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Permeability, space syntax, and the patterning of residential burglaries in urban China

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ABSTRACT

There are a wide variety of explanations for reasons why crime clusters at particular locations. They reflect the range of factors that influence where crime incidents occur. In this article, we focus on the influence of the *space syntax* and in particular the *permeability* of the street network on the location of residential burglaries in Wuhan, China. We first review existing research to summarize the different approaches being used to analyze the impacts of the configuration of street networks on crime and the findings about that have so far emerged. Then we analyze residential burglaries at the street segment level with considerable variation in street network configuration and socioeconomic factors. In the conclusion of the paper we discuss the implications of the statistical output.

Introduction

Environmental criminology strongly emphasizes the importance of a place in influencing the character of crime (Brantingham & Brantingham, 1993; Johnson et al., 2007; Rey, Mack, & Koschinsky, 2012; Ye & Wu, 2011). The physical configuration of a street network may affect crime risk. In this context, permeability is a construct devised to reflect and summarize how the street network influences pedestrian and vehicular movements, which in turn, affects the occurrence and character of crime (Johnson & Bowers, 2010). Street segments are the individual links in a street network that connect one intersection to another. They represent a meaningful unit of analysis for criminological inquiries as they form the basic building blocks of transportation and accessibility in a given area. Their location also determines where homes could be built and where businesses and other facilities could be best located.

The influence of permeability of the street networks on crime risk remains hotly debated. "New Urbanists" assert that a permeable environment can decrease crime risk, because it encourages the use of streets and increases the number of eyes on the street (Rudlin & Falk, 1999). In contrast, defensible space theory (Newman, 1972) states that in order to establish a sense of territoriality and to control and deter criminals from entering spaces that are well ordered and unfamiliar to them. Barriers that would restrict mobility should be erected or designed into new developments because these barriers to entry to a place would reduce crime. Conversely, mixed land use and the use of spaces by non-residents would decrease territoriality, limiting protection and natural surveillance of strangers that would be provided by neighbors. Consequently, areas with greater accessibility would have higher rates of crime. Moreover, increased permeability would lead to ambiguity about who is responsible for the natural policing of different locales. Essentially, Newman (1972) suggests that lower crime risks should be expected in those areas for which non-resident pedestrian and vehicular traffic usage is low, where the ownership of homes and businesses is clear and neighbors consequently look out for each other.

A number of studies have examined the influence of street permeability on crime risk using data measured at different spatial scales, or using different methods of statistical analysis. Armitage (2007) examines the risk of burglary and total crime using data of 1058 households in 50 housing estates in West Yorkshire in the UK, finding that an increase in street network permeability would increase the risk of residential burglary. Johnson and Bowers (2010) analyze one police district in Merseyside in the UK, concluding

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that cul-de-sacs and dead end streets, especial those sinuous ones, are at a lower risk of residential burglary compared with through roads.

Researchers have also suggested that the studies of permeability need to consider neighborhood characteristics and utilize control variables for such socioeconomic factors as poverty, age and race. Bevis, Nutter, and Center (1977) examine the relationship between burglary rates in Minneapolis and street network complexity measured at the census-tract level. Their results indicate that, after controlling for variations in socio-economic factors, there is a positive correlation between permeability measured at the census-tract level and burglary risk. White (1990) concludes that permeability is a significant influence on neighborhood burglary rates when neighborhood economic factors, instability, and structural density are controlled for. Elevated burglary risk in a neighborhood is associated with lower economic levels, higher density, and lower stability.

An alternative type of analysis is to use a methodology known as space syntax. Space syntax is a set of techniques for representing the street networks to analyze the underlying patterns and structures which influence movement of people and land use. Street permeability is not only related to street characteristics, but also to the spatial configuration of the street network. Hillier (2004) applies this theory of space syntax to the analysis of crime risk. A street network is analyzed as a network of choices, and then represented in maps and graphs that describe the relative connectivity and integration of those streets.

As described in Hillier (2004), three popular space syntax analysis methods for street networks are the Integration, the Choice and the Depth Distance approaches. Hillier uses data from London and Australia, demonstrating that the burglary risk at the street segment level is associated with how integrated into the street network a particular street segment is. The research suggests the risk of burglary is over two times higher on cul-de-sacs than it is on more permeable through-roads (Hillier & Shu, 2000; Shu & Huang, 2003). This result seems to counter the notion of widespread efforts to close off streets with barriers to reduce crime.

In the space syntax approach, integration measures how many turns have to be made from a street segment to reach all other street segments in the network, using the shortest path algorithm. The first intersecting segment requires only one turn, the second two turns and so on. The street segments that require the fewest turns to reach all other streets are called the most integrated. Integration can also be analyzed in local scale instead of at the scale of the whole network. Theoretically, the integration measure shows the cognitive complexity of reaching a street, and it is often argued that it is a good way to predict the pedestrian use of a street. If it is easier to reach a street by making fewer turns, the street will be more accessible. Integration gives a value indicating the degree to which an axial line is integrated or segregated from a street system as a whole (global integration) or from a partial system consisting of axial lines within a limited depth away (local integration).

In the context of Choice, Connectivity is the number of other street segments that intersect with the focal street segment. Control is a parameter which expresses the degree of choice each axial line represents for its directly linked neighbor lines. When the studied axial line has n neighbors, and for each neighbor, the Connectivity of it is $C(l_i)$, then the control of the axial line is defined as $Control = \sum_{i=1}^{n} 1/C(l_i)$. Depth Distance explains the linear distance from the center point of each street segment to the center points of all the other segments. If every segment is successively chosen as a starting point, a graph of accumulative final values is achieved. The streets with lowest Depth Distance values are said to be the nearest to all other streets. The search radius can be limited to any distance. Accordingly, mean depth is the mean depth value of the studied axial line to all other axial lines. Local mean depth, on the other hand, is the mean distance of axial lines within a number of steps from the studied axial line.

In this paper we examine a large metropolitan area across geographic scales. A large area is used to ensure adequate variation in the geometry of the street network across the different units of analysis, ranging from grid-like systems to sinuous hierarchies of cul-de-sacs.

Data

The research setting of this study is the City of Wuhan, the largest city in Central China and a top transportation hub of China (Cheng & Masser, 2003). Wuhan has over 10 million residents and comprises of seven urban districts and six suburban and rural districts. The current study is carried out in Jianghan district, the most densely populated urban district in Wuhan. This district has a population of 1.01 million within 33.43 km^2 land area in January 2014. This district is divided into 13 sub-districts, which are further divided into 114 residential neighborhoods and 5 urban villages. Fig. 1 shows the location of Jianghan district.

The study utilizes three datasets: residential burglaries, demographic data, and street network. Residential burglary data is generated from the 110-reporting automated system, which is operated by the Public Safety Bureau. However, it is manually geocoded to the residence level with great efforts. In China, 110-call is the only method to report crime and emergencies to the police, and thus the system is the primary resource for generating official crime information. Residential burglary includes all theft involving illegal entry of any residential premise, without any violence involved. A total of 1364 residential burglaries were recorded in Jianghan from January 1, 2013 to August 31, 2013. Each record in the dataset includes the *XY* coordinates of crime location (using World Geodetic System 1984) and the date. China has a household registration system and population information management system which is the source demographic data used in the current study.

The unit of analysis is street segments. The dependent variable in the study is the count of residential burglaries in each street segment. Factors considered to influence the distribution of burglaries along each street segment in the network include three broad categories that total to 13 parameters including factors from space syntax (Connectivity, Control, Integration, Depth), characteristics of the segments (Road type, Cul-de-sac, Length, Sinuosity), and socio-demographic variables (Household size, Gender, Age, Education, Unemployment). Variables that quantitatively describe street network permeability include Connectivity, Control, Local integration, and Local depth.

Road type is the hierarchical street-layout as implemented in city planning in China, including major arterial streets, minor arterial streets, collector streets, and local streets. Major arterial streets (width 30–45 m) serve as the main transportation paths in the city, connecting the main transportation junctions and public places in the city. Minor arterial streets (width 25–40 m) are the supplementary transporting paths between arterial roads. Collector streets (width 12–15 m) connect larger neighborhoods and also neighborhoods to arterial roads. Local streets form the urban backcloth on which residential estates are built, and they often can only be used for local trips. Cul-de-sacs are defined as street segments with only one inlet or one outlet and include “dead end” streets. It is not difficult for us to detect the cul-de-sacs directly from our GIS–based analysis of the street network. However, some street segments are connected with two other segments and one of them is dead end. As street segments in Fig. 2 shows, the red (in the web version) segments are those with only one inlet or one outlet,

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