}^{**} + 333.448x_{10}{}^{**}$$
$$\quad (-0.778) \quad (3.330) \quad (13.088)$$
(*t*-values in brackets)

**Significant at the 1% level

R^2 X 100 = 68.8%
R^2 (adjusted) X 100 = 68.3%

Shapiro-Wilks normality test: 0.969 Prob 0.072
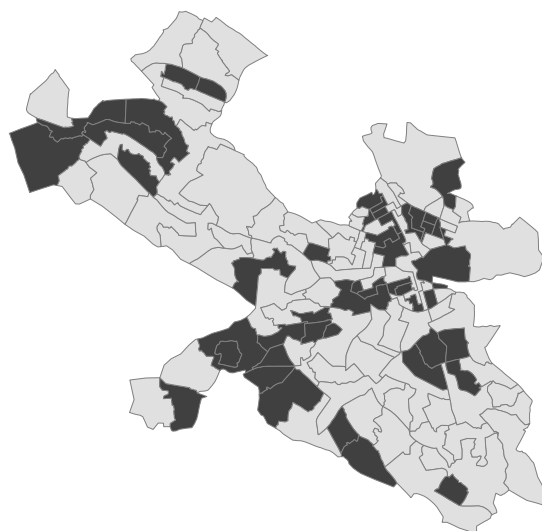Moran I on residuals: 0.096 Prob 0.0560762

Figure 14 Positive residuals of the Multiple Ordinary Linear Regression
Theft of and from cars

The value of Moran's I test on the residuals suggests a problem of residual spatial autocorrelation. A spatial error model is fitted in order to avoid inferential errors that can be created as a result of possible model misspecification (Haining, 1990). The results from the spatial error model suggest that the earlier findings are unchanged - although parameter estimates are slightly adjusted. In Table 3 lambda refers to the autocorrelation parameter in the spatial error model (Haining, 1990).

Table 3 Fitting Spatial Error Model - Theft of and from cars

Fitting Spatial Error Model

Dependent variable: Theft of and from cars				
R^2 x100= 65.3%				
Maximum Likelihood Estimation				
Variable	Coefficient	St. Dev.	Z-value	P
Lambda	0.229	0.123	1.860	0.063
Constant	-34.537	47.249	-0.731	0.465
X7	1.776	0.540	3.287	0.001
X10	321.871	28.800	11.176	0.000
Shapiro-Wilks normality test: 0.970 Prob 0.088				
Diagnostics for spatial error dependence: Test: LR, DF=1, Value= 2.674, P=0.102				

St.Dev denotes standard deviation. LR denotes likelihood ratio. DF denotes degrees of freedom. P denotes probability of retaining the null hypothesis

4.3 Residential burglary

Model results suggest two contrasting components to the burglary map. High relative risks of residential burglary appear to occur both in the more affluent areas and in the more deprived areas (Figure 15). The level of explanation attained by the model is poor (around 20 per cent) but this may in part be due to the dichotomous nature of the underlying pattern.

The results from the regression model show on the one hand that the higher the income the higher the relative risk rate of residential burglary. This fits into the Swedish pattern for this type of offence noted by Wikström (1991), which supports the view that an area's attractiveness affects its rate of residential burglary (section 2.4). Another variable that can be associated with income distribution is the percentage of people moving in/out - that is the population turnover. The results show that the lower the population outflow, the greater the residential burglary rate. Such relative population stability might be expected in areas with relatively high-income levels, high levels of house ownership and single family dwellings. The results also point to another component to the offence pattern. The higher the percentage of multifamily houses and the higher the percentage of people who are born abroad, the higher the rate of residential burglary.

The two components to the pattern in Stockholm are consistent with earlier findings in other countries. Wealthy areas, have high vulnerability to residential burglary because they provide attractive targets for offenders. At the same time, multifamily housing areas have high rates of residential burglary because they may be located close to where the offenders live.

Regions with high relative risks of residential burglaries, which are not explained by the model (Figure 15), include the inner city and also a significant part of Southern and Western Stockholm City, both high and low income areas.

Figures 16 and 17 show only the areas with positive residuals from the linear regression model. A common characteristic among these areas is that they are almost all low-income areas. In Figure 17, seven out of ten shaded areas are composed of low-income areas. This might indicate that low-income areas have a special dynamic that makes analysis of their offence patterns a difficult task. High turnover rates associated with rapid changes in demography are two examples of such complexity that are closely linked with the role of community change in explaining offence patterns (Bottoms and Wiles, 1995).

Y = Residential Burglary

$Y = 45.479 + 1.200x_1^{**} + 0.026x_4^{*} + (-3.842)\ x_5^{**} + 0.905x_7^{**}$
   (2.268) (3.032) (2.224)   (-2.774)   (4.256)
(*t*-values in brackets)

*   Significant at the 5% level
** Significant at the 1% level

R^2 X 100 = 20.9%
R^2 (adjusted) X 100 = 18.1%

Shapiro-Wilks normality test 0.926 Prob 0.000
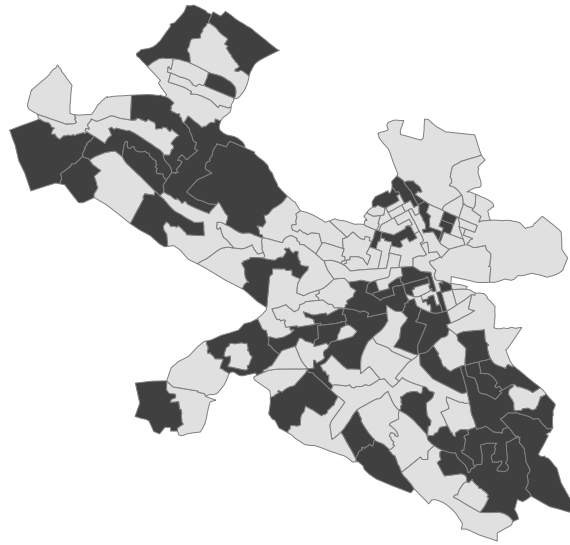Moran I on residuals: 0.024 Prob 0.431869

Figure 15 Positive residuals of the Multiple Ordinary Linear Regression
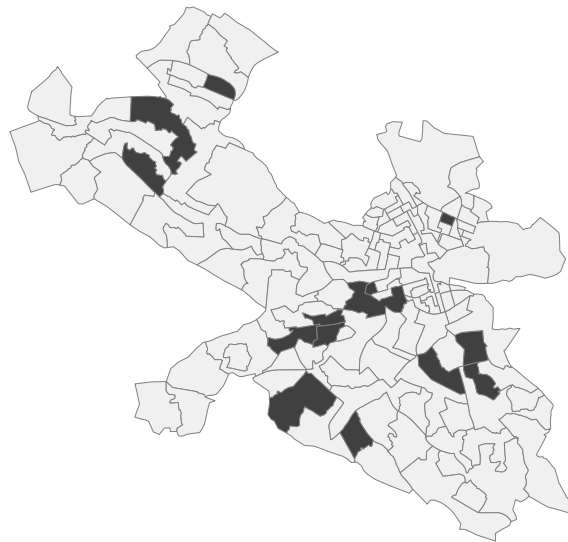Residential burglary.

Figure 16 Positive residuals of the Multiple Ordinary Linear Regression
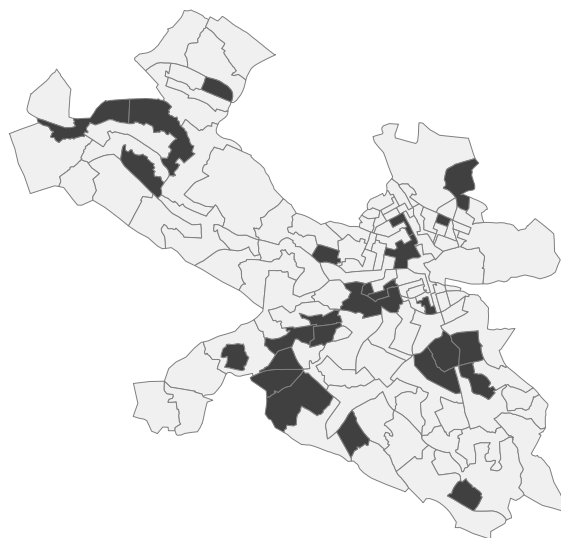Vandalism and Theft of and from cars.

Figure 17 Positive residuals of the Multiple Ordinary Linear Regression
Vandalism, Theft of and from cars and Residential burglary.

5. FINAL CONSIDERATIONS

Since the early 1980's Stockholm has become a more international and a more segregated city and new patterns of mobility have been imposed with the arrival of, for instance, out of town retailing. Renewal programs have stimulated population turnovers and there are indications of an accentuated gentrification process in the inner city areas. All these changes are expected to impact on offence patterns.

Results reported here suggest no dramatic changes in the geographies of vandalism, theft of and from cars and residential burglary rates since the findings of Wikström (1991). However there have been shifts both in terms of geographical patterns, notably in relation to the outer areas of Stockholm and in terms of the association of relative risks with underlying socio-economic conditions.

Vandalism and theft of and from cars are offences that take place mostly in the inner city where administrative, commercial and cultural activities are still located. SOR and cluster maps show concentrations around the CBD, and other small areas in the South and West of Stockholm. Although these offences still have a concentrated geography, they may have become more scattered than in the 1980's. Outside the inner city, areas with traditional social problems are the main targets but new areas have also emerged as being of high risk for these types of offences. High risks of theft of and from cars are now seen in more affluent areas perhaps because of declining levels of guardianship or because offenders are themselves more mobile.

The risk of residential burglary is relatively high in several areas in southern, western and central areas of the city. However residential burglary is no longer concentrated in the more affluent areas of Stockholm. Results here suggest the risk of burglary has increased significantly in more deprived areas characterised by multifamily houses and residents who were born abroad. This may signal that the offence of burglary in Stockholm is being increasingly conducted under two different scenarios. Burglary in affluent areas is often seen as the outcome of deliberate behaviour based on target attractiveness. Burglary in deprived areas, close to where offenders live, is understood as an opportunistic activity. The routine activities of motivated offenders in neighbourhoods close to where they live enables them to identify opportunities as they arise. These opportunities may stem from an absence of capable guardians in the immediate area and/or ease of physical access. This new component of the pattern coincides with findings elsewhere and links to the sorts of economic and social transformations occurring in many large cities in Europe and North America. On the other hand, and less interestingly, it could be the result of incorporating burglaries of attics and cellars into the data on residential burglary. Burglary in cellars seems to be related mostly to areas dominated by multi-family houses. In either event, with two such different processes potentially underlying the geographical distribution of burglary attention may need to be paid to constructing other model specifications.

The incorporation of new variables into these regression models is essential if their explanatory performance is to be improved. In the specific case of theft of and from cars and vandalism, information about variations in land use (e.g. the location of public transport stops, and the mixture of different types of land use) might improve model performance. Also of interest are the type of tenancy and the incorporation of information on crime prevention measures, such as neighbourhood watch and other activities directed specifically towards curbing juvenile delinquency.

In the case of residential burglary, there are other variables that may help to explain the pattern of high relative risk (Figure 15). It is known that areas with high relative risks of residential burglary tend to be located close to areas with high offender rates in the outer city or parts of the inner city (Wikström, 1991). This argues for the inclusion of aggregate data on where offenders live. An analysis of types of offenders could also explain contradictory spatial patterns of offences, helping to understand the differences between young, opportunistic amateurs and older, deliberate, professional offenders. A further variable that would help to explain residential burglary is housing ownership rather than housing type. The variables housing type and housing ownership are strongly correlated in Sweden but they are not the same. Differences between rental housing (public housing and private housing companies) and owner occupied housing are expected to explain patterns of offences (Wikström et al.,1997). Data on the proximity of residential areas to communications links, such as railways, motorways and underground stations could improve not only models for vandalism and car related theft but also for residential burglary.

The findings reported in this paper are based on the implementation of a two stage methodology for constructing reliable maps of relative risks where spatial variation is not an artefact of the data. The methodology required first the construction of a spatial framework where each area had a minimum population size and population size differences were constrained. The area with the largest population had only three times the population of the area with the smallest population as compared with a nearly thirty fold order of difference in the original spatial units (Basområde). Population was used for the criterion because burglary rates use population for the denominator. Although the other two offence rates use area in their denominator, population size provides the best compromise for making comparisons across the different offences. At the second stage, rates were then further modified by the adoption of a Bayesian adjustment procedure that shrinks rates for areas with small populations towards the rate for Stockholm as a whole. This is recommended because such rates whilst they have low bias also have low precision.

Analysis involved inspecting the risk maps to identify areas with high relative risks and, through use of the Getis-Ord statistic, testing for different scales of spatial clustering of high SORs. The final stage employed spatial regression modelling in order to identify covariates that would describe the variation in relative risk. The modelling methodology was limited to fitting the linear regression model including a spatial error term only in the case of thefts of and from cars in order to deal with residual autocorrelation arising in the original specification. Wikström's model does not make explicit the role of spatial relationships between areas with different socio-economic characteristics in understanding variations in offence rates. Further work in this area will, it is hoped, give a clearer indication of the types of spatial regression model specifications that would be appropriate (see for example, Anselin, 1988, Haining, 1990).

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APPENDIX 1 - Description of the socio-economic explanatory variables (Xs)§

Variables	Calculated based on
1. Percentage of inhabitants born abroad	RTK's definition, which includes both foreign citizens and Swedish citizens who are born abroad
2. Percentage of unemployed inhabitants in age between 18-24 (not included those in trade union education-ALU or labour market training)	The total population in age between 18-24 of each area
3. Percentage of unemployed inhabitants in age between 25-64 (not included those in trade union education-ALU or labour market training)	The total population in age between 25-64 of each area
4. Average income (yearly)	Average income per economically active member of the population (16-64) of each area
5. Percentage of inhabitants who move into the area during 1996-97	The total population of each area
6. Percentage of inhabitants who move out the area during 1996-97	The total population of each area
7. Percentage of multifamily houses (multi-stores houses)	Total number of households which corresponds roughly to the total of dwellings of each area
8. Percentage of single family houses (detached houses)	Total number of households which roughly corresponds to the total of dwellings of each area
9. Percentage of households receiving social benefits (A-kassa, bostadbidrag, barnbidrag, ALU)	Total of households of each area

Appendix 2 – SAGE - Spatial Analysis in a GIS Environment

SAGE – Spatial Analysis in a GIS Environment, is a software package for interactively studying area-based data. SAGE can be used for analysis of spatial data, with emphasis on rapid interactive visualisation of data supported by a suite of cartographical, graphical and analytical tools as a result of integrating spatial statistical analysis (SSA) techniques with a state-of-the-art GIS, ARC/INFO.

SAGE has been implemented on Sun workstations with the Solaris 2.5 operating system. It also requires ARC/INFO 7.0 with Arctools and Motif 1.2 shared library. SAGE has been implemented as an appliaction of client-server technology. It is composed of two separated but co-operative programs: a client program and a server program. The server program is based on ARC/INFO, while the client is made from a set of SSA tools. The server is the provider of services, while the client is the consumer. SAGE requires two working directories as its working space, one for the server and one for the client, to manage temporary files.

The software is designed to handle area-based data sets (although it is possible to use point data). Each area, together with its associated attributes, is considered as a single object by SAGE, and is identified internally by a unique integer – object identifier.

In this case study, all data for a SAGE view was stored in a single coverage, with the attributes held in a single Polygon Attribute Table (PAT). It was also possible to attach additional attributes held in separate INFO tables to this PAT using the ARC/INFO RELATE mechanism.

Regarding data manipulation, SAGE allows the user to import data from ASCII file as new attributes. It also offers tools to export attributes and weights matrices to ASCII files so that they can be used in other software packages. SAGE also provides tools which create weights matrices in pre-defined forms by using feature attributes but it also allows the user to modify pre-defined weights matrices and build weights from scratch. SAGE also provides a set of tools allowing the user to perform a set of arithmetic and statistical computations on the original data and save results as new attributes.

Data visualisation in SAGE can be done through three components, a map window (map), a spreadsheet-like window (table) and graph window (graph). A map shows the shape of an object, while a row in the table window presents all active attributes of an object. A point or bar gives a view of the partial properties of an object such as an item in a histogram, an XY scatter, an XW scatter or a boxplot. For further information about the functionality and architecture of the system see Haining et al, (1996, 2000) and a copy of the software is freely available from the website www.sheffield.ac.uk/~scgisa.

APPENDIX 3 - Values of tests for global spatial concentration and autocorrelation.

Based on the results of Bayesian adjusted SOR, the global Getis-Ord test for spatial concentration and Moran's I test for spatial correlation have been applied. The values of Moran's I indicate positive spatial autocorrelation. The Moran's I is positive when nearby areas tend to be similar in attributes; it would be zero if the attribute values were arranged randomly and independently in space.

Values of tests for global spatial concentration and autocorrelation

	Global Getis-Ord[1]	Global Moran's I[1]
Vandalism	0.081	0.897
Theft of and from cars	0.070	0.927
Residential burglary	0.047	0.869

[1]All values are significant at the 1 per cent level.