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Cartograms, Crime and Location Quotients

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CARTOGRAMS, CRIME, AND LOCATION QUOTIENTS

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Visualizing spatial information has a long history in the field of cartography. Though there are generally accepted forms of spatial data visualization to represent different types of spatial data, the interpretation of the resulting maps tends to be subjective at best and incorrect, at worst. Cartograms are an increasingly popular form of spatial data visualization, recently applied in political and epidemiological analyses in an attempt to better represent the spatial data under analysis. We use the cartogram procedure to map crime rates and location quotients. Using this visualization approach, we are able to show the usefulness of cartograms to represent crime.

Introduction

Modern crime mapping began more than a century ago in France (Guerry 1833; Quetelet 1842), most notably followed by subsequent work in England (Plint 1851; Mayhew 1862) and the United States (Halpern et al. 1934; Shaw and McKay 1942). The purpose of this mapping has been to convey information regarding the spatial distribution of crime at a variety of scales: neighbourhoods, counties, states, provinces, and nations. The importance of this spatial information is now generally accepted in both criminological research and practice, and since the 1990s has expanded rapidly within American police agencies (Weisburd and Lum 2005). Currently, there are textbooks for crime mapping/analysis within geographic information systems (Boba 2005; Chainey and Ratcliffe 2005; Wang 2005), and there has been the emergence of the field of crime science that focuses on, among other factors, the spatial component of crime (Clarke 2004; Laycock 2004; Pease 2001). In fact, Clarke (2004, 60) goes so far as to say that "crime mapping will become as much an essential tool of criminological research as statistical analysis is at present." Only time will tell if Clarke's prediction is correct, but his point is clear: crime mapping is an important component in the future of crime analysis and criminal justice.

Of critical importance in crime mapping is how to geovisualize crime data. The representation of spatially-referenced crime data must be undertaken with care as there is the potential for misrepresentation, an inherent limitation of maps (Monmonier 1991). As such, the choice of representation for (criminological) data is critical. There are four primary methods of displaying data such as criminal occurrences on a map: dot maps, graduated symbol maps, surface maps, and choropleth maps. Dot maps display one dot for each criminal occurrence; graduated symbol maps place a symbol (most often a dot) at all locations of a criminal occurrence, with the size of the symbol increasing as the number of occurrences increase; surface maps are three-dimensional representations of the dots or, as commonly used, two-dimensional interpolations of the dots; and choropleth maps use colour or shading to represent the rates of criminal occurrences assigned to units such as census tracts, counties, and nations (Dent 1999; Krygier and Wood 2005) – see Chainey *et al.* (2008) for a comparison of the various forms of mapping commonly employed in crime analysis. Choropleth mapping is the most commonly employed because it allows for various socio-demographic and socio-economic variables measured by national statistical agencies to be associated with crime (Andresen 2006; Cahill and Mulligan 2003).

Irrespective of the representation of the (criminological) data on the map, there is also the issue of projections that complicate the visualization of any spatial data. Projections are mathematical algorithms that allow the three-dimensional Earth, or portions thereof, to be represented on a two-dimensional surface (Dent 1999). To do so, choices have to be made regarding each two dimensional representation. Most often, some form of an area-preserving projection (planimetric maps) are employed that represent circumscribed areal units proportional to their measured geographic areas. Though an intuitive representation of spatial information, planimetric maps have their limitations: representing counts of occurrences may be misleading because areal units with greater populations (irrespective of their geographic size) will simply have more criminal occurrences, and representing rates of occurrences may be misleading because attention may be focused on areal units with a very low incidence of crime that have even lower levels of populations (Dorling 1994).

This paper presents an alternative form of representing spatial data – the cartogram. The cartogram has been used in a number of social science applications recently, reviewed below, but not using criminological data at the neighbourhood level. We believe the use of the cartogram methodology is instructive for criminological research on at least two fronts: first, when presenting the conventional measure of crime rates and, second, when representing a measure of crime specialization, the location quotient. Because of the nature of crime data and its spatial interpretation, however, standard cartogram methodologies are problematic. Therefore, we also present an alternative cartogram methodology that is particularly instructive for the geovisualization of crime data.

Cartograms

A cartogram is an alternative form of visualization with the purpose of addressing the two limitations of planimetric maps, discussed above (Dent 1999). Rather than the two-dimensional area of the map representing the geographic area of the areal units, a cartogram represents the two-dimensional area of the map using another variable, such as the population. As such, the cartogram is a variant of a graduated symbol map; however, instead of varying the size of the symbol, the size of the areal unit is varied (Krygier and Wood 2005). This is why a cartogram is sometimes referred to as a value-by-area map or, in the case of varying the size of the areal units with the population, a density-equalizing map. By making the size of the areal unit proportional to the population, cartograms control for population density. Therefore, the values represented in a choropleth-cartogram map may be counts and the size of the areal units act as the normalizing variable. This addresses both of the limitations above. Areal units with greater populations are larger such that counts of occurrences may be interpreted relative to their importance (geographically large areas with relatively low population counts do not dominate the map, and vice versa). There is no need to map rates of occurrences because the size of the areal unit normalizes the count (areal units with low counts and low populations also do not dominate the map). The resulting cartogram is then explicitly a tool for the visualization of spatially-referenced data that is richer than the planimetric map. Every aspect of the cartogram has value; not only does the colour-shading represent data, but so do the shapes of the areal unit boundaries.

Cartograms come in two general forms: contiguous and non-contiguous. Contiguous cartograms maintain areal unit boundary and adjacency relationships, whereas non-contiguous cartograms maintain the shape of the original areal units and alter their size. Continuous cartograms can be difficult to interpret because of the distortions necessary to maintain boundary and adjacency relationships and non-contiguous cartograms can be difficult to interpret because boundary and adjacency relationships are not maintained. As a result of these limitations, cartograms tend not to be effective if the map reader is not familiar with the region under study. Consequently, care must be employed when using cartograms, especially now that they are becoming incorporated into geographical information systems software packages.

Tobler (1963; 1973) was the first to automate the generation of cartograms using computers. Many other computer algorithms followed—see Sui and Holt (2008) for a list of available methods—but most of these are computationally intense, taking up to 16 hours to compute (Gastner and Newman 2004). Dorling (1996) developed a simpler cartogram computer algorithm that is not nearly as computationally intense, but the resulting cartograms are distorted significantly more than other methods such that any map-reader not familiar with the area would be unlikely to obtain meaningful results.

In this paper we use Cartogram Creator, an extension for the ArcGis Desktop developed and documented by Wolf (2005). An alternative extension is the Cartogram Geoprocessing Tool (version 2), developed by Tom Gross, that uses the Gastner and Newman (2004) cartogram algorithm. Both extensions generate similar cartograms in short periods of time, but the Cartogram Creator is preferred because it allows the user to export the cartogram as a shapefile rather than a geodatabase.[1]

Applications of the Cartogram

With the generation of cartograms dating back to the mid-19th century (Dent 1999), their applications are many and varied. There are, however, a number of more recent applications that are worthy of discussion. Each is discussed in turn.

The recent academic research involving the use of cartograms in the social sciences (not always undertaken by social scientists, however) has focused on politics and public health.

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[1] Because cartograms are the product of a topological transformation algorithm and there are a variety of such algorithms available. Future work is needed comparing the different visualizations obtained using different algorithms. Though computational time may be an issue, the different cartograms may prove to be instructive in different ways for the interpretation of spatial information. This is, however, beyond the scope of the current work.

Probably the most well-known application was the 2000 and 2004 U.S. presidential election results. When using a planimetric map to represent these election results, it appears as though the Democrats had relatively little support in both election years despite it being known based on proportional reporting that support was evenly divided between the Democrats and the Republicans. When Gastner and Newman (2004) and Gastner *et al*. (2005) created cartograms of these election results, however, the resulting maps greatly increased the sizes of the northeast and west coast U.S. states that supported the Democratic candidates. This cartogram showed that the support for both candidates was split quite evenly.

In addition to this recent academic work, there is also the Worldmapper Project, a cartogram project carried out through collaboration between Mark E.J. Newman and the University of Sheffield: http://www.worldmapper.org. This URL contains hundreds of cartograms of the world using the cartogram method of Gastner and Newman (2004). These cartograms of the world represent a broad range of categories from food to manufacturing to health to religion. Although these cartograms do reveal information that is generally known (income is concentrated in the West, for example) the relative magnitudes are rather dramatic.

This brief review of cartograms and, in particular, their applications shows the utility of cartograms in the visualization of spatial data. The visualization of spatially-referenced crime data using cartograms, as shown below, is also instructive. To properly interpret cartograms of crime, however, we must first address methodological concerns specific to crime data.

Data, Measurement, and Cartogram Methodology

The data used to generate the planimetric maps and cartograms in this study represent the City of Vancouver in British Columbia, Canada, in 1996. Vancouver is the largest census metropolitan area in Western Canada with a population of approximately 2 million residents the year of data under analysis. The City of Vancouver had a population of approximately 550,000 that same year. The spatial units shown in the resulting maps are the 87 census tracts (CTs), defined by Statistics Canada's 1996 Census of Population. Of course, the areal unit boundaries can be removed for map generation, but these boundaries aid in the interpretation of the cartogram by providing more reference to the planimetric map.

Crime Data

Two common crime classifications are employed for the analysis: violent crime and burglary. Although a relatively aggregated crime classification, violent crime is instructive for the generation and interpretation of cartograms. Similarly, burglary is chosen as a property crime because it is instructive for the use of the location quotient.

Crime data were obtained from the Vancouver Police Department (VPD) Calls for Service (CFS) Database. Each CFS contained the location and the complaint code/description for each incident. These two crime classifications are at times identified as attempts or "in progress." These calls were included in the crime data mapped below.

One final issue with geographically referenced (criminological) data is geocoding. Geocoding has the potential for error because of the inaccuracy of computer geocoding algorithms (Ratcliffe 2001) and ecological bias generated through unmatched addresses (Ratcliffe 2004). Little can be done with regard to the inaccuracy of geocoding algorithms, or with issues such as assuming addresses are uniformly located along street segments; but Ratcliffe

(2004) identifies 85 percent as the minimum acceptable hit/success rate to avoid ecological bias. Additionally, ungeocoded data should not indicate any patterns or concentration of addresses. At the time of geocoding, an inspection of the ungeocoded data revealed no such patterns or concentrations. The geocoding procedure here produced a 93 percent success rate. As such, the analysis is undertaken with little concern for ecological bias.

Crime Measurement

Three measures of crime were used in the generation of the planimetric and cartogram maps: crime rates, crime counts, and location quotients. Crime rates and counts require no explanation aside from all rates being crimes per 1000 in each census tract: violent crime rates are per 1000 residents and burglary crime rates are per 1000 housing units. The use of housing units for burglary rates has become more common in recent years with its availability in census data (see Andresen 2006 for an example); however, the use of the resident population as the normalizing variable in the burglary rate does not alter the patterns of burglary.

The location quotient, a specifically geographical measure, provides an alternative measurement to the crime rate that attempts to address the difficulties of rates. The location quotient has been used in economic geography since the 1940s to measure employment or industrial specialization (Isard *et al*. 1998; Miller *et al*. 1991). In the early 1990s, Brantingham and Brantingham (1993, 1995a, 1998) introduced the location quotient into criminological research, but its adoption into criminological measurement has been both sparse and generally quite recent.[2] Rengert (1996) and Hirschfield and Bowers (1997) are the only works found that used the location quotient to study crime during the 1990s, with Andresen (2007), McCord and Ratcliffe (2007), Ratcliffe and Rengert (2008), and Robinson (2008) recently using the location quotient in crime analysis.[3] This lack of adoption in criminological research is surprising given that the interpretation of the location quotient allows it to measure specialization of an activity across areas.

In the current context, the location quotient measures the percentage of a criminal activity in a census tract relative to the percentage of that same criminal activity in Vancouver as a whole. This provides a measurement of under-, over-, or expected representation of criminal activity within each census tract. For example, the west side of Vancouver has a low burglary *rate* relative to the rest of Vancouver; however, as shown below, Vancouver's west side exhibits significant specialization, a disproportionate *share*, in burglary.

To show how crime specialization is measured using the location quotient, it is calculated as follows:

$$LQ = \frac{C_{in}/C_{tn}}{\sum_{n=1}^{N} C_{in} \Big/ \sum_{n=1}^{N} C_{tn}}, \tag{1}$$

where C_{in} is the count of crime i in census tract n, C_{tn} is the count of all crimes in census tract n, N is the total number of census tracts in Vancouver, and all crimes are based on property and violent crimes reported in the VPD-CFS Database. According to this formula, the location quotient is a ratio of the percentage of a particular type of crime in a census tract relative to the

[2] Barr and Pease (1990) did mention how the location quotient could be used in the context of crime prevention, but did not actually employ it in an analysis.

[3] Though their research is criminological, Andresen, Ratcliffe, and Rengert are all trained as geographers.

percentage of that same crime in all of Vancouver. If the location quotient is equal to one, the census tract has a proportional share of a particular crime; if the location quotient is greater than one, the census tract has a disproportionately larger share of a particular crime; and if the location quotient is less than one, the census tract has a disproportionately smaller share of a particular crime. Specifically, if a census tract has a location quotient of 1.20, that census tract has 20 percent more of that crime relative to Vancouver as a whole. Miller *et al*. (1991) provide the following classifications that are useful for interpreting the location quotient: very underrepresented areas, $0 \leq LQ \leq 0.70$; moderately underrepresented areas, $0.70 < LQ \leq 0.90$; average represented areas, $0.90 < LQ \leq 1.10$; moderately overrepresented areas, $1.10 < LQ \leq 1.30$; and very overrepresented areas, $LQ > 1.30$. These classifications are used in the legend classifications below.

Cartogram Methodology

As discussed above, rates are problematic because an area on a map with a high rate may be relatively small such that its importance is not emphasized on the map, and a high rate may be present with a low count of events and an even smaller population at risk. To combat these problems on a planimetric map, cartograms often represent the count of a phenomenon using colour shading and then use the population at risk as the normalizing or value-by-area variable. Under the right circumstances, this procedure provides relevant information regarding the data under study. In the context of crime, however, this procedure may produce misleading representations. Consider two census tracts, each with 1000 criminal occurrences and the same geographic size. Using colour shading and a variable representing crime counts, these two census tracts look identical. One of these census tracts (A) has a population of 1000 residents and the other (B) a population of 500 residents. If the resident population is used as the value-by-area variable, census tract A will be twice the size of census tract B in the cartogram. This gives the impression that more attention must be paid to census tract A, when in fact the risk of victimization is much greater in census tract B. Consequently, this method of cartogram creation creates as many interpretation issues as it attempts to solve, at least in the context of crime.

To utilize a cartogram and provide meaningful (and simple) interpretation in the context of crime, an alternative cartogram methodology is used here. Rather than using counts as the variable for colour shading, the rates (violent crime and burglary) are used for colour shading, and the value-by-area variable is the crime count. This cartogram shows the risk of victimization in each census tract through colour shading, and shows the volume of victimization through the size of the census tract in the cartogram. The difficulty of a planimetric map (showing a high rate in a low volume of crime area) is therefore dealt with by representing both risk and volume. In the case of location quotients, the location quotient classifications of Miller *et al*. (1991) represent the colour shading in the maps, with the crime rate being the value-by-area variable. This allows crime specialization to be shown in conjunction with the risk of that crime actually occurring. Using crime counts as the value-by-area variable generates very similar cartograms.

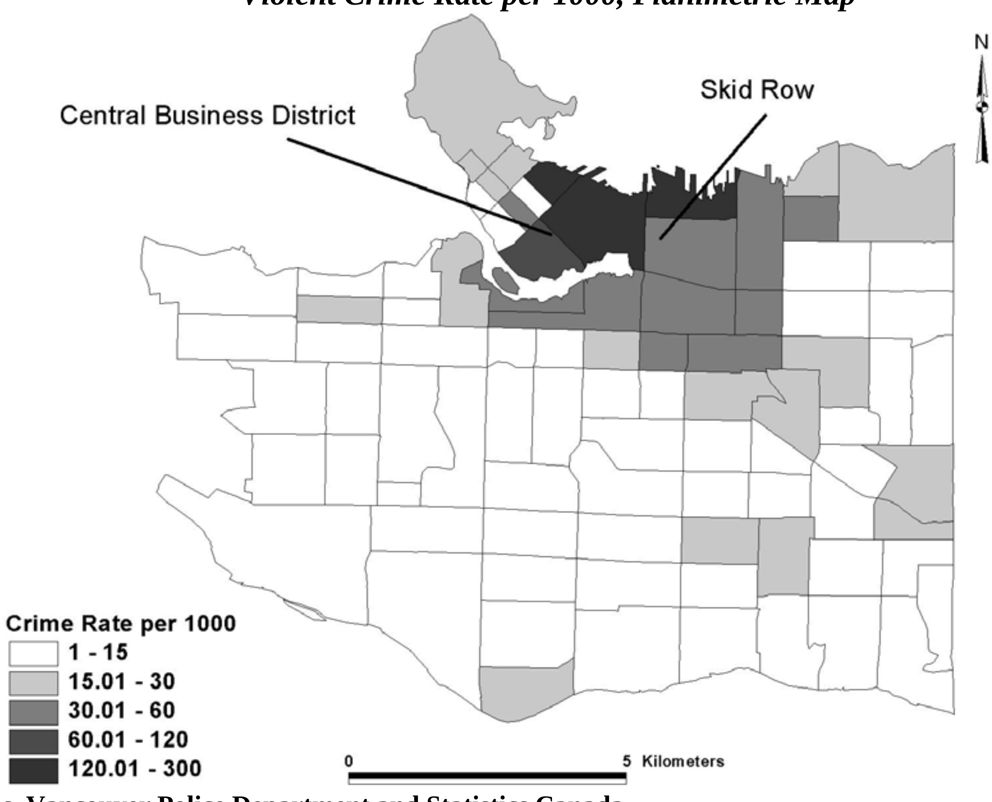
Cartograms of Crime

Although cartograms may be presented in many different formats, essentially based on what the researcher wants to find out, two of the most relevant types of cartograms will be discussed in this section of the article. These are cartograms based on crime rates and cartograms based on location quotients.

Cartograms of Crime Rates

The choropleth-planimetric map of the violent crime rate in Vancouver is presented in Figure 1. Violent crime rates are highest in the central business district region, decreasing quite rapidly as the distance from the central business district region increases. Such a pattern is a long observed criminological fact (Shaw and McKay 1942; Schmid 1960a; 1960b), particularly given Vancouver's Skid Row on the outskirts of the central business district in a stereotypical zone in transition (Shaw and McKay 1942). Although this was an expected spatial distribution, the high violent crime rates in the central business district region may simply be an artifact of the relatively low residential population through most of this area.

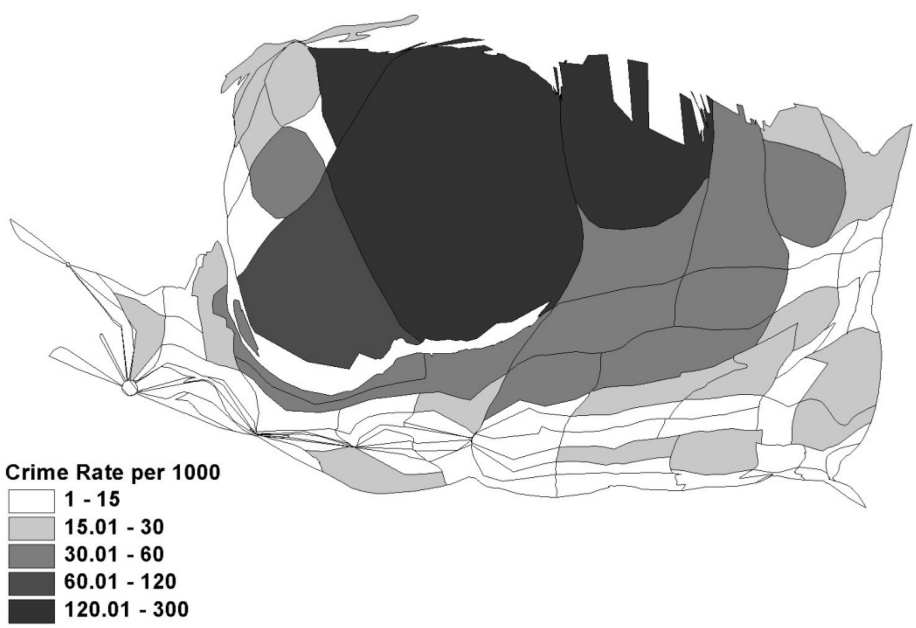
Figure 1
Violent Crime Rate per 1000, Planimetric Map



Sources. Vancouver Police Department and Statistics Canada

The cartogram for the violent crime rate, with the value-by-area variable being the violent crime count in each census tract, is shown in Figure 2. The north arrow and scale bar are not shown in any of the cartograms because they have no meaning in the context of a cartogram, but the legend remains the same as Figure 1 because the colour shading is the same in both maps for all census tracts. The cartogram is quite clearly and significantly distorted. The central business district and Skid Row are now greatly exaggerated because of the high volume of violent crime in these areas. As such, the planimetric map of violent crime rates (Figure 1) does correctly depict problem areas of violence in Vancouver, but does not give them enough prominence relative to the volume of crime. Also worthy of note is that the west side of Vancouver is practically non-existent for violent crime: low risk of victimization and low volume of violent crime. The east side of Vancouver, particularly the southern portion, is also quite small relative to its actual geographic size. The actual risk of violent crime and the high volume of violent crime is located in the same census tracts, central business district and Skid Row. The utility of the cartogram is shown here.

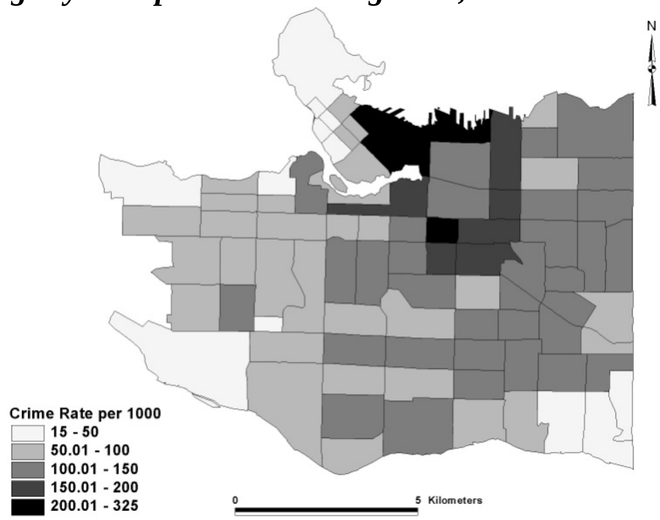
Figure 2
Violent Crime Rate per 1000, Cartogram



Sources. Vancouver Police Department and Statistics Canada

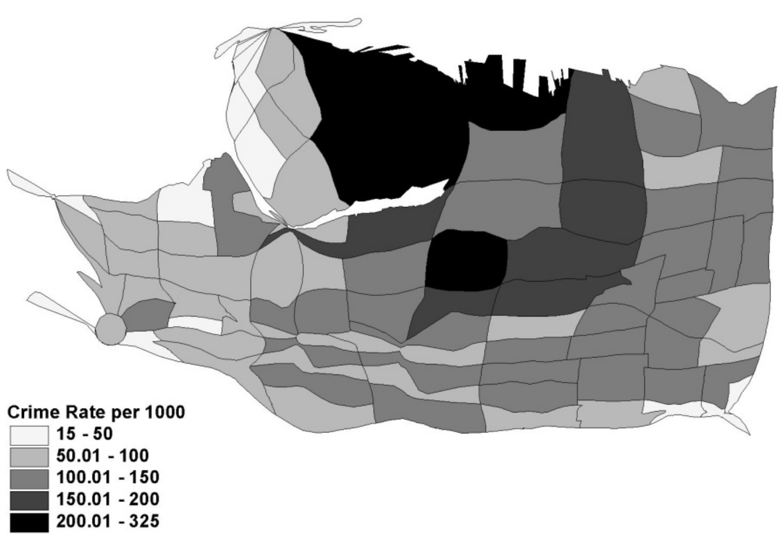
Figure 3 is a planimetric map of burglary rates, which have a similar spatial distribution as the violent crime rates. Noteworthy is that the burglary rates do not have the same magnitudes as the violent crime rate, and a moderate level of burglary risk is present for a significant portion of Vancouver; however, such an interpretation is difficult to confirm or deny on a planimetric map.

Figure 3
Burglary Rate per 1000 housing units, Planimetric Map



The cartogram of the burglary rates, Figure 4, is not nearly as dramatic as the cartogram for violent crime. Aside from a moderate enlargement of the central business district and Skid Row, most of the cartogram resembles the planimetric map. Ignoring the central business district, Skid Row, and a small portion of Vancouver in the south-west, the cartogram reveals that the volume of burglary is rather uniform across the urban landscape. Though there are more census tracts that are larger on the east side of Vancouver (areas with lower socio-economic status, generally speaking), there are also a number of census tracts on the west side of Vancouver that are a similar size. Therefore, aside from a few exceptions, the volume of burglary (but not the rate) is not as socially stratified as violent crime.

Figure 4
Burglary Rate per 1000 housing units, Cartogram

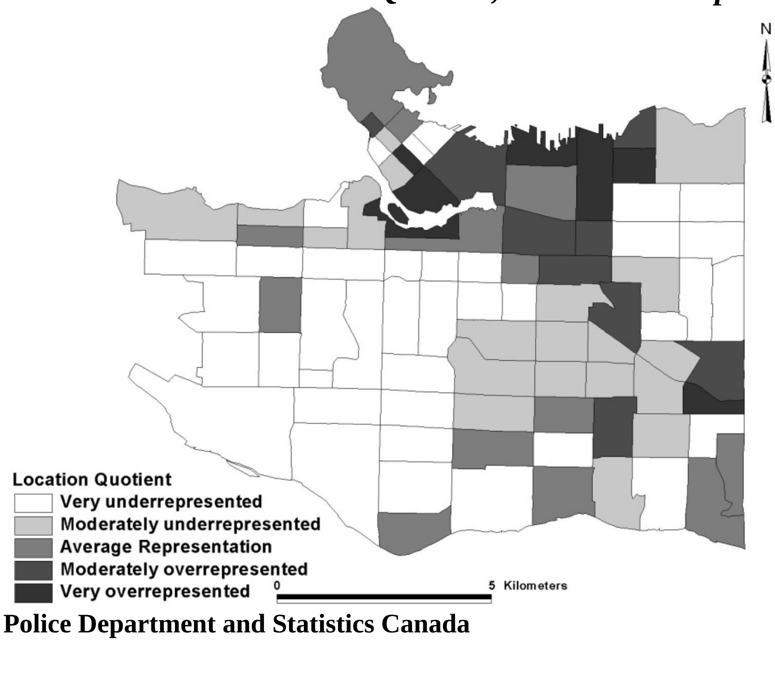


Generally speaking, both planimetric maps and cartograms are useful methods of presenting data. The areas of high risk for both violent crime and burglary in the planimetric maps are also shown to be of significant concern in the cartograms using the volume of crime as the value-by-area variable. In addition to this general confirmation of the patterns in the planimetric maps, the cartograms provide other insight. The cartogram for violent crime rates shows that the only place that really matters, in terms of both rates and volume, is the central business district and Skid Row; and the cartogram for burglary rates shows that the volume of burglary (aside from a few noted areas) does not vary that much across Vancouver.

Cartograms of Location Quotients

The planimetric map of violent crime location quotients, Figure 5, is both similar and different from the violent crime rate planimetric map, Figure 1. Immediately apparent is the specialization of violent crime in Vancouver's central business district and Skid Row. This is expected for two reasons. First, the central business district brings together high volumes of people each day for commercial purposes and each night for entertainment purposes. Whether it is day or night, the convergence of high volumes of potential offenders and victims is expected to correspond to high volumes of (violent) crime (Cohen and Felson 1979). Second, Vancouver's Skid Row consists of a relatively large injection drug user population that brings with it a relatively violent drug culture. There are, however, a number of census tracts on both the west and east sides of Vancouver that have average or overrepresentation of violent crime. Given the high volume of violent crime in the central business district and Skid Row, an average representation of violent crime is a level of specialization about which to be concerned. As merely a representation of specialization, a planimetric map of location quotients gives no indication of crime risk or crime volume.

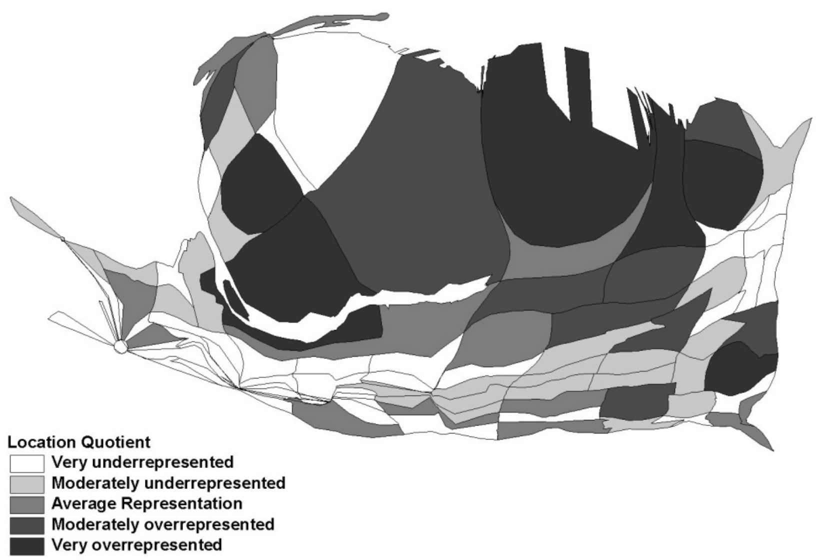
Figure 5
Violent Crime Location Quotient, Planimetric Map



Sources. Vancouver Police Department and Statistics Canada

The cartogram of the violet crime location quotients, Figure 6, uses the violent crime rate as the value-by-area variable. Using the crime count produces a very similar cartogram, see Figure 2 to compare the shapes of the two cartograms. This representation of the location quotient simultaneously provides information regarding the risk of violent crime from the perspective of victimization, in general (crime rates), and the risk of violent crime victimization for a census tract, in particular (crime location quotients). As with Figure 2, the central business district and Skid Row are the places of significant specialization and high risk of violent crime. The "pockets of violence" outside of the central business district and Skid Row are still easily seen, but they are not nearly as prominent on the map because of their low volume.

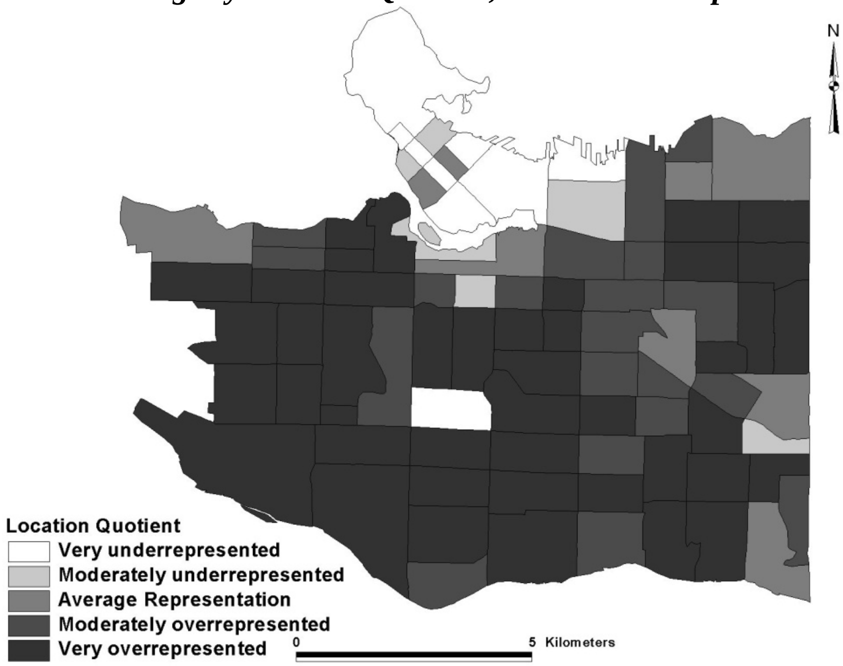
Figure 6
Violent Crime Location Quotient, Cartogram



Sources. Vancouver Police Department and Statistics Canada

The planimetric map of burglary location quotients, Figure 7, reveals a radically different spatial distribution than all previous maps for Vancouver. In fact, the spatial distribution in Figure 7 is essentially opposite of all other maps. Overrepresentation of burglary is present in most areas outside of the central business district and Skid Row. In particular, the west side of Vancouver, a relatively high socio-economic status area, is almost very overrepresented. The only notable exception is the underrepresented area in the centre of Vancouver. This census tract is dominated (spatially) by Vancouver's largest shopping mall outside of the central business district with few opportunities for burglary (relative to other crimes, such as automotive theft) because of a relative lack of residential housing. Recalling that the risk of criminal victimization, measured using the violent crime and burglary rates, is low in the west side of Vancouver, this result may be interpreted as follows: the risk of criminal victimization in the west side of Vancouver is low, but if one were to be a victim of crime it would likely be a burglary.

Figure 7
Burglary Location Quotient, Planimetric Map

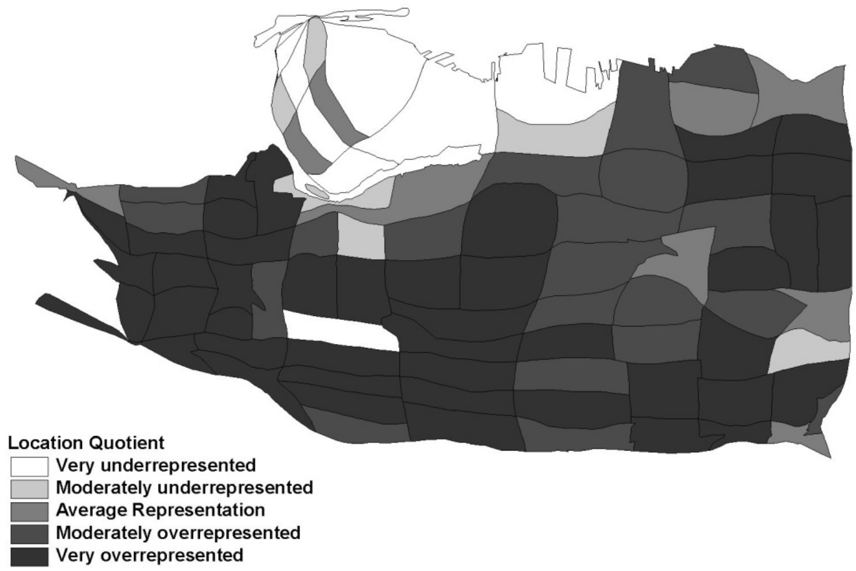


Sources. Vancouver Police Department and Statistics Canada

The burglary location quotient cartogram, Figure 8, uses the burglary crime rates as the value-by-area variable, similar to Figure 6. A number of general results from this cartogram are evident. Although the central business district and Skid Row are underrepresented in burglary, the risk of burglary victimization is high, leading to enlarged census tracts in these areas. This information is presented in Figures 3 and 4, but is in a convenient format in Figure 8. In the planimetric map of the burglary location quotient, the overrepresented areas on the west side of Vancouver dominate the visualization. In the cartogram, however, this area of Vancouver shrinks substantially, particularly in the south-west portion of Vancouver. This provides a much more realistic representation of the distribution of burglary: the west side of Vancouver does have a problem with burglary, relatively speaking, but the actual risk of burglary is low compared to the rest of Vancouver. Finally, the central and eastern areas of Vancouver are both overrepresented in burglary and have relatively high risks of burglary victimization.

The areas in Vancouver that are overrepresented and have relatively high risk of burglary victimization are easily understood when considering criminological theory. These high risk, over represented, areas throughout Vancouver (west, central, and east) are often located in neighbourhoods of mixed land use and/or commercial establishments (see also Kinney et al. 2008). These areas are neighbourhoods with high volumes of people that: allow for the convergence of potential offenders and potential targets in time and space (Cohen and Felson 1979), are activity nodes for high volumes of people containing many arterial pathways (Brantingham and Brantingham 1981), and, contain many crime generators and crime attractors (Brantingham and Brantingham 1995b). These are all areas that are expected to have high volumes of crime as well as well as high risk of crime, primarily because of increased criminal opportunity. Consequently, when considering the information in the cartogram of burglary location quotients and burglary crime rates, it appears as though the nature of land uses or the built environment of an area are important for burglary, not necessarily its socio-economic status.

Figure 8
Burglary Location Quotient, Cartogram



Sources. Vancouver Police Department and Statistics Canada

As with the cartogram for violent crime and burglary rates, the cartograms for violent crime and burglary location quotients provide a convenient representation of multiple variables simultaneously. The location quotient is a valuable statistic on its own, but may misrepresent areas that have low levels and risk of criminal activity. Through the manipulation of the areal units, this misrepresentation may be avoided. This avoidance is particularly evident in Figure 8, the burglary location quotient cartogram.

Conclusions and Discussion

This article presented a relatively old cartographic methodology using neighbourhood level crime data. Because it is readily available though geographic information system software extensions, we believe cartograms should be used to accompany planimetric maps of criminal activity. Through the use of a cartogram, we were able to show that not all crime areas that appear similar using planimetric-choropleth maps are similar through the employment of a value-by-area variable and its corresponding cartogram. This provides a significant amount of additional information regarding crime in a convenient format.

One could argue that this additional information could be obtained through other means: a planimetric map of crime counts and tables of the crime count data, for example. While this is true, there are two primary limitations of these other means. A planimetric map of crime counts necessarily categorizes the crime counts into five or more classifications. If this classification is divided along the lines of natural breaks, probably the most common default representation, the count of crimes across census tracts appears very similar to the planimetric maps, Figure 1 and 3 – similarly for the location quotients. Alternative planimetric maps would be able to show this relatively uniform count of crimes across most of the city, but one would have to go beyond the default maps generated in most geographic information system software. Consequently, these representations would raise questions regarding their reliability and trustworthiness because the classification system would be different from a standard planimetric map.

Tables of the crime count data are limited in two ways. First, the volume of data that would have to be sifted through could be immense. Even the 87 census tracts used here presents a large amount of information. Smaller census units of enumeration/dissemination areas, approximately 1000 in Vancouver, would make such assessments even more difficult. Second, unless one is also using information regarding the statistical distribution of crime counts (means and standard deviations, for example), discerning similar volumes may be difficult.

Overall, the cartogram provides a significant amount of new information in a relatively easy format to interpret. Insight into the spatial distribution of crime may be gathered using a methodology that has been used for over a century and is now gaining popularity because of the ease of their production in geographic information system software packages. As such, we echo Dorling's (1994) call for a more extensive use of the cartogram in crime analysis.

As noted above, however, cartograms do need to be used with caution when map readers are unfamiliar with the study area. At a minimum, any cartogram should be accompanied by its corresponding planimetric map to assist in interpretation. Even if this requirement is met, however, it is possible that the cartogram is so distorted that even a map reader familiar with the study area may have difficulty with interpretation. This will particularly be the case if certain cartogram algorithms are employed. It may be necessary, therefore, for locations to be indicated on both the planimetric map and the cartogram to provide references points for interpretation. Moreover, unsophisticated map readers may find a cartogram so different from a planimetric map that they are unable to make any meaningful interpretations. Consequently, it may also be prudent to have knowledge regarding potential map readers when deciding how many reference points (or other information) to include with a cartogram.

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