USING SPACE SYNTAX SOFTWARE IN EXPLAINING CRIME

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Abstract. Space syntax provides methods for analyzing spaces using recent developments in computer programs. This paper reports a study that was undertaken to investigate the role of space syntax in identifying geographical patterns of crime in Ypsilanti, Michigan. All the spaces in the city were analyzed using the *Spatialist*, a computer program developed by Georgia Tech. The Spatialist computes the accessibility level of all the spaces in a spatial system. Sociodemographic variables such as median income, racial composition, youth concentration and level of education were available from the U.S. Census. The crime report was obtained from the Ypsilanti Police Department and Eastern Michigan University. It includes data on four types of crime at an address level with the exact date and time. Both sociodemographic variables and crime data were merged with the Spatialist map using ArcGIS. The data was analyzed using SAS, an advanced statistical package. Findings showed strong relationships between attributes of space and crime locations.

1. Introduction

A considerable body of literature now exists on the impact of spatial configuration on human behavior. Wayfinding performance, for example, decreases in buildings characterized with high number of hallway intersections (Best, 1970) and with more complex relations between choice points (O'Neill, 1991). On an urban scale, some studies have given some weight to assertions that curvilinear street networks, T-intersections, and spatial relationships influence walking and bicycling (Frank and Engelke, 2001; Southworth and Owens, 1993.). Much of these researches, however, were not able to illuminate the extent to which spatial configuration influences human behavior. Additionally, it was difficult to derive an objective methodology that can reliably demonstrate a statistical relationship between environment and behavior.

Only recently, some researchers have begun to give more attention to the properties of spatial configuration and their effect on human behavior using *Space Syntax* techniques. Space syntax, a group of theories that examine the social use of space, was developed in the late 60s by Hillier and Hanson (1984). Briefly, this theory is based on breaking all the spaces in a plan into long lines of sight. For example, all the hallways in a building plan will be flood-filled by long lines of sight. Similarly, all the streets in a city will be broken into interconnected long lines of sight. According to space syntax, these lines are known as axial lines.

Gradually and over the years, several space syntax measures were developed based on the relation between each axial line and all the lines in the system (e.g. in a building plan or in a city). This research will focus on two of these measures: Integration and Connectivity. To elaborate on these two measures, Connectivity gives the number of lines that are directly connected to a specific line. Integration, on the other hand, is an indicator of how easily a line is reached from all other lines in the spatial area. Mathematically speaking, it is the average number of spaces that one needs to pass through to reach a specific line from all other axial lines in the system. In other words, integration values suggest the extent to which a selected space in the system is more *integrated* (can be easily reached from other spaces), or more *segregated* (one has to travel through many spaces in order to reach that selected space). Two additional measures were also derived from integration measure: 1) global integration measures the relationship between a specific line and all the other lines in a system, and 2) local integration measures the accessibility of the line from lines that are few steps away as specified by the researcher.

Several computer programs have been developed to compute these measures. Most of these programs produce two types of output: alphanumeric data with spatial parameters assigned to each axial line and graphic data with a map that has colored lines where red indicates the most integrated or connected line to indigo for the most segregated or least connected line. Simply put, looking at the resulting map one will enable the researcher to make inferences about streets, areas or neighborhoods in a city. Examples of these programs include the *Spatialist*, developed by Peponis and Wineman at Georgia Tech; *Depthmap*, developed by Turner at University College London; and *Omnivista*, developed by Dalton and Dalton at University College London.

As a result of advancement in computer technologies, several studies have looked at the implications of space syntax measures on human behavior. For example, we investigated the effects of spatial behaviors and layout attributes on individual's perception of psychosocial constructs in four U.S. federal office settings (Rashid et al., 2005). Using space syntax techniques, questionnaire surveys and behavioral mappings, we found that measures like integration and connectivity had significant effects on individual's perception of psychosocial constructs in office settings.

On an urban scale, several studies found strong correlations between space syntax measures and walking behavior. Reid (1999), for example, found that Deutch neighborhoods with higher mean connectivities and integration had higher movement rates with a correlation coefficient of 0.829. Similarly, Nubani (2003) confirmed similar results in three cities in Southeastern Michigan. Correlations between integration and walking were strong.

The objective of this paper is to use similar computer technologies in understanding geographical distribution of crime as a behavioral outcome. It examines the relationship between measures of space syntax and certain types of crime in order to address the question of 'opportunity.' Specifically the research applies the techniques of space syntax to explore the characteristics of streets that might contribute to the reduction of opportunities for criminal acts. In addition to examining street characteristics, the paper also addresses theories related to crime as set forth by criminologists.

2.Background Literature

Generally, most of the 'design for crime prevention' work has been grounded in three theories related to crime: the rational offender theory (also known as rational choice theory), the behavioral geography theory and the routine activities theory (Taylor, 2002). The rational offender theory stemmed from the classical school of criminology founded by Cesare Beccaria. He believed that people have the will to act freely and that crime is controllable by means of punishment. However, this perspective declined by mid-twentieth century as the positivist criminology argued that crimes are the results of genetic, social and psychological factors rather than personal choice and decision-making (Siegel, 2002). In 1970s, the rational choice theory supported the thoughts called by the classical school of criminology and assumed that the benefits of crime influence patterns of offenses. In other words, criminals are rational actors who weigh the potential costs of crime and the consequences of their actions (Siegel, 2002). Their decision process considers both their personal needs such as money and excitement and situational factors such as the likelihood of being caught and surveillance.

The behavioral geography theory, on the other hand, considers the fact that places that are closer to where offenders work or reside are at higher risk of being burglarized than places that are not within the offenders' regular route. One may infer that this theory suggests that crime rate is linked to easy accessibility (Taylor, 2002).

The routine activities theory looks at the interaction of three everyday variables: 1) the availability of attractive targets such as unlocked homes and attractive valuables; 2) the absence of guardians such as neighbors, homeowners or police; and 3) the presence of motivated offenders such as teenagers and unemployed people (Reid, 2002; Siegel, 2002). If targets are exposed to all three variables, they are at higher risk of being victimized.

It is worth mentioning that the rational offender theory provided the basis for the situational crime prevention program (Bennett, 1989). It is targeted at reducing the opportunities to commit burglaries based on the belief that offenders freely and actively commit crimes as a response to immediate circumstances and depending on costs and rewards.

Based on the review provided by Bennett (1989), situational measures operate at three levels. First, at an individual level, situational measures call for target hardening and installing alarms and surveillance cameras. The time it takes to overcome such obstacles is perceived as a risk by offenders. Secondly, at a community level, neighborhood watch programs have been implemented to involve residents in reporting suspicious activities. Research to date has not shown whether this had a perceived risk among offenders or not. Thirdly, at a physical environment level, situational measures are based on Jacobs and Newman's concepts of controlling pedestrian and traffic flows, territoriality and natural surveillance. Jacobs believed that through the occupation and use of space, residents come to consider a particular space as theirs and exert control over it (Jacobs, 1961).

To a certain degree, it can be deduced from the afore-mentioned theories and prevention programs that offenders share four general concerns: how quickly it takes to get to the target, how quickly it takes to run away, how much value the target possibly has, and, how likely the offender is to be caught while committing the crime or leaving the scene (Taylor, 2002; Rengert, 1980).

Previous literature has also shown that the three basic elements necessary for someone to commit a crime are ability, opportunity and motive (Stollard, 1991). Thus, if it could be shown using space syntax techniques which streets offer the opportunity to commit a crime, then it becomes easier for police to know which streets to increase patrolling

3. Space Syntax and Crime

Building on the idea that neighborhood layouts provide opportunities and access to commit a crime, Shu and Huang (2003) studied the influence of spatial configuration on the distribution of burglary in 121 residential neighborhoods. In the first part of their analysis, they controlled for social factors by looking at three districts in Northern Taiwan inhabited by different social classes. Police crime data was gathered for an 8 month period; there were total number of 241 crime incidents. Through correlational analyses, a strong connection was found between global integration and burglary rates in low-income neighborhoods. Further findings indicated that there were correlations between local integration and global integration and burglary rates in middle-income neighborhoods. The authors proposed that globally and locally integrated middle-income neighborhoods are safer than segregated ones. In addition, the authors found no correlation between global or local integration and burglary rates in high-income neighborhoods. This is possibly explained by the fact that "target hardening" features are more common within high income neighborhoods.

Similar to previous work by Shu and Huang, Jones & Fanek (1997) looked at the effect of spatial configuration on crime in Austin, Texas. They selected four pairs of tracts in which each pair had similar income, poverty rates, population and racial composition. Using Axman software, developed at University College London, their findings showed that pairs with higher integration values were associated with lower crime rates. The authors explained that more connected streets will attract higher pedestrian movement, and thus more eyes on the street.

As a result of promising findings using Space Syntax for identifying the spatial distribution of crime, Gosnells, a city in Western Australia consulted the Space Syntax laboratory at University College London and Murdoch University to identify the spatial distribution of crime (Australia's National Government Newspaper, 2003). The Space Syntax Lab compared the movement of pedestrians and vehicles to crime statistics and space syntax measures. The results were consistent with previous findings and showed a strong link between spatial configuration and burglary and theft.

Farooq (1999) looked at crime in Metro Atlanta in his doctoral dissertation. He investigated spatial and sociodemographic measures in different types housing settings using similar computer programs. Contrary to previous research, his findings showed that in private rental housing and public housing, crimes against property and persons were higher in integrated areas. The author suggests that this is explained by the fact that these buildings were located on vehicular routes that offered an easy escape to offenders.

4. Types of Crime and Description of Case Study

Generally, different types of crime have been found to be associated with different types of land use and social characteristics (Dunn, 1980). Personal attack crimes, for example, occur more often in lower class neighborhoods, while property crimes occur more often in neighborhoods that are accessible or close to other land uses, or in neighborhoods with higher percentages of underemployed or single residents. Arsons, robberies and burglaries share monetary gain objectives and are more likely to occur in middle- and high-class neighborhoods (Rengert, 1980). For these reasons, we excluded non-residential neighborhoods from this study. We also excluded organized crimes or crimes that involve acquaintances or for the purpose of revenge such as assaults and murder. Specifically, we focused on four stranger-to-stranger types of crime. These are larceny, motor vehicle theft, breaking and entering, and robbery.

According to the FBI Uniform Report (1998), larceny, motor vehicle theft and breaking and entering are considered property crimes where the object of the offense is the taking of property without any threat involved. More precisely, larceny is taking away property from the possession of another. Purse-snatching and shoplifting are good examples of larceny. Motor vehicle theft is the stealing of a truck, automobile, motorcycles, and any other vehicle. Breaking and entering is defined as the unlawful entry into a property without putting people under threat (Hill, 1995). Robbery on the other hand is a violent crime that involves putting victims under threat. It includes taking anything of value from persons (FBI Uniform Report, 1998).

In this study, we looked at Ypsilanti, a city located within the Metropolitan Detroit area of Michigan. With a population of approximately 22,362, 1273 crime incidents were reported in year 2003. Crime types in this figure include larceny, breaking and entering, robbery and motor vehicle theft. According to FBI Crime Reports, the crime level in Ypsilanti is worse than the national average particularly for burglaries, robberies, and thefts (FBI Crime Reports, 2002). The crime report was obtained from the Ypsilanti Police Department and Eastern Michigan University. It includes data on the four types of crime at an address level with the exact date and time.

5. The Axial Map Analysis

A street map of Ypsilanti was imported into the Spatialist program. All the streets were then broken into long lines of sight that if two people stand at each end of the line, they should be able to see each other. These lines are also known as *axial lines*. Ypsilanti comprised of an average of 2000 axial lines. Analyzing the relationship among these lines is impossible to calculate manually. The Spatialist assigned an ID to each axial line and appended three space syntax measures to each line. These measures were connectivity, local integration and global integration. The Spatialist also produced a colored graphic representation of these values on the map of Ypsilanti (see Figure 1). The colors range from red indicating highly accessible routes (high values) to indigo indicating the least accessible routes (low values). Accessibility is explained in terms of the average number of turns one needs to make to get to any part of a street from any point in the city. As explained in the next section, a glance at this map tells the researcher which of the streets offered escape route to criminals.

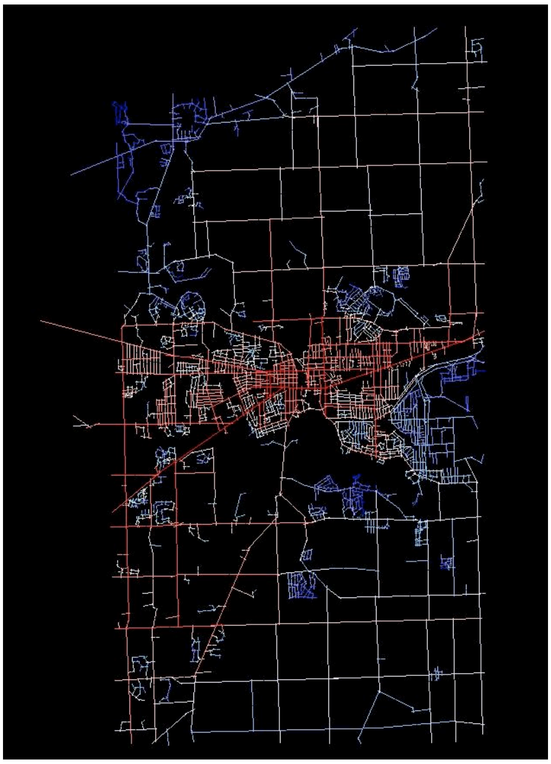

Figure 1. The Spatialist output of the Ypsilanti Axial Map.

Since the unit of analysis is the axial line (or the street space), it was necessary to append sociodemographic data along with crime data to each line. Therefore, a street map of Ypsilanti was prepared showing 30 block groups using ArcGIS. Data on population density, youth concentration, level of education, percentage of owners, age distribution and racial composition were available from U.S. Census and were appended to each block group in Ypsilanti. The report on crime at an address level was semi-manually entered into the same database. Moreover, the original axial map that was prepared using Spatialist was later converted into an appropriate format and was given accurate geographic coordinates for Ypsilanti, allowing us to match the Spatialist axial map with the ArcGIS Ypsilanti road map (Figure 2), and to merge our two databases.

Figure 2: Crime locations plotted on Ypsilanti Axial Map. Line weight indicates level of connectivity where thick lines represent highly connected spaces and thin lines represents spaces with low number of connections

6. Results and Analysis

The GENMODE Procedure in SAS (Version 9) was used in these analyses. Because of the clustered nature of the data, axial lines were clustered within randomly selected block groups, random intercepts and random spatial measures effects associated with the randomly sampled block groups were also included, to test the hypothesis that the crime counts and effects of spatial measures on crime counts tend to randomly vary from one block group to another.

Since space syntax measures were highly correlated with each other, it was necessary to look at the effect of each measure on crime in a separate model. Each model also contained sociodemographic variables. When connectivity was entered in the model, it was positively correlated with larceny ($p<0.0001$), breaking and entering ($p < 0.0001$), motor vehicle theft ($p < 0.0001$), but not with robbery. However, additional findings showed that the effect of connectivity on different types of crime was moderated by levels of home ownership at the block group level. In the model, the product of both connectivity and home ownership on larceny was negative and was significant at p<.0001. These results suggest that the higher the percentage of people who own their residences at a block group level, the more negative the relationship between connectivity and larceny (see Table 1). Similarly, models that looked at other crime types revealed that there were interactions between the two variables connectivity and level of home ownership.

TABLE 1: Results of the model showing the effect of sociodemographic measures and connectivity on larceny

Analysis Of GEE Parameter Estimates
Empirical Standard Error Estimates

Parameter	Estimate	Standard Error	95% Confidence Limits		Z	Pr > |Z|
Intercept	1.4933	0.5934	0.3304	2.6563	2.52	0.0118
Connectivity	1.0976	0.2234	0.6598	1.5354	4.91	<.0001
PEROWNER	-1.4959	0.6367	-2.7438	-0.2480	-2.35	0.0188
YOUTH	-2.4470	3.7417	-9.7805	4.8865	-0.65	0.5131
DENSITY	0.0000	0.0001	-0.0001	0.0001	0.51	0.6099
EDUC2PER	-1.5182	1.6517	-4.7554	1.7190	-0.92	0.3580
conn*PEROWNER	-1.0815	0.1675	-1.4098	-0.7533	-6.46	<.0001
conn*YOUTH	0.0815	0.9203	-1.7223	1.8852	0.09	0.9295

The sample plots in Figure 2 illustrate the nature of these interactions. Home ownership is displayed on the X-Axis and crime count is plotted along the Y-Axis. Three regression slopes were plotted to predict larceny at different levels of home ownership and connectivity. The unstandarized regression coefficients were examined and were used in the model. For example, the estimated model that was used to assess the effect of the two independent variables (home ownership "X" and connectivity "Z") on larceny "Y" is as follows:

$$\text{Larceny } (Y) = -3.519 + 1.933\,(Z) + 4.062\,(X) - 2.040\,(Z*X)$$

The methodology described here has been recommended by Aiken and West (1991).

Perhaps these results can be related to the effects of 'eyes on the street.' If there are higher levels of home ownership (indicating a more stable population), under conditions of high and moderate levels of connectivity (supporting neighboring and ‘eyes on the street’), larceny is significantly lower, while under conditions of low connectivity, larceny is significantly higher. Similarly, when other crime types were examined, high levels of home ownership in the neighborhood with high levels of connectivity (supporting neighboring and ‘eyes on the street’), are associated with lower levels of breaking and entering, motor vehicle theft, and robbery.

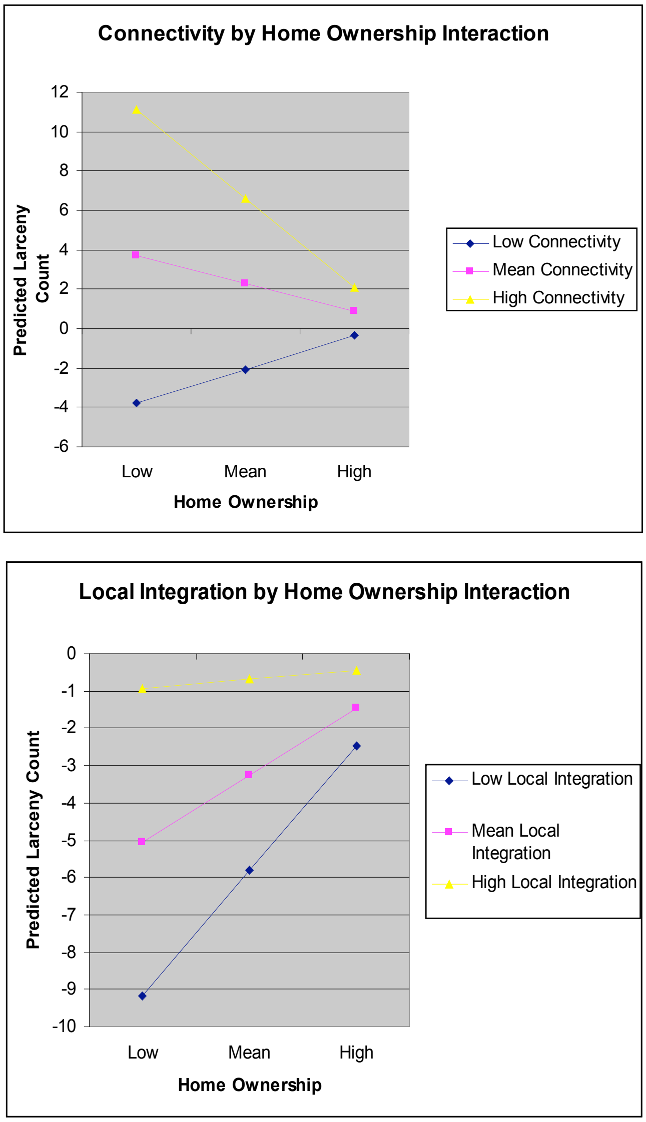

Figure 2: *Plots of interaction effects of connectivity and integration by home ownership on larcenies*

The analysis also looked at the association of global integration and local integration with crime types and demographic measures. Global integration was not related to any of the crime types. Local integration on the other hand was positively linked with higher breaking and entering ($p<0.0001$), higher motor vehicle theft ($p=0.0139$), but to not to robbery. There were also significant interactions between local integration and home ownership with all types of crimes. For example, motor vehicle theft, breaking and entering, and robbery are positively associated with higher levels of home ownership along low to moderately accessible routes. There are several factors that may affect these results. It is perhaps less likely to be caught along more segregated routes. Home ownership may indicate a higher level of valuables and thus a more attractive target to criminals. Highly integrated routes had no effects on these crimes. Larceny, on the other hand, tends to increase with higher levels of home ownership along less integrated routes. Fewer larcenies appeared in integrated areas with higher levels of home ownership. A careful examination is needed to compare both sets of interaction plots.

7. Conclusions

Results of the analysis showed that two space syntax measures, local integration and connectivity, were highly associated with different crime types through interactions with levels of home ownership in different block groups. In other words, the number of intersections a route has and the average number of turns one needs to reach it from any route in the city objectively express the nature of its accessibility. Other factors such as median income, youth concentration, density, racial composition and global integration did not feature in the model. It is interesting to note that although criminals have different motives for committing a crime whether it is to burglarize a property or snatch a purse on the street (Davidson, 1993), the effect of spatial measures was consistent in all types of crimes except for larceny. Unlike other crimes types, larceny increases slightly with the increase of levels of home ownership along highly accessible routes. According to Brantingham (1984), if a criminal is searching for a target with all things being equal, the closest target will be chosen. In the case of larcenies, the effect of home ownership is weaker because larcenies are crimes that occur to people in the streets rather in their homes. However, if that route had more intersections, larcenies tend to dramatically drop with higher levels of home ownership indicating higher potential movement and eyes on the street.

To conclude, recent developments in space syntax computer software and methodologies appear to add a promising new tool to examine the implications of spatial layout characteristics on crime outcomes as well as other behavioral outcomes. In this study, for example, we were able to identify the type of streets that offered escape routes to criminals simply by comparing the topological relationships among all the streets within a city to actual crime counts. People usually select routes intuitively without the aid of a map or without having an understanding of how that route is connected to all the routes in the city. However, space syntax software enabled researchers to understand how people behave in urban environments and offered predictions about the streets that are more likely to be occupied by people and the streets that are more likely to be vulnerable to crime. It is also interesting to know that the resulting colored map may capture at a glance the accessibility level of streets. This in turn may prove to be valuable for police as it helps them understand where they should increase their patrolling.

In sum, space syntax relies on advancement of computer technology to map out spatial interrelationships and thereby allowing the researcher to understand the structure of the city and how it is related to behavioral outcome. It represents the physical complexity of the city as systems of spaces created between and within buildings. This objective method is proven powerful as it allows cities of different forms and structures to be compared in terms of spatial interrelationships. Additionally, new urban developments could also be tested in terms of how space will be used.

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