Crime and Space

PATTERNS OF OFFENCES AND OFFENDERS' PATHS TO CRIME PORTRAYED BY GIS

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SPACE IN URBAN CRIMINOLOGY

The way *spatial information* has been approached by literature in crime analysis varies highly, following both the development of urban criminology as a discipline (Shaw and McKay 1942, Newman 1972, Cohen and Felson 1979, Brantingham and Brantingham 1991, Sampson et al. 1997, Wikström 2003, 2004) and the diffusion of spatial technologies such as Geographic Information Systems (GIS) in human sciences (Haining 1990, 2003, Anselin 1999, Fotheringham and Rogerson 2002, Chainey and Ratcliffe 2006). In this article, I review how certain notions of *space* have been incorporated into urban criminology research using GIS.

Space is discussed as:

- location, density and distance measures
- mental description of an environment
- discrete demographic and socio-economic entity
- structural backcloth for social interactions
- measure of environmental risk

The advance of new technologies for data storage and analysis such as GIS has led to the creation of systems for visualising and analysing the growing amounts of geocoded crime data both within academia and police forces. These techniques are making geographical analysis of crime data more in-depth and interactive than they were in the past and therefore space can now be addressed more dynamically, both in time and space. Spatial analysis of crime data often uses information on the unique location of individual crimes (x,y co-ordinates) or aggregated data (combining individual point data into larger areal units, such as a city's statistical units). There are also cases when lines are used either to portray offenders' paths into crime or environments which residents perceive as unsafe. Some of these spatial analyses are illustrated later in this article. I do not intend however to make a complete review of applications but rather provide a sample of important areas in this field by showing some of my own research examples. The article concludes with directions for future research.

SPACE AS LOCATION, DENSITY AND DISTANCE MEASURES

When a crime event occurs, it happens at a certain location and an offender who commits a crime can be found at a place near or far from the crime event. A crime target or victim must be where the offender is at exactly the same time as the event takes place. Thus, the intersection of these elements exemplifies how *space* as *location* plays a vital role in understanding crime and how crime occurs. The police have long recognised the inherent geographical component of crime by marking maps with pins, where each pin represents a crime event. It was however not until the development of spatial analysis and advent mapping techniques that the importance of 'space' in understanding crime was further investigated by scholars and practitioners.

Space has extensively been approached in urban criminology as a measure of *concentration or density*. In these studies the goal has often been to identify, predict and in certain cases, manage "an area that is the target of a higher than expected level of criminal activity" (Rattcliffe and McCullagh 2001) sometimes referred to as 'hot spots'. Hot spots evolve or change over time (Johnson and Bowers 2004, Ceccato 2005), are mobile or in transit (Tremblay and Tremblay 1998, Loukaitou-Sideris et al. 2002, Newton 2004) or even depend on human perception (Rengert 1995, Rattcliffe and McCullagh 2001). A number of different mapping techniques have been developed for identifying hotspots of crime: from location quotients, thematic mapping of area based data, spatial ellipses, grid thematic mapping, kernel density estimation to indicators of global and local spatial association (Canter 1995, Anselin 1995, Rattcliffe and McCullagh 1999, Block and Block 1995, Rattcliffe 2004). The global popularity of hot spot analysis is due to the fact that being able to identify high crime areas is an important crime prevention tool for police forces.

Figure 1. Cluster of total thefts in Vilnius' Old Town, Lithuania, 2004–2005 using Nearest Neighbour Hierarchical Cluster. Source: Ceccato and Lukyte, 2008:7.

Figure 1 illustrates the use of the Nearest Neighbour Hierarchical (NNH) cluster technique to identify a high concentration of thefts in Vilnius Old town, Lithuania. The NNH used here is a clustering technique that defines a threshold distance and compares the threshold to the distances for all pair of points. In this first criterion, we have chosen 100 meters for the threshold distance. Only points that are closer to one or more other points than the threshold distance are selected for clustering (represented by the ellipses in Figure 1). What is evident in this pattern is how hot spots of thefts follow main roads and areas with diverse land use, where there is a lack of 'capable guardians' despite being crowded places. These areas mostly comprise transport links (such as main streets), transport nodes (such as bus stops) and places where large groups of people gather (close to museums, galleries, hotels, theatres, restaurants and hospitals). Similar geography was previously found in North American and Western European cities (Brantingham and Brantingham 1991).

Criminology has also focused on *space* as synonymous with *distance* between two places, crime location and offender's place of residence. These studies might be simple average distance analysis (a bi-polar connection of an offender's residence and crime location) or complex methodological proposals to predict an individual's offending behaviour. The work of White (1932) is regarded as a basis for many scholars (Turner 1969, Capone and Nichols 1976, Rhodes and Conly 1981, Phillips 1980, Lundrigan and Canter 2001, Wiles and Costello 2001, Fritzon 2001, Gore and Pattavina 2004). None of these studies however regard crime in relation to an individual's mobility within the city, either prior or subsequent to the crime event. This is important to highlight because crime may occur only when motivated offenders, suitable targets and an absence of responsible guardians intersect in space and time (Cohen and Felson 1979).

SPACE AS A MENTAL DESCRIPTION OF EN ENVIRONMENT

One relevant question is whether crime official statistics reflect people's perception of safety. Using GIS, it is possible to create maps of the perceived safety for different groups of residents. These maps constitute mental descriptions of an environment and can be useful for studying spatial patterns of crime. For instance, if the perceived pattern of safety does not correspond to the actual pattern, then important data can be learned about the perceived and actual environment instigators and inhibitors to criminal events (Smith and Patterson, 1980, Rengert, 1995, Rattcliffe and McCullagh, 2001). Figure 2 shows how patterns of offences match the perceived safety in an urban renewal project of a residential area (Jordbro) in Stockholm County, Sweden. The data in this case refers to the people's perception of their personal safety obtained from surveys. Those who felt unsafe were invited to indicate on a map the areas they avoid. These sketch maps were later transferred to the

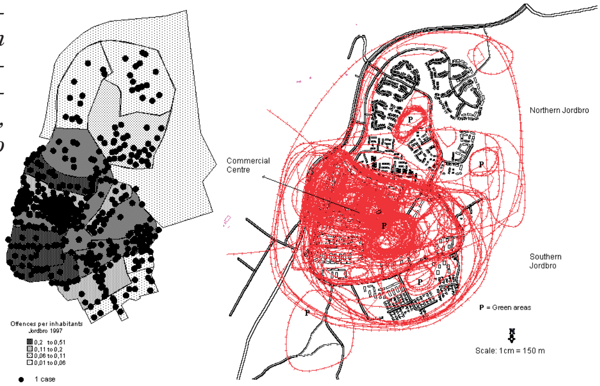


Figure 2. Offences per inhabitants and indication of 'unsafe places' by residents in Jordbro, Stockholm region, Sweden, 1999. Source: Ceccato and Snickars, 2000.

basic digital map by using GIS. The lines in Figure 2 (right) show the areas people indicated as unsafe. The map shows that those areas that are close to the commercial centre, the tram station, and bus stops are perceived as unsafe places with disturbances, which fairly matches the pattern from the map based on official statistics (left). Open and less guarded green areas are also commonly perceived as less safe.

Criminologists have also been interested in looking at *space* as a potential *landscape* for crime. Space, and the factors within it, can be assessed as a condition that facilitates or deters crime. The central point of these studies, therefore, is on features of urban space rather than offenders or criminal events. The scale is at the level of *micro environments*, such as facades or street corners, but also the composition of these parts that make an area more or less susceptible to crime. Different parts of an urban space can be *perceived* as vulnerable to various types of crime. For example, muggers need busy and semi permeable areas, whilst burglars may prefer secluded access. Although these studies have been fundamental to establishing key factors for situational crime prevention (Jacobs 1961, Jeffery 1971, Newman 1972, Hillier 2002), they have also been controversial, especially when the influence of physical environment in determining crime has been exaggerated by supporting factions.

SPACE AS A DISCRETE DEMOGRAPHIC AND SOCIO-ECONOMIC ENTITY

There has been a long tradition in criminology to approach *space* as *discrete zones* (such as neighbourhoods) in the attempt to understand crime distribution. Often aggregated data are attached to spatial entities that are thought to be *ecologically* exposed to different sorts of crimes. Such data may be ecological (a group-level property), or contextual (an aggregation of a property belonging to the individuals comprising the group). Shaw and McKay (1942) in their seminal work on Chicago argued that low economic status, ethnic heterogeneity and residential instability led to 'community disorganisation', which in turn resulted in sub-cultures of violence and high rates of delinquency. Social disorganisation theory suggests that structural disadvantage breeds crime. The main focus is placed on offenders and motivation (often indicated by an offender's place of residence). More recent investigations have drawn on new concepts (such as social cohesion and collective efficacy) but are still linked to crime location or an offender's place of residence as discrete zones (Rosenfeld et al. 2001, Sampson et al. 1997).

Although ecological studies have continued to reveal strong associations between characteristics of urban areas and the locations of certain types of offences, there is little evidence to show how exposure to different urban environments (beyond place of residence or crime location) can influence an individual's decision to commit a crime. Other limitations refer to the use of 'zones' as a unit of analysis. For instance, the impact of shape and size of zones on the results (the Modifiable Area Unit Problem – MAUP) as well as the risk for *ecological fallacy* have been extensively documented (Fotheringham and Wong 1991, Robinson 1950). Using cross-sectional aggregated zone data we are able to ascertain the links between the occurrence of crime and small-area socioeconomic and demographic characteristics (conclusions are drawn at ecological level only). However, what cannot be done, is to observe how these causal mechanisms take place at an individual level within zones and over time.

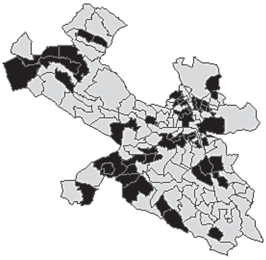


Figure 3. Positive residuals of the Multiple Ordinary Linear Regression, Car related thefts, Stockholm, Sweden, 1998. Source: Ceccato et al. 2002

Ecological studies in Western cities have shown that for example, inner city areas are vulnerable places for car related thefts, especially those close to deprived neighbourhoods or with diverse land use (Wikström 1991, Evans 1992). In these studies, regression models are often used to test to what extent socio-economic and/or land use variables reflect the variation of crime in space. An example of this type of analysis is depicted by Figure 3, which shows a map of positive residuals of the Multiple Ordinary Linear Regression model for car related thefts in Stockholm city, Sweden. The positive residuals indicate areas where car related thefts are under-predicted by the regression model. In the Stockholm's case, they are high-income areas and parts of the inner city, which may indicate the emergence of a new element in the geography of car related theft since the 1980's, when they occurred in relatively poor neighbourhoods and inner city areas only (Wikström 1991). High risks of car theft and theft from cars are now seen in more affluent areas perhaps because of declining levels of guardianship or because offenders are themselves more mobile, moving beyond the city boundaries. These findings show that a city's internal geography is sometimes not enough to explain its crime distribution. Crime patterns can be affected by external forces that go beyond the city's initial demographic and socio-economic make up. Figure 4 shows an example of when a construction of a transport link (a bridge connecting two cities) impacts on intra-urban crime levels and geography. The map indicates neighbourhoods of a Southern Swedish city that had an unexpected increase in car related thefts after the transportation link was built (the Öresund's bridge, connecting Malmö to Copenhagen).

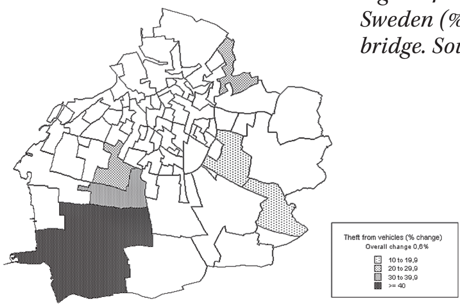


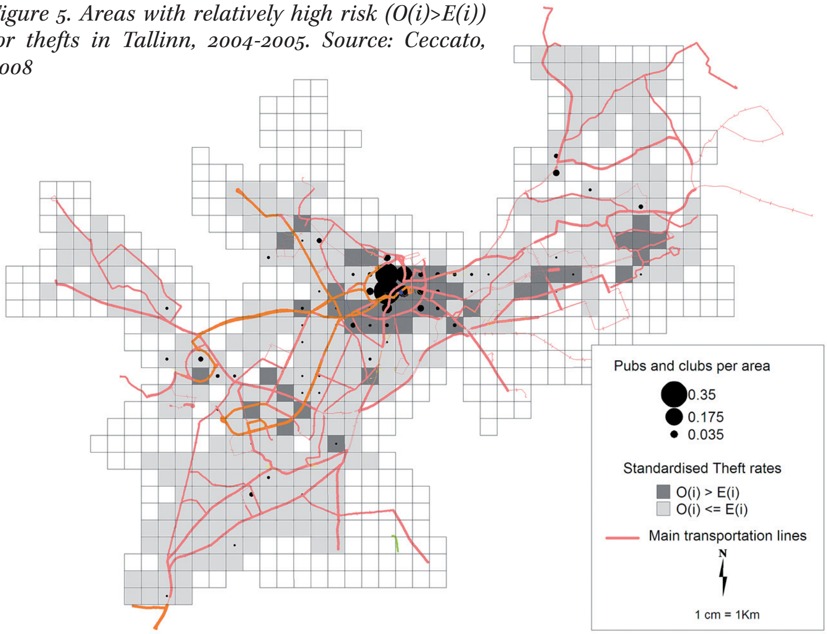
Figure 4. Changes of car related thefts in Malmö, Sweden (%), 18 months before and after Öresund's bridge. Source: Ceccato and Haining 2004

SPACE AS STRUCTURAL BACKCLOTH FOR SOCIAL INTERACTIONS

The 'routine activity theory', as it is called, suggests that an individual's activities and daily habits are rhythmic and comprise repetitive patterns. *Space* is like a *structural backcloth* that generates certain types of social interactions that may lead to crime. The goal of studies based on routine activity theory is to direct their work away from static ecological correlations between socio-economic characteristics and crime toward a more dynamic view of crime within the context of daily activity patterns. The dynamic aspect of this theory has however been empirically limited by the lack of individual level data on a person's actions over time and space. Empirical studies have so far taken land use indicators (e.g. location of city centre, resident population density) as proxies for an individual's mobility or potential social interactions that may lead to crime (Roncek and Maier 1991, Osgood et al. 1996, Oberwittler 2004). Figure 5 illustrates how land use data can be used as indicators of the criminogenic conditions of different environments in Tallinn, Estonia.

Co-coordinates of the location of pubs and clubs, bus/tram/train stops and transport lines were mapped using GIS. A digital grid cells map covering the city of Tallinn was used as a basis for the spatial modelling analysis (500 by 500 meter squares) instead of irregularly shaped polygons from administrative areas. The map also shows the intersection of high-risk areas for thefts (dark gray) derived from a

Figure 5. Areas with relatively high risk (O(i)>E(i)) for thefts in Tallinn, 2004-2005. Source: Ceccato, 2008



standardised offence ratio (Ceccato et al. 2002) with transportation lines and location of pubs and clubs. One-third of total thefts take place in the central area of Tallinn, which encompasses about 5 percent of the city's area. As expected, these areas bring people together, creating an opportunity for thefts, with potential offenders and victims present at the same place and time (Cohen and Felson 1979, Wikström 1991). If data were available, the time dimension could be split up into sections, such as day-time, night-time population, or convergent-divergent times at group level, providing a greater picture of people's routine activity and an improved basis from which to 'explain' crime patterns. In this case, GIS in combination with space-temporal techniques (such as the *Kalldorff's scan test*, (Kulldorff, 1997) can be used to test concentration of crime as clusters in time and space. Since crime clusters might expand or shrink in size over time (Johnson and Bowers 2004, Ceccato 2005) police forces may use this information to better tackle crime by taking decisions on *where* and more importantly, *when* to dispatch police patrols.

SPACE AS A MEASURE OF ENVIRONMENTAL RISK

Traditional urban criminology has during several decades focused either on the characteristics of crime location or the context of an offender's residence to predict crime. Several attempts focused on interactions between these bipolar locations but excluded the complexity of an individual's mobility between the two points. Relatively little empirical evidence exists on whether the quality of the environment and settings where individuals spend time have any influence on their decision to commit a crime. Wikström and Loeber (2000) has, for instance, shown that being exposed to risky environments makes some individuals more prone to offend. The analysis draws upon Wikström's Developmental Ecological Action Theory of Crime in which acts of crime are considered to be a result of the interplay of mechanisms linking individual characteristics, behaviour settings and community context (Wikström 2003, 2004). The novelty of this analysis lays in the combined application of GIS and space-time budget techniques. Space-time budgets constitute a technique for data acquisition that provides a basis for detailed description and analysis of individuals' behaviour over time and space (in this case, a longitudinal database sample of juveniles from Peterborough state schools). The potential for using individual data in GIS is argued to provide insights on whether, how, where and when human interactions take place and how this affects actions that may lead to offending.

One of the GIS techniques tested to represent movement patterns is space-time prism (or aquarium), which is perhaps the most similar form of representation to the original Hägerstrand's daily prisms (1970:13-14). Hägerstrand used the space-time path to demonstrate how human spatial activity is often governed by limitations and not by independent decisions by spatially or temporally autonomous individuals. This means, for instance, that an individual cannot be in two places at the same time or travel instantaneously from one location to another – a certain trade-off must be made between space and time.

The activities of an adolescent on a Monday were mapped using the

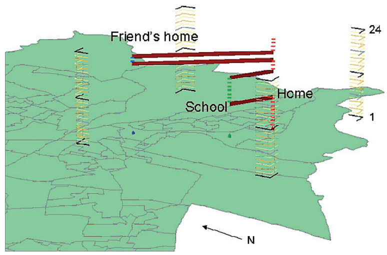
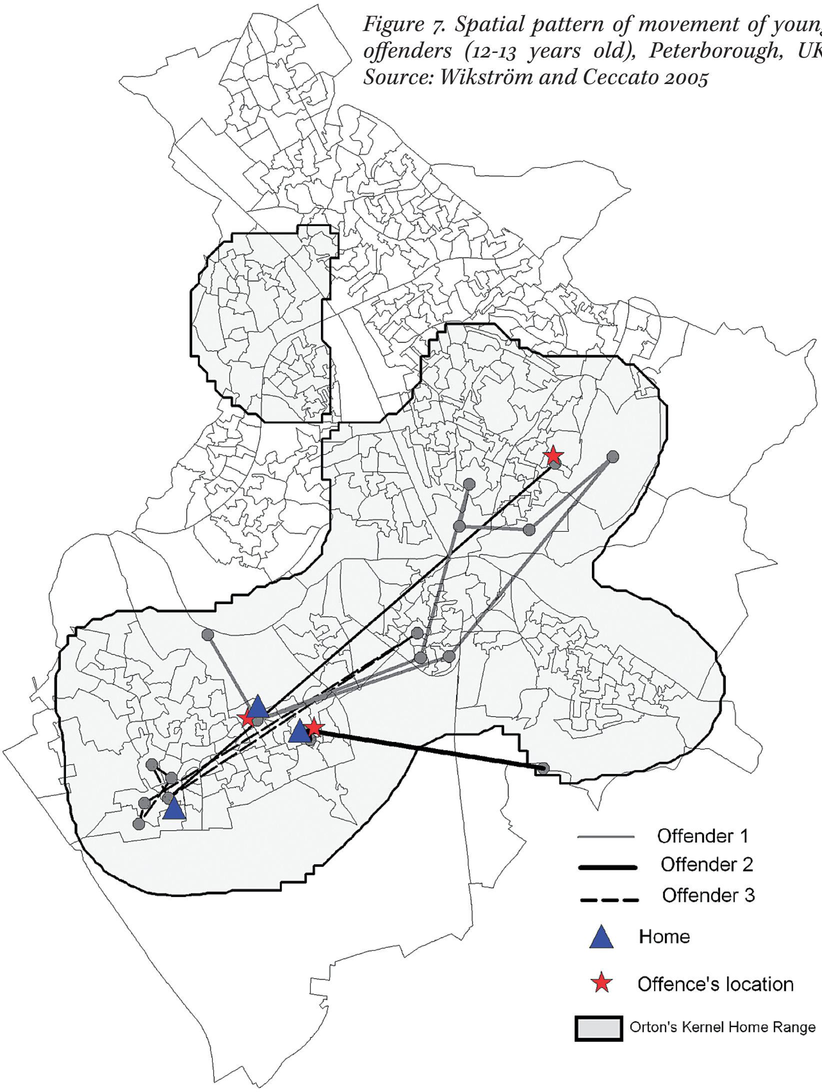


Figure 6. Space-time prism of an adolescent on a weekday.

co-ordinates of each enumeration districts' centroids (Figure 6). The co-ordinates were generated initially in 2-D and then converted to 3-D shape files together with three other background layers (lines connecting places, time scale and the Enumeration District map). An advantage is that angles of lines connecting places shows the direction of a path whilst the time scale indicates duration of each activity. Although the use of individual data mapped at very detailed level (e.g, street address) has considerable potential for development of person-specific scales, it still has limitations. The use of multiple paths at once in a space-time prism can for instance be visually challenging since it is very difficult to disentangle a path from another (Kwan 2000), failing to provide a comprehensive picture of activity patterns emanating from distinct groups. *Activity density surface* is an alternative technique able to identify potential differences in spatial paths.

Figure 7 exemplifies the spatial pattern of movement of three young offenders, where they live, where they committed offence(s) and the areas that they most likely passed through during that week. This picture illustrates a combination of points (e.g. home and offence locations), lines (individual paths) and areas (e.g. kernel home range). Using default parameters, a fixed kernel home range utilisation distribution (Worton 1989) as a grid coverage in GIS was calculated for a group of adolescents living in a southern Peterborough neighbourhood (Orton), where all three offenders live. The gray polygon represents the area with a 95% probability where the children moved around (significant differences in gender can also be found when girls' and boys' movement patterns were tested). This map shows that although young offenders'

Figure 7. Spatial pattern of movement of young offenders (12-13 years old), Peterborough, UK. Source: Wikström and Ceccato 2005



movement patterns are strongly influenced by their place of residence, many activities happen far from where they live (see the gray polygon). By using space-time budget data (Wikström and Ceccato 2005), their paths can be broken down by time (hour) and space (output areas) and mapped using GIS. A similar approach is used to determine how much time each individual spends in different parts of the city, including settings or environments that are risky (e.g. measures of environment risk and setting risk). Individuals are classified into risk groups (based on morals and self-control), which in combination with their weekly activity patterns, can be used as a measure of environmental risk and a predictor for offending.

SUMMARY AND LOOKING AHEAD

Crime events are far from being random phenomena. They tend to occur in particular places; they may occur at certain hours of the day and even in association with specific demographical, land use, and socioeconomic aspects of the population. It was not until the advent of spatial technologies such as GIS that it was recognised that crime could be explained and understood in more depth by exploring its geographical components. Spatial analyses have for decades made possible the identification of patterns and concentrations of crime, the exploration of factors that explains its geography and, more recently, tracking individuals over space and indicating risky environments that may affect their decision to offend. Linking data on *offence*, *victims* and *offenders* is one of the core issues in modern urban criminology and the GIS applications shown in this article illustrate where the linkage is crucial to understanding spatial processes.

An important area of study that has not been covered by this article is the quality of crime data. Underreporting is a known cause for lack of reliability within official police offence databases (which varies by type and crime seriousness). There are other problems of data quality that take place during the process of recording offences. For instance, the lack of information about an event from the victim (not knowing exactly where the offence took place) or by the police officer failing to record the event properly (missing records on the exact location/time of the event). There are also risks for inaccuracies in the process of map creation. Geocoding is the process of matching records in two databases: the offence address database (without map position information) and the reference street map or any other "address dictionary" (with known map position information). In cases where the matching of the exact offence location is not possible, a common practice is to choose a near location (such as midpoint of street) or the polygon centroid of a region (e.g. district polygon). This practice may create the so-called "dumping sites" for records, which generates false offence concentrations and consequently, a poor basis for research or any police intervention. Future research should devote time to assessing how these multiple sources of inaccuracy (when reporting, recording or geocoding) affect the reliability of the outcomes in spatial crime analysis.

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