A SPATIAL ANALYSIS OF NEIGHBOURHOOD CRIME IN OMAHA, NEBRASKA USING ALTERNATIVE MEASURES OF CRIME RATES

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ABSTRACT

This paper analyzed the spatial patterns of four types of crime (assault, robbery, autotheft, and burglary) and their relationship with neighbourhood characteristics in the City of Omaha, Nebraska by using geographic information systems procedures and ordinary least square regression methods. Location quotients of crime and crime density were employed as two alternative measures of crime rates. This article has three important findings: First, the rationale of the employment of official crime rates for neighbourhood crime study is questionable; Second, while location quotients can be used to highlight the prevalent types of crime across urban neighbourhoods, they have limited use for the statistical analysis; and third, crime density focuses on the spatial intensity of crime and is more appropriate as the indicator of neighbourhood level crime than population-standardized crime rates and location quotients. This article not only presents important insights into the enhanced interpretation of the geography of neighbourhood crime, but also can be considered as testing the social disorganization theory and routine activity theory by using different measures instead of crime rates. Policy implications pertaining to neighbourhood crime mapping and law enforcement intervention are discussed at the end.

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1. INTRODUCTION

Research on the geographic distribution and the determinants of urban crime has long been an important area of interest for criminologists, sociologists, and geographers. Criminologists and sociologists believe that crime results from social stress and conflicts and the rates of crime in urban neighbourhood are highly affected by the demographic and socio-economic contexts (Reith, 1996). From the perspective of spatial analysis, geographers consider that crime has a geographic dimension and it is disproportionately distributed across different geographic scales (e.g., national, regional, and local). Within cities and metropolitan areas, crime is exceptionally concentrated in a relatively few, small areas – crime hot spots (Anselin et al. 2000; Sherman 1992; Weisburd and Green 1994). Started from Shaw and McKay's work on explaining the spatial disparities across neighbourhoods in the city of Chicago in early 1940s, neighbourhood crime has been the most vibrant arena for research on the regional variability of crime (Cahill and Mulligan, 2003; Santiago, 2003; Shaw and McKay, 1942).

A fundamental problem confronting the analysis of neighbourhood crime using aggregated crime data is the selection of appropriate measures of crime because such indices may directly affect the characteristics of crime on maps and the results of statistical analysis. Widely used by previous literature and law enforcements as an official measurement of the frequency of crime, crime rate[1] is simply defined as the per capita police recorded crime incidents at different geographic scales. It is an enhanced measure than raw counts of crime when comparing the variations of crime cross geographic areas (Albanese, 2002). However, using the population standardized crime rates to measure the seriousness of crime in small geographical areas (e.g., census tracts in the U.S. and enumeration districts in the U.K.) may be problematic and can cause serious distortions. This is partly because that at neighbourhood level, for many cases, neither criminals nor victims is from the same neighbourhood where the scene of crime is. Therefore, it is theoretically unsound to use census population statistics to normalize the number of incidents in neighbourhoods (Roncek, 2004).

Despite the limitations of crime rates, only limited previous studies attempted to use other alternative measures such as location quotients of crime (LQCs)[2] (Brantingham and Brantingham, 1995 and 1997; Cahill, 2005; Carcach and Muscat, 2002) and crime density[3] (Nicolau, 1994; Harries, 2006) in recent years. In particular, gaps still exist with respect to the applicability of these two substitute measures for mapping the geography of crime and for the investigation of the contextual determinants of crime through statistical analysis. This research expands the previous studies by answering the following three research questions: First, is crime rate a reasonable measure of neighbourhood crime? Second, what are the advantages and disadvantages of LQCs for crime mapping and statistical analysis? Third, could regression models using density as measure of neighbourhood crime produce as robust explanatory power as crime rates?

[1]. There are two types of crime rates: one is the police recorded crime rates and the other is survey-based crime rates (e.g., The British Crime Survey). The current analysis and criticism on employing crime rates to study geographical distributions of crime refer to official/recorded crime rates.
[2]. Location quotient of crime (LQC) is a measure of the relative frequency of a type of crime in a small area in comparison to the ratio for the same type of crime in a big reference area of interest (e.g., a city).
[3]. Density of crime or crime density is measured as the total amount of crime incidents within a particular unit of space (e.g., square mile is used in this study).

This study first utilizes location quotients of crime (LQC) to investigate the prevalent types of crime across neighbourhoods in Omaha, Nebraska. Crime density is then used as an alternative measure of crime rates for the exploration of the relationships between neighbourhood socio-economic characteristics and the occurrence rates of four types of crime (i.e., assault, robbery, autotheft, and burglary). For comparison purposes, regression models using crime rates and location quotients as indicators of crime are also included. The findings of this research not only add to our understanding of the spatial profiles of urban crime, but also provide supplemental evidence for the social disorganization theory and routine activity theory.

2. LITERATURE REVIEW

2.1. Understanding Neighbourhood Crime

Substantial neighbourhood crime research has documented that urban crime occurs most frequently in stressful and disadvantaged areas with disproportional concentration of poverty, unemployment, and minority populations (Ackerman, 1998; Anselin, 2000; Kershaw and Tseloni, 2005; Nagle, 1995; Osborn et al., 1992). Two predominant criminal justice theories - social disorganization theory (Shaw and McKay 1942) and the routine activity theory (Cohen and Felson 1979; Felson and Cohen, 1980; Hindelang et al., 1978) have been created and frequently cited to interpret the linkage between crime and the urban neighbourhood contexts. The social disorganization theory argues that socio-economic stress (e.g., poverty, racial/ethnic issues, etc) undermines social control level and strikes the foundations of social cohesion, which results in occurrence of crime (Ackerman, 1998; Agnew, 1999; Bursik, 1988). The routine activity approach claims that criminal activities are related to the characteristics of the social environment and the behavior patterns of people who live in the neighbourhood or community. Three indispensable elements are related to the rate of occurrence of crimes: abundant opportunities, profitable targets, and least risk or lack of surveillance (Anselin et al., 2000; Roncek and Maier, 1991; Sherman et al., 1989).

A number of empirical research has tested the social disorganization theory (Carcach and Muscat, 2002; Kershaw and Tseloni, 2005; Lauritsen, 2001; Osborn et al., 1992; Rice and Smith, 2002; Sampson and Groves, 1989; Tackovosky, 1983) and routine activity theory (Felson and Cohen, 1980; Maxfield, 1987; Osborn and Tseloni, 1998; Rice and Smith, 2002; Roncek and Maier, 1991; Sampson and Wooldredge, 1987; Tricket et al., 1995). Socio-economic characteristics such as socioeconomic status (SES), racial/ethnic heterogeneity, a young population, family disruption, and unfavorable environment settings are frequently used to evaluate the effects of crime correlates (Ackerman, 1998; Beasley and George, 1974; Harries, 1994; Rice and Smith, 2002; Roncek and Maier, 1991; Tachovsky, 1983; Weatherburn and Lind, 2001).

Previous research on urban crime in the U.S. has used aggregate data at different neighbourhood levels such as census tracts (Krivo and Peterson, 1996; Harries, 1994; Kohfeld and Spraque, 1988; McClain, 1989; Martin, 2002), block groups (Cahill and Mulligan, 2003; Santiago et al., 2003), blocks (Roncek and Maier, 1991) or face blocks (Smith et al., 2000; Rice and Smith, 2002). Census tracts are recommended as the most appropriate research unit mainly because socioeconomic data are compiled for explanation of various types of crime in U.S. cities (Harries, 1994; Kohfeld and Spraque, 1988; Krivo and Peterson, 1996; McClain, 1989). An additional advantage of using census tract is that it is large enough to capture an adequate number of criminal offenses during a given period (e.g. three or five years) (Krivo and Peterson, 1996).

2.2. Limitations of Crime Rates

Previous literature and law enforcements have commonly used official crime rates to measure of the frequency of crime at different geographic scales. Crime rate is defined as the number of incidents committed in a given area standardized by the population at risk, often expressed per thousand populations per year (Albanese, 2002). Police recorded crime incidents and census demographic data are often used to calculate crime rates of different geographic entities. Crime rate is a better measure than raw counts of crime when comparing the variations of crime cross space. Especially when analyzing aggregated crime data at large or medium levels (e.g., inter-state and intrastate in the U.S.), population standardized crime rates provide a reasonable indication of the risk of crime, because research has found that most criminals commit crime in the cities or communities, where they live or are most familiar with (Ellis and Walsh, 2000).

However, when employed for neighbourhood level analysis, the conceptual framework of using crime rates has apparent theoretical lapse. A handful of research has addressed the problems of employing official reported crime rates for neighbourhood (i.e., local level or small area) analysis (Goldsmith et al., 2000; Osgood, 2000; Roncek, 2004). The major problem of crime rates for neighbourhood level analysis is the "meaninglessness" of standardizing the incidents of crime by the population in an urban neighbourhood (e.g., tracts or blocks) (Roncek, 2004, p. 20). For many incidents, neither criminals nor victims (especially for violent crime) are necessarily from the same neighbourhood where the scene of crime is. For example, a lot of incidents are committed in the commercial zones and tourist attractions which are mainly due to the large number of transient populations (e.g., tourists and shoppers), abundant profitable targets (e.g., shops), and facilities that may trigger crime (e.g., bars) for in these areas. Even this, the crime rates of these business or recreational districts may be further overestimated because of the relatively small number of residents based on the existing census data. In particular, because of the difficulties of tracking the total populations (including both local residents and transient populations) at risk in these areas, simply using population data from the census source to calculate crime rates is theoretically unreasonable.

On the contrary, crime rates in residential neighbourhoods with a lot of apartment complexes especially high-rise ones may be unintentionally underestimated because of the large population in these areas. Actually the census data can hardly trace the population changes in these multifamily houses because of their high residential mobility, which is largely related to the high risk of crime in these areas (Roncek and Meier, 1991). In addition, apartment complexes tend to have higher occurrence rates of crime than single family residential areas largely because people who live in apartments are more likely to be low income families and a majority of them are minorities. However, the calculation of crime rates just takes the raw number of populations into consideration without differentiating people's socioeconomic backgrounds in different neighbourhoods. In fact, urban neighbourhoods, especially inner city neighbourhoods in the U.S., are highly separated by class, income and race/ethnicity (Eitzen and Zinn, 1994, p. 119; Hochschild and Scovronick, 2003). The relationships between poverty and racial heterogeneity and crime have been considerable documented. Therefore, standardizing the crime incidents in each neighbourhood by population overlooks the influences of the geographic and demographic contexts (i.e., SES) and is theoretically un-reasonable measuring for neighbourhood level crime (Carcach and Muscat, 2002).

Limited research has extended the application of location quotients to crime analysis (Brantingham and Brantingham, 1995 and 1997; Cahill, 2005; Carcach and Muscat, 2002), but the sampling distribution of location quotients as a spatial index is not clearly known (Shaw and Wheeler, 1994). Brantingham and Brantingham (1995) first adopted LQCs to study the hot spots of crime in Canadian cities and suggested that LQCs are useful for revealing the spatial inequalities of different types of crime across urban neighbourhoods. Carcach and Muscat (2002) examined the statistical properties of LQCs in the spatial analysis of regional crime structure in Australia. Cahill (2005) used LQCs as measure of neighbourhood crime in Nashivill, Tennessee for the empirical analysis of crime.

Although the application of density in academic research is common, unfortunately, employing density as an indicator in empirical analysis of crime is very limited. To the best of our knowledge, crime density was only used by Nicolau (1994) and Harries (2006) for investigating the associates of crime through statistical models. Nicolau (1994) investigated the influences of socioeconomic characteristics over crime in Lisbon, Portugal using multiple linear regression methods. Harries (2006) investigated the impact of population density on the occurrence rate of property and violent crime using bivariate correlation approach. However, gaps still exist with respect to the applicability of LQCs and crime density for mapping the distribution of crime and for the investigation of the contextual determinants of crime through multivariate statistical analysis (e.g., regression). This research fills the void in literature by investigating the effectiveness the use of LQCs and crime density in urban crime analysis.

3. DATA AND METHODOLOGY

3.1. GIS Procedure

Omaha is the largest city in the State of Nebraska and its crime rate has been consistently lower than other mid-size U.S. cities in recent years. The crime data for this research was the police reported total crime incidents during the period of 2000 – 2001 in Omaha. The original data file included seven types of crimes including homicide, assault, robbery, larceny, auto-theft, burglary, and misdemeanor. In this article, assault, robbery, auto-theft, and burglary were selected, and they made up the predominant types of crime in Omaha and were of the major concerns to the police and the public. First G*eocoding* approach in geographic information systems (GIS) was used to locate crime incidents on maps (Harries, 1999). Nearly 91 percent of the 18,136 incidents of the four types of crime that occurred in 2000 and 2001 were successfully matched. To incorporate demographic data from the 2000 U.S. Census for the explanation of the spatial pattern of crime, the *Spatial Join* function in GIS was used to aggregate the point incidents of each type of crime to census tract polygons. If an incident falls inside a census tract, it is assigned to that tract and all incidents in this tract are then summarized. In addition, because the census tract boundaries do not match with the city's jurisdictional limits in which crime incidents were recorded, the city boundary was used to "cookie-cut" the census tract *shapefile* in GIS. All tracts that are completely within or partly intersect with the city boundary were included in the study area except for three census tracts because they either have a small portion falling inside the city boundary or have very small populations. In the end, 134 census tracts were included for this analysis (Figure 1)**.**

After aggregating crime data to census tract level, location quotients, crime density, and crime rates of each type of crime were calculated. Generally, the city of Omaha can be divided into four sub-regions based on their demographic characteristics: North Omaha, Downtown area, Southeast Omaha, and West Omaha. North Omaha is notorious for poverty and is dominated by African Americans, while Southeast Omaha includes a concentration of Hispanic peoples. Downtown Omaha is the old central business district and West Omaha is the newly developed suburban area comprised of many middle class and affluent neighbourhoods. In addition to the 2000 U.S. Census data, we also incorporated the multifamily and commercial parcel data of Omaha to test the influences of commercial and multifamily zones on crime occurrence rate...

3.2. Location Quotients

A location quotient is a relative indicator that has been used widely in geographic and regional science research. Brantingham and Brantingham (1997) first extended its application to the field of hot spot mapping of urban crime and pointed out that location quotients of crime (LQCs) can lead to an understanding of how areas differ in terms of crime structure and concentration. LQC is a ratio between the number of incidents for each type of crime in a small area (e.g., a neighbourhood) and the total of each type of crime in the whole city (i.e. big reference area). The advantage of LQCs is that it highlights an area's relative concentration of a specific crime in comparison to it's ratio for the entire area and identify whether a specific crime is disproportionately high or low in a particular place regardless of the total number of incidents or population in a neighbourhood or area (Carcach and Muscat, 2002).

Based on the GIS generated crime database, this article used the equation designed by Brantingham and Brantingham (1997) for calculating the location quotients of assault, robbery, auto-theft, and burglary for each census tract in Omaha (Equation 1).

$$LQC_{i_n} = \frac{C_{i_n} / C_{t_n}}{\sum_{n=1}^{N} C_{i_n} / \sum_{n=1}^{N} C_{t_n}} \qquad \text{(Equation 1)}$$

Where:

LQC_{i_n} is the location quotient of crime *i* for a census tract n.

n = unique identification number of each census tract
N = total number of area units (total number of census tracts in the city)
Ci = count of crime *i in each census tract*
Ct = total count of all incidents in each census tract

The LQC value for crime *i* within a census tract (n) is an index that compares the proportion of crime *i* in census tract *n* with crime *i*'s share of the total incidents in the whole city. If LQC value is larger than 1, it means that the tract has a relatively higher frequency of crime *i* compared to the city as a whole. In this article, LQCs were designed as an alternative measure of crime rates to show the relative frequency of each type of crime and the profiles of all dominant crimes in each census tract.

3.3. Crime Density

In this study, density of crime was calculated by dividing the number of incidents of each type of crime in a census tract by its area in square miles. We believe that density of crime has at least three advantages when compared to crime rates: First, crime density focuses on the locations of incidents rather than criminals' or the victims' locations, which are of the major concerns of the public and law enforcements. Because it is difficult or almost impossible sometimes to find the residential addresses of criminals or their victims, calculating the density of offences of crime in each area or neighbourhood is technically efficient.

Second, crime density is a reasonable reflection or indication of the rate of occurrences of crime across space. Normalizing the number of incidents by the area of a geographic entity can produce a more precise picture of the spatial patterns of crime by eliminating the bias caused by various entity sizes. As the advent of GIS technology, it is technically possible to measure the area of polygon of any irregular shape. Furthermore, it is also possible to employ GIS to calculate density of crime in a more accurate way under certain circumstances. For example, if a big lake is inside the boundary of a census tract, generally speaking it is far less likely to have offences on the lake than on the land area. We can use GIS to subtract the water area from the census tract and calculate the “real” density of crime by dividing the number of incidents just by the land area.

Third, crime density is more appropriate for illustrating the intensity of crime across urban neighbourhoods although it is applicable to different geographical scales ranging from the local to the nationwide. Providing crime density is the reflection of the spatial intensity of crime across geographic areas and the finer the scale the more accurate it is, simply because the details of the spatial patterns of crime can be recorded if small unit is used. In addition, crime density is not subjective to the distribution of population and thus the density of crime in districts with large business or multifamily zones can be objectively manifested. In fact, crime density could effectively reflect the close relationship between demographic characteristics and neighbourhood crime level. Neighbourhoods with low SES, concentration of minorities and high population density tend to have a high crime density; neighbourhoods with high SES, low population density and dominated by white population are more likely to have a low crime density. Therefore, crime density is an appropriate indicator that exhibits both the geographic and demographic dimensions of crime across urban neighbourhoods and can provide a more accurate and more reliable picture of crime for the public and the law enforcement agencies.

3.4. Statistical Methods

Ordinary least square (OLS) multiple regression methods were used to explain the relationship between neighbourhood characteristics and crime by using density as the measure of neighbourhood crime in SPSS. Regression models using crime rates and LQCs as dependent variables were also included to compare the explanatory power of the density models. Independent variables consisted of the U.S. 2000 census demographic and household characteristics and the land use attributes extracted from the Omaha parcel data (Table 1).

3.41. Dependent Variables

Following the common practice of averaging multi-year data to reduce the fluctuations of crime over years (Martin, 2002), the average number of incidents of each crime type during 2000 and 2001 was used to calculate the crime density of each census tract. Table 1 shows the descriptive statistics including Minimum, Maximum, Mean, and Standard deviation (SD) and Skewness of crime density. As expected, the distributions of crime density of these four types of crime were highly skewed,[1] suggesting most census tracts had low densities of crime and a small number (of census tracts) with very high values. Therefore, log (10) transformations were conducted in order to apply OLS (Rice and Smith, 2002). The descriptive statistics of the logged values exhibited that much of the skewness of the raw values of crime density of the four types of crime had been removed.

3.42. Independent Variables

[1] A rough guide is that if the skewness value is more than twice of its Standard Error, it indicates a departure from a symmetrical distribution.

A list of 14 socio-economic variables was included for the investigation of the etiology of crime across space (Table 1). Population density refers to the number of residents per square mile in each census tract. It was included based on the basic assumption that the higher the population density, the higher the rate of crime occurrence (Beasley and Antunes, 1974; Mencken and Barnett, 1999; Roncek and Maier, 1991; Rotolo and Tittle, 2006). Percentage of minority population reflects the racial and ethnic heterogeneity of the neighbourhood. It has been established that minorities are relatively more likely to be involved in crimes and more likely to be victimized than whites (Ellis and Walsh, 2000). Percentage of young males between ages 15-24 in each census tract was included because research has found that criminal behavior is predominantly overrepresented in male teens and 20s (Ackerman, 1998; Hannon, 2002; Krivo and Peterson, 1996).

Percentage of adults (25 years and over) without high school diploma and percentage of female-headed households reflect the disadvantageous education attainment and family disruption status which have been commonly used as explanatory variables for crime analysis (Roncek and Maier, 1991; Zhao and Thurman, 2001). Median household incomes, percentage of residents with income below poverty level, percentage of unemployed people in labour force, and percentage of population who live in housing with 1.01 or more persons per room are a group of variables representing the economic status of each neighbourhood (Beasley and Antunes, 1974; Kohfeld and Sprague, 1988). Both theoretical and empirical literature has concluded that low socioeconomic status is highly associated with crimes. Since census tracts have relatively homogeneous socio-economic characteristics, median household income was used to represent the general income level of each tract (although income inequality is often used by the literature as an indicator of the relative social deprivation) (Ackerman, 1998; Weatherburn, 2001).

The percentage of owner-occupied houses, percentage of vacant houses, and percentage of people who live in the present houses for more than five years are dimensions used to capture the housing characteristics and the community mobility. It has been found that these variables are highly correlated with crime (Ackerman, 1998; Ellis and Walsh, 2000; Rice and Smith, 2002; Tockovsky, 1983; Zhao and Thurman, 2001). The last two variables - density of commercial parcels and density of multifamily parcels were included to capture the effects of land use on the variation of urban crime because prior studies and the public perception have addressed the linkages between commercial places and multifamily apartments, and crime incidents (Roncek and Meier, 1991). It is commonly believed by citizens that these two types of land use categories are more prone to attract crime than single residential houses.

It is hypothesized that social stress indices such as racial/ethnic composition, female-headed households, poverty, low education attainment, vacant house, and unemployment rate have a positive impact on the density of crime, while other social control variables such as residential stability, house ownership, and median house income have a negative relationship with crime density. The density of commercial and density of multifamily parcels in each urban neighbourhood were hypothesized to be positively associated with crime.

4. PROFILE OF CRIME ACROSS NEIGHBOURHOODS

Based on the geocoded results of assault, robbery, autotheft, and burglary crimes, the number of incidents of each type of crime was aggregated to the census tract level. Then, the LQC values of assault, robbery, autotheft, and burglary for each census tract were calculated and mapped in Figure 2. The general patterns of assault and robbery (violent crime) was that neighbourhoods in North Omaha and Downtown area showed relatively higher LQC values than the rest of the city, suggesting that violent crime is disproportionately concentrated in downtown commercial districts or blighted neighbourhoods predominantly resided by African Americans. The LQC maps of auto-theft and burglary (property crime) were largely different from those of violent crimes. North Omaha and the Downtown Omaha showed relatively low LQC values, while the rest of the city has relatively higher LQC values especially in West Omaha. This means West Omaha had a relatively higher frequency of property crime in comparison to property crimes over the city as a whole.

For identifying census tracts that have relative higher risks of certain types of crime than the city average, Figure 3 is a comprehensive map showing LQC values larger than 1.0 for all the four types of crime in each census tract. The background choropleth map provided the variations of density of the sum incidents of all four types of crime in each tract. It is clear that the eastern part of the city (North Omaha, Downtown Omaha, and Southeast Omaha) area had the highest crime density it decreased from northeast to the rest of the city.

Labeled letters on the map shows the dominant crime(s) in each census tract (S-assault, R-robbery, U-autotheft, and B-Burglary). For example, if a tract has a label of S, it means that assault is the dominant crime in that tract. If a tract has a label of A/B, it means that the relative frequencies of both autotheft and burglary are higher than the city average. The label of S/A/B or S/R/U represent that a tract has three dominant crimes in comparison with the city as a whole. It can be seen that some census tracts in North Omaha and downtown areas exhibited diversified crime profiles (e.g., S/R/A, S/R/B or S/A/B) dominated by violent crimes (assault, robbery, or both), while tracts in West Omaha generally have a specialized crime structure (e.g. U or B or U/B) dominated by autotheft or burglary (property crimes) or both of them. This finding is consistent with the literature that violent crime is more likely to be related to poverty and property crime is more likely to be associated with high property values (Ackerman, 1998; Roncek and Meier, 1991). This finding is not only useful for the police to deploy patrols to targets of high risk but also is beneficial for the public to comprehend the prevalent types of crime in different neighbourhoods (Canter, 1997).

While LQCs can be successfully used to display the profile of crime for each urban neighbourhood, caution needs to be paid when interpreting areas with extraordinary low or high crime incidents. Table 2 lists three census tracts (7449, 6000, and 6806) in similar size to illustrate the pitfalls of LQCs. Located in the western edge of the city, tract 7449 experienced only 2 incidents (1 assault and 1 autotheft - extremely low frequency of crime) during 2000-2001. However, the LQC values of these two types of crime were 8.2 and 1.03 respectively, indicating this tract has a much higher risk of being victimized by assault and autotheft than the city average, especially for assault crime. Since this is a very low crime neighbourhood, the chance of having these two incidents of autotheft and assault could be just random.

Tract 6000 is situated in North Omaha which is the high crime area. During 2000-2001, totally 417 incidents including 47 assaults, 51 robberies, 204 autothefts, and 115 burglaries were committed in this small tract (0.65 square mile). The LQC value of assault of Tract 6000 was larger than 1.0 (1.85) and this indicated this neighbourhood suffered more assault crimes than the city average. However, when comparing the much higher LQC value of assault of Tract 7449 (very low crime neighbourhood with just a single incident of assault crime, but its LQC value was 8.2), its disproportional smaller LQC value but much larger count of assault incidents (than that of tract 7449) was really incomprehensible. An equally impenetrable fact was that the LQC value of burglary of Tract 6000 was only 0.77 with the amount of incidents 115, which means the relative frequency of burglary of this neighbourhood was lower than the city as a whole.

Above two examples indicate that LQCs could cause misleading, especially for neighbourhoods with excessive low or high frequencies of crime. The LQC values of neighbourhoods with extreme low crime tend to be overestimated or inflated because of the very low overall count of all types of crime. For very low crime areas, the frequency of each type of crime is very low, such as one or two incidents which could be committed very randomly. If its percentage of a type of crime in the small area (e.g., census tract) is larger than the corresponding percentage of the same type of crime in the big reference area (e.g., a city), its LQC is larger than 1.0 and could be any large values. Neighbourhoods such as Tract 7449 with just a small amount of crime belonging to one or two types, their higher LQC values signal people a picture of higher risk of being victimized than in high crime areas (e.g., Tract 6000) which is not the case (Cahill, 2005). On the contrary, LQC values of high crime neighbourhoods are more likely to be underestimated or deflated because in high crime areas all types of crime tend to have high frequencies, which results in the relative smaller LQC values of each type of crime (Roncek, 2004).

Tract 6806 is an example of neighbourhoods with medium level crime frequency. Autotheft and burglary were the two types of crime with the highest frequencies and their LQC values were also larger than 1.0. This exhibits that only for neighbourhoods with medium level crime frequencies do LQCs provide reasonable statistics for cross-sectional analysis of crime - the larger the frequency of a type of crime in a neighbourhood, the larger the corresponding LQC value it is. In addition, another problem with LQCs is that LQC values of neighbourhoods with frequencies of a certain type of crime below the reference average are compressed between 0 and 1; but above the reference averages are expanded to very large values (Shaw and Wheeler, 1994).

While LQCs can highlight the relative concentration of a type of crime in a neighbourhood in comparison to the larger reference area (i.e., city of Omaha), it is noticeable that a LQC value is sensitive to both the frequencies of other types of crime in the same neighbourhood and to the total frequencies of the particular type of crime in the reference area. Therefore, cautions need to be exercised when explaining the geographic meanings of LQCs and using LQCs for statistical analysis. The problems of LQCs discussed beforehand may also affect the applicability of LQCs when used for empirical analysis of crime across urban neighbourhoods. When interpreting LQCs, it should not be confused with conventional measurements that mainly reflect the absolute number of crimes or relative indices standardized by population (crime rates) or by area (density of crime). The application of LQCs for statistical analysis will be further discussed in the next section.

5. STATISTICAL ANALYSIS OF CRIME

5.1 Correlation Analysis Results

Table 3 shows the correlation coefficients between the independent variables and density of each type of crime as well as correlations between the independent variables. It is noteworthy that some of the independent variables were highly correlated, suggesting the existence of multicollenirity, such as the significant positive correlation between percentage of minority population and percentage of female-headed households (0.90) and the significant, inverse correlation between female-headed households and median household income was (-0.80).

All independent variables were statistically significant and in expected directions with each of the four dependent variables – the log values of the density of each type of crime. For example, the percentage of minority population, poverty, and unemployment rate showed significant positive correlations with all four types of crime; median household income, home ownership, and residence stability showed significant negative correlations with all four types of crime. The significant correlations between the explanatory variables and the dependent variables indicated that using crime density as alternative measure of crime rates is applicable. Furthermore, it provided preliminary supplemental evidence for the social disorganization theory and routine activity theory because crime rates were predominantly used to test these theories by previous empirical studies of crime.

5.2. OLS Regression Results

Table 4 showed the OLS regression results of assault and robbery measured by density, rime rates, and LQCs respectively. For assault crime, the density model explained 80 percent of the variation, an improvement of 7.9 percent over the assault rate model and 59.9 percent over the LQC model (Adjusted R^2 were 0.80, 0.721, and 0.201 respectively in Table 4). Percentage of minority population, population density, and density of commercial parcels showed significant positive impact on log value of assault crime (Beta coefficients 0.341, 0.332, and 0.204 respectively in Table 4). Consistent with the results of the assault density model, percentage of minority population and density of commercial parcels showed significant coefficients in the assault rate model, exhibiting that assault crime is typically associated with impoverished neighbourhoods because of the high level of social dysfunction and lack of police patrol over these areas (Ackerman, 1998). Other independent variables failed to show significant correlations with log assault density, although most of them showed expected signs except percentage of vacant homes and percentage of people who lived there for more than five years. The negative impact of the proportion of population in poverty was unexplained because it was expected to be positively related to crime density. No independent variables had significant impact on the variation of LQC of assault. The very low Adjusted R^2 value indicated the unsuccessful application of LQC as an indicator of crime for statistical analysis.

For robbery crime, as robust as the assault density model, the robbery density model explained nearly 73 percent of the variation. In particular, percentage of minority population and population density had significant positive impact on the variation of robbery density (log value), while median household income and density of commercial parcels had significant inverse effect on the occurrence of robbery crime. These three independent variables together with density of multifamily parcels also showed significant impact on the robbery rate model (log value) with less robust explanatory power than the density model (Adjusted R^2 was 0.624 in Table 5).

Table 5 showed the OLS regression results of the two property crimes (autotheft and burglary). Once again, the density models of autotheft and burglary showed larger adjusted R^2 than their corresponding crime rate models, suggesting the better suitability of crime density than crime rates for the statistical analysis of crime. They also reinforced the social disorganization theory by showing the positive effects of social stress variables (i.e., population density, female-headed households and percentage of young population) and the inverse impact of social control variables (i.e., such as household income, home ownership, and residential stability. For example, the percentage of female-headed households is an important indicator of family disruption that could result in the increase of crime rates (Ackerman, 1998; Martin, 2002). In addition, the property crime density models also provided supportive evidence for the routine activity theory by demonstrating the significant impact of commercial and multifamily parcels on the occurrences of autotheft and burglary crime. For example, a large number of unguarded cars parked in the multifamily and commercial parcels constituted abundant opportunities for car thieves. In contrast, affluent neighbourhoods usually took more security measures (e.g., more police patrols, neighbourhood watch, and more protective systems) to prevent the loss of their cars and other properties.

In comparison to the density and crime rate models, the LQC models were least satisfactory. Only less than one third of the variations of autotheft and burglary could be explained by the LQC models. It can be concluded that using LQCs in statistical analysis is problematic. Because LQC is a ratio that measures the relative concentration of a type of crime in a neighbourhood in comparison to its proportion of this type of crime in the city as a whole, neighbourhoods with high crime incidents do not necessarily have high LQC values. However, it is noteworthy that the variable of household income showed significant positive coefficients in the LQC models of autotheft and burglary (Table 6 and 7). Theses results looked peculiar but it was expected in fact because autotheft and burglary were the dominant types of crime in wealthy urban neighbourhoods (e.g., West Omaha). In section 4, high LQC values of autotheft and burglary had been recorded. Prior research has also found that affluent areas are more likely to be victims of thefts or burglaries rather than violent crimes (Carcach and Muscat 2000; Harries and Norris 1986). This finding indicates that LQCs has the advantage of highlighting the dominated crime in urban neighbourhoods in spite of its limitations for the causation analysis of crime.

With respect to the multicollinearity issue among the independent variables, second round regression models of crime density were run by just including explanatory variables that showed significant coefficients in the first round. The results of the second round regression models reinforced the findings from the first four models (i.e., density of assault, robbery, autotheft, and burglary) with the multicollinearity successfully removed and the explanatory powers were just slightly lower than the original models. For brevity, they were not presented in this article.

In general, the results of four groups of twelve OLS regression models demonstrated that using density as the alternative measure of crime rates can consistently produce the most robust explanatory power (better than using crime rates and LQCs). These findings further confirmed the social disorganization theory and the routine activity theory by using density instead of crime rate as the measure of crime. In addition, two suggestions can be raised from this section for subsequent studies: First, using crime density as a substitute for crime rate can produce promising results for the causality analyses of neighbourhood crime; Second, while LQCs are useful as measures of the relative concentration of neighbourhood crime, their use for the statistical analysis of the contextual factors of crime are not advisable because of the completely different statistical properties of LQCs in comparison to conventional scales such as crime rates or density of crime.

6. CONCLUSIONS

This research expands the previous work by using LQCs to map the prevalent types of crime across urban neighbourhood and adopting crime density to investigate the relationships between neighbourhood characteristics and crime. The contributions of this study to crime research can be summarized into the following three aspects: First, the rationale of the employment of official crime rates for neighbourhood crime study is dubious. Second, an enhanced understanding of the effectiveness and statistical properties of LQCs has been gleaned. We found that high crime neighbourhoods tend to have a diversified profile and low crime neighbourhoods are more likely to have a specialized profile of crime. While LQCs could help us identify the prevalent types of crime across urban neighbourhoods, LQC values may be misleading (inflation or deflation) by especially for neighbourhoods with extremely low or high occurrence rate of crime. Thus LQCS are of limited value. Cahill (2005) addressed the inflation problem of LQCs for low crime areas by just including observations with certain amount of incidents or above in statistical analysis, but it neglected the deflation problem of LQC values in high crime areas. Besides, eliminating the outliers from the dataset may affect the statistical power and produce misleading results.

Third, our study compares the explanatory power of different OLS regression models of crime measured by density, crime rates, and LQCs. The statistical results not only confirmed the effectiveness of crime density for the causation analysis of crime, but also provide additional evidence for the social disorganization theory and the routine activity theory because crime rates were predominantly used by previous empirical literature for testing these two theories. Variables such as minority concentration, population density, SES, residence instability, and multifamily and commercial land use features were highly associated with the spatial disparities of crime density across urban neighbourhoods in Omaha.

Overall, the findings of this article add to our understanding of the geography of crime and its socio-economic contexts at neighbourhood level by using LQCs and crime density as alternative measures of the irrational crime rates (Cahill, 2005). Subsequent research should emphasize the following four issues: First, in terms of the problems of LQCs, it is worth trying to use other simplified forms of LQCs such as the ratio between the number of incidents for a certain crime type in a small area and the sum of the same type of crime in the reference area of interest, or the ratio between the amount of a certain type of crime in a neighbourhood and the total quantity of all types of crime in each small neighbourhood. Second, the modifiable area unit problem (MAUP), a possible source of error resulting from using artificial spatial boundaries (e.g., census geographic entities) for aggregating geographic data (e.g., crime), needs to be addressed (Ratcliffe and McCullagh, 1999). Therefore, it is necessary to design research frameworks to conduct analyses of crime at different geographical scales for Omaha or other cities. Third, conducting research with data aggregated to finer scale such as block groups or blocks may be useful for capturing a higher resolution picture of crime across urban neighbourhoods. In addition, prior research has addressed the issue of spatial autocorrelation in recent years when conducting cross-sectional crime research (Martin, 2002; Rice and Smith, 2002; Roncek and Maier, 1991). Thus, investigating the existence of spatial autocorrelation among observations and finding reasonable solutions to correct the neighbourhood effects is essential for future studies.

Important policy implications can be raised from the findings of this research. The employment of crime density can help law enforcement agencies map a more accurate picture about the intensity of offenses across urban neighbourhoods without the bias caused by the population-based crime rates. In addition, as unveiled by previous theoretical and empirical research, the concentration of poverty and racial segregation are the two most important factors associated with the occurrences of crime, any strategies or efforts to eliminate poverty and racial barriers in urban neighbourhoods are beneficial for the reduction of crime across urban neighbourhoods (Cahill and Mulligan, 2003).

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Table 1 Descriptive statistics of dependent variables and independent variables

	Minimum	Maximum	Mean	Std. Deviation	Skewness	
					Statistic	Std. Error
Density of assault	.00	85.00	7.01	12.41	3.55	.21
Density of robbery	.00	122.50	10.64	17.46	3.19	.21
Density of autotheft	.00	295.00	48.79	53.89	1.74	.21
Density of burglary	.00	220.00	36.45	42.16	2.07	.21
Log (10) of density of assault	-.70	1.93	.55	.61	.11	.23
Log (10) of density of robbery	-1.10	2.09	.72	.63	-.19	.23
Log (10) of density of autotheft	-.59	2.47	1.37	.64	-.81	.21
Log (10) of density of burglary	-.62	2.34	1.30	.54	-.60	.21
% of minority population	2.26	93.12	21.87	23.53	1.62	.21
% of people with low education	.71	47.40	14.66	12.58	.959	.21
% female headed households	2.58	66.18	21.77	13.77	1.10	.21
% of young male population	3.62	28.95	7.61	3.01	3.46	.21
% housing with 1+ persons per room	.00	13.54	1.79	2.68	2.28	.21
Population per square mile	212.07	14710.00	4263.39	2226.79	1.16	.21
Median household income	7833.00	109225.00	45242.78	20112.67	.89	.21
% owner-occupied homes	3.24	99.25	62.74	22.85	-.57	.21
% of vacant homes	.26	24.90	5.41	3.96	1.83	.21
% same residence for 5+ years	12.94	79.22	52.50	12.25	-.82	.21
% of unemployment rate	.00	27.49	4.68	4.31	2.27	.21
% of population in poverty	.16	50.28	11.43	11.11	1.37	.21
Density of commercial parcels	.00	386.84	55.43	70.69	2.44	.21
Density of multifamily parcels	.00	751.28	64.36	129.99	3.56	.21

Table 2 LQCs values of three example tracts in Omaha, NE

Tract Number	Area	Number of Incidents					LQCs*				Note
		A	R	A	B	Sum	A	R	A	B	
7449	1.01	1	0	1	0	2	8.2	0	1.03	0	Low crime area
6000	.65	47	51	204	115	417	1.85	1.3	1.01	.77	High crime area
6806	.89	6	14	77	36	133	.74	1.12	1.19	.76	Medium level crime area

Note: A = assault; R = robbery; U = autotheft; B = burglary.
* If a LQC value is larger than 1.0, it means this census tract has a relatively higher frequency of a certain type of crime than the city of Omaha as a whole, and vise versa.

Table 3 Correlations Coefficients

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00													
2	.70**	1.00												
3	.90**	.70**	1.00											
4	.22*	.36**	.25**	1.00										
5	.47**	.73**	.42**	.148	1.00									
6	.23**	.23**	.30**	.21*	.19*	1.00								
7	-.62**	-.73**	-.80**	-.31**	-.42**	-.39**	1.00							
8	-.43**	-.45**	-.55**	-.52**	-.16	-.46**	.71**	1.00						
9	.47**	.57**	.53**	.51**	.25**	.35**	-.58**	-.70**	1.00					
10	-.11	-.14	-.10	-.41**	-.09	-.25**	.16	.57**	-.47**	1.00				
11	.81**	.68**	.82**	.29**	.50**	.167	-.61**	-.44**	.52**	-.14	1.00			
12	.85**	.78**	.89**	.45**	.45**	.30**	-.75**	-.60**	.68**	-.23**	.84**	1.00		
13	.28**	.45**	.38**	.40**	.13	.45**	-.52**	-.68**	.63**	-.40**	.35**	.52**	1.00	
14	.18*	.23**	.24**	.27**	.18*	.74**	-.37**	-.50**	.44**	-.35**	.17*	.31**	.53**	1.00
A	.71**	.65**	.74**	.25*	.41**	.60**	-.74**	-.56**	.56**	-.24*	.64**	.74**	.53**	.49**
R	.58**	.53**	.65**	.20*	.28**	.63**	-.71**	-.61**	.56**	-.33**	.54**	.64**	.58**	.57**
U	.57**	.66**	.70**	.34**	.40**	.58**	-.84**	-.67**	.51**	-.12	.52**	.67**	.58**	.50**
B	.57**	.60**	.70**	.30**	.36**	.64**	-.79**	-.68**	.53**	-.22*	.52**	.66**	.57**	.56**

NOTE: 1 = % of minority population; 2 = % of people with low education degrees; 3 = % female headed households; 4 = % of young male population; 5 = % of housing with 1+ persons per room; 6 = population density; 7 = median household income; 8 = % of owner-occupied homes; 9 = % of vacant homes; 10 = % same residence for 5+ years; 11 = % of unemployment rate; 12 = % population in poverty; 13 = density of commercial parcels; 14 = density of multifamily parcels; A = log value of assault density; R = log value of robbery density; U = log value of autotheft density; B = log value of burglary density.

** Correlation is significant at the 0.01 level (2-tailed).
*   Correlation is significant at the 0.05 level (2-tailed).

Table 4 Comparisons of OLS regression results of assault and robbery measured by crime density, crime rates, and LQCs

Independent variables	Assault			Robbery		
	Density (log10)	Rate (log10)	LQC (log10)	Density (log10)	Rate (log10)	LQC (log10)
% of minority population	.341**	.342*	.432	.257*	.287*	.430
% of people with low education	.084	.149	-.003	-.008	.022	-.369
% female headed households	.123	.164	-.042	.069	.010	-.295
% of young male population	.021	.064	-.035	-.069	-.070	-.209
% housing with 1+ persons per room	.041	.048	.070	.006	-.027	.030
Population density (persons/sqm)	.332**	-.167	.106	.316**	-.203*	-.034
Median household income	-.190	-.150	.317	-.245*	-.286*	.092
% owner-occupied homes	-.028	-.008	.092	-.137	-.063	-.084
% of vacant homes	-.056	.040	.027	.006	.098	.136
% same residence for 5+ years	.060	.105	-.058	.071	.055	-.018
% of unemployment rate	.067	.104	.114	.064	.145	.201
% of population in poverty	-.092	-.092	.199	-.088	-.062	.176
Density of commercial parcels	.204**	.179*	.077	.203*	.184*	.158
Density of multifamily parcels	.041	.222**	-.031	.095	.311**	.208
Adjusted R^2	.800	.721	.201	.729	.624	.168

Table 5 Comparisons of OLS regression results of autotheft and burglary measured by crime density, crime rates, and LQCs

Independent variables	Autotheft			Burglary		
	Density (log10)	Rate (log10)	LQC (log10)	Density (log10)	Rate (log10)	LQC (log10)
% of minority population	.060	.057	.133	.005	.021	-.196
% of people with low education	.144	.185	.261	.106	.133	-.197
% female headed households	.163	.141	-.425	.342**	.297	.165
% of young male population	.093	.149*	.101	.041	.090	-.133
% housing with 1+ persons per room	.030	.029	-.071	.021	.008	-.061
Population density (persons/sq mile)	.257**	-.221**	-.083	.330**	-.282**	-.025
Median household income	-.433**	-.520**	-.704**	-.251*	-.388**	.486*
% owner-occupied homes	-.203**	-.184	.078	-.223*	-.179	.080
% of vacant homes	-.111	-.046	.030	-.086	-.017	.037
% same residence for 5+ years	.198**	.257**	-.218	.168*	.221**	-.020
% of unemployment rate	-.038	-.016	-.130	-.008	.050	.148
% of population in poverty	-.157	-.184	-.269	-.151	-.165	.149
Density of commercial parcels	.159**	.133	-.033	.125	.094	-.164
Density of multifamily parcels	.021	.180*	-.185	.075	.317**	.188
Adjusted R^2	.815	.742	.179	.794	.708	.298

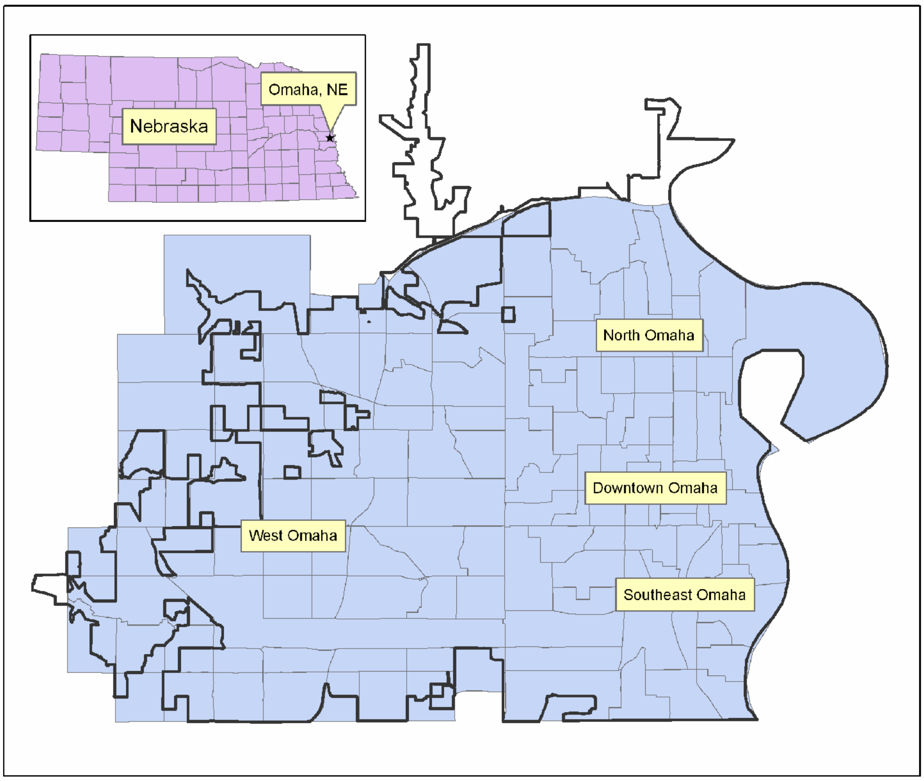

Figure 1 Census tracts in Omaha, NE with city limits (bold lines) overlaid

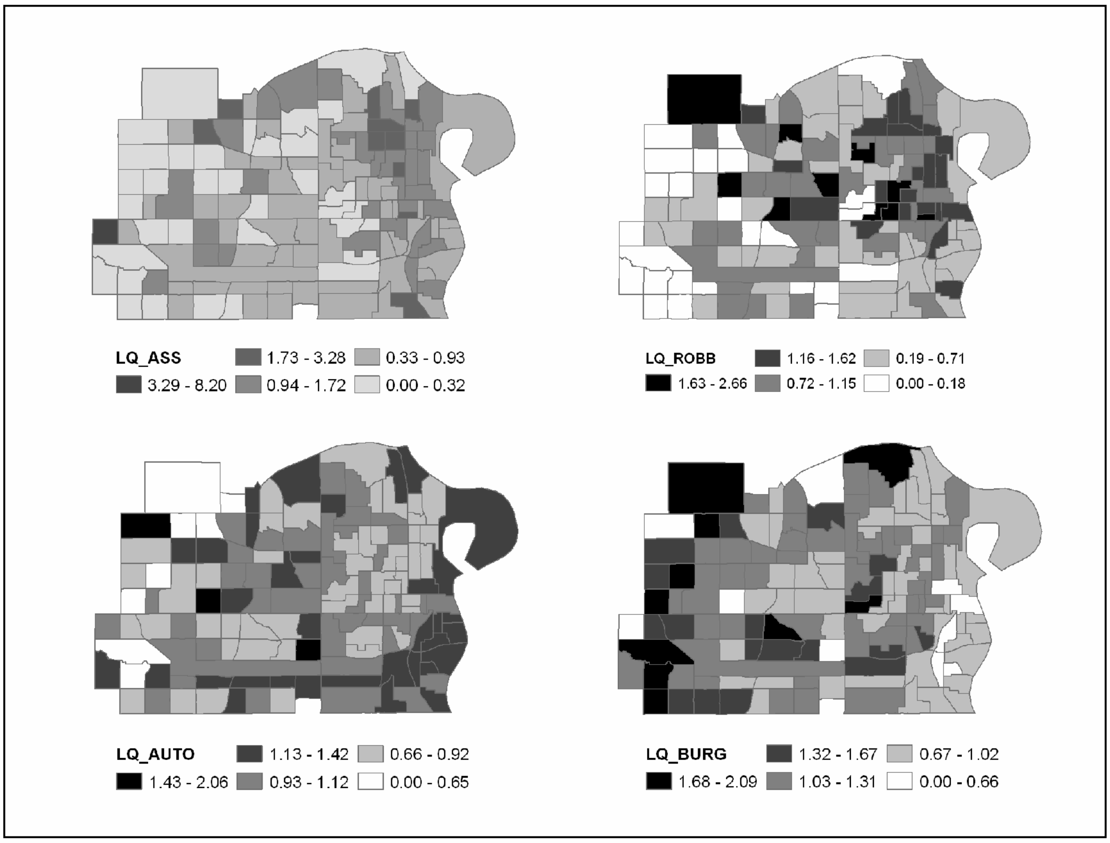

Figure 2 Location quotients (LQs) of assault (LQ_Ass), robbery (LQ_Robb), autotheft (LQ_auto), and burglary (LQ_Burg) across census tracts in Omaha, NE

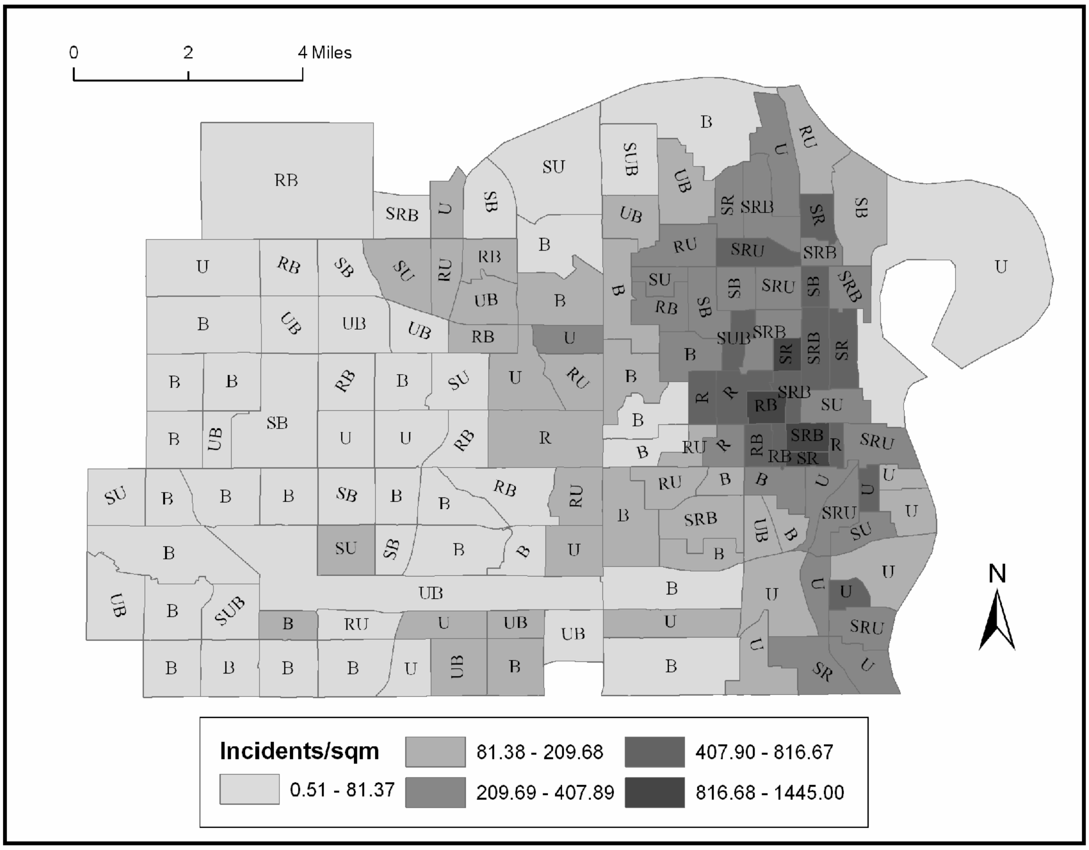

Figure 3 Dominant types of crime (A = assault; R = robbery; U = autotheft; B = burglary) across census tracts in Omaha, NE with background map showing the density of total crime incidents in each census tract