Hot spots of crime in Vancouver and their relationship with population characteristics

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Executive Summary

This research paper investigates the relationship between a number of social, economic, demographic, and physical neighbourhood characteristics and the spatial distribution of crime in the City of Vancouver. The investigation is undertaken using data from the 2001 census, the Vancouver Police Department’s Calls for Service Database, and Oak Ridge National Laboratory ambient population estimates.

Crime occurs neither randomly nor evenly across Vancouver’s landscape. Rather, crime concentrates in neighbourhoods with distinctive social, economic, demographic, and physical characteristics. Though most crime is concentrated at or near the city centre, some crimes are found to be more distributed across the city, but in predictable (or historically known) ways. These findings are consistent with recent Canadian studies focussing on the geographic patterns of crime in Montreal (Savoie, Bédard, and Collins 2006), Winnipeg (Fitzgerald, Wisener and Savoie 2004) and Regina (Wallace, Wisener and Collins 2006), Saskatoon and Ottawa (Kitchen, upcoming).

Descriptive bivariate statistics showed relationships similar to those found in recent studies of Montreal, Winnipeg, and Regina: crime is more prevalent in neighbourhoods with residents that are at a disadvantage with respect to social and economic resources. High crime neighbourhoods are found to have higher population turnover, more single people, fewer immigrants and visible minorities, higher unemployment, lower family income, and more renters. These results were consistent for both property crime and violent crime, and for both resident based and ambient population based crime rates.

The patterns observed through multivariate analysis are also largely consistent with past research on the spatial analysis of crime: recent movers, single people, visible minorities, and low income are all positively related to crime, with post-secondary education and average dwelling values being negatively related to crime. The most powerful predictors of crime were single people and visible minorities.

Two interesting results emerged in the context of previous research: the complex interaction between ethnic heterogeneity, visible minorities, and crime; and the relationship between average family income and crime. The former is partially understood within the context of Vancouver’s ethnic mix and immigrant settlement patterns; and the latter when considering average family income relative to that within neighbourhoods, rather than relative to the city as a whole.
1. Vancouver in a Canadian context

The Vancouver Census Metropolitan Area (CMA) is the third largest metropolitan area in Canada, based on population (approximately 2 million people), and the largest metropolitan area in western Canada. However, the City of Vancouver, the geographic area under study, is the eighth largest municipality in Canada, and the fourth largest municipality in Western Canada. In the context of these studies on crime, Montreal (1,040,000), Ottawa (775,000), and Winnipeg (620,000) all had populations greater than Vancouver in 2001.

In 2001, Vancouver had a population of 546,000. Vancouver has experienced recent substantial growth in its population: 431,000 in 1986, 472,000 in 1991, and 514,000 in 1996. These population increases correspond to 5-year growth rates of 9.5, 8.9, and 6.2 percent with the latter being well above the 4 percent average for the other 26 CMAs in Canada. This high rate of growth is often attributed to the 1986 World Exposition on Transportation and Communication that garnered Vancouver tremendous world attention. Because of this immense population growth over the past 20 years, Vancouver has become quite ethnically diverse with more than one half of its residents having a first language other than English or French.

Figure 1: Crime rates in Canadian metropolitan areas, 1991 to 2005
Rates based on count of total *Criminal Code* incidents excluding traffic offences.

**Source: Statistics Canada, Canadian Centre for Justice Statistics, Uniform Crime Reporting Survey, 1991 to 2005.**

With an area of approximately 115 square kilometres, the City of Vancouver has 110 census tracts (CTs) and is served by the Vancouver Police Department’s force of 1124 officers (1356 if you consider civilian members) through its central station and 8 Community Policing Centres in 2004. This number of police officers places Vancouver as one of the most highly served central cities in Canada on the basis of resident population alone (Reitano, 2006).
Despite this high level of police service, crime rates in Vancouver are higher than expected on the basis of population size. Unlike the cities of Regina and Saskatoon, Vancouver follows the national trend of a decreasing crime rate from 1991 – 2005, but its crime rate remains substantially higher than the national average. The Vancouver Census Metropolitan Area (CMA) had the highest crime rates among the three largest metropolitan areas in Canada at 11,367 criminal code offences per 100,000 persons in 2001, more than doubling the rate found in Toronto (5381 per 100,000 persons) and almost doubling that in Montreal (6979 per 100,000 persons).

The same relative standing held for the 2001 property crime rate in the Vancouver CMA (7365 per 100 000 persons) in comparison to the Toronto CMA (2944 per 100 000 persons), and the Montreal CMA (4240 per 100 000 persons), and to a lesser extent for the 2001 violent crime rate in the Vancouver CMA (1058 per 100 000 persons) in comparison to the Toronto CMA (882 per 100 000 persons), and the Montreal CMA (886 per 100 000). These differences in crime rates, however, have been decreasing in recent years (Kong, 1997; Savoie, 2002; Wallace, 2003). The Vancouver CMA had relatively more property crime (64.9 percent) than the CMAs of Toronto (54.9 percent) and Montreal (60.7 percent), and relatively less violent crime (9.3 percent) than Toronto (12.9 percent) and Montreal (16.4 percent). As noted by Savoie, Bédard and Collins (2006), this pattern is also present at the municipal level within these three metropolitan areas.

2. Distribution of crime in Vancouver

Table 1 shows the counts and rates of various crimes in Vancouver. Though the minimum count of crime across census tracts (CTs) is zero for all offences, the zero count CTs are all very small area census units on the boundary between Vancouver and its neighbouring eastern municipality, Burnaby. In some cases these CTs fall between roads. Consequently, the lack of crime in these CTs may simply be because of spatial data quality (roads not being properly aligned with CTs), or the Burnaby Royal Canadian Mounted Police (RCMP) may have been allocated to any calls for service from these CTs.

Table 1

Counts and rates of incidents reported by police in Vancouver, 2001

<table>
<thead>
<tr>
<th>Count of incidents</th>
<th></th>
</tr>
</thead>
</table>
### Hot spots of crime in Vancouver and their relationship with population characteristics

<table>
<thead>
<tr>
<th></th>
<th>CT average</th>
<th>CT minimum</th>
<th>CT maximum</th>
<th>Total, all CTs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total incidents</strong></td>
<td>539</td>
<td>0</td>
<td>6642</td>
<td>59340</td>
</tr>
<tr>
<td><strong>Total violent incidents</strong></td>
<td>106</td>
<td>0</td>
<td>2448</td>
<td>11629</td>
</tr>
<tr>
<td><strong>Total property incidents</strong></td>
<td>434</td>
<td>0</td>
<td>5802</td>
<td>47711</td>
</tr>
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</table>

#### Selected offences

<table>
<thead>
<tr>
<th>Offence</th>
<th>CT average</th>
<th>CT minimum</th>
<th>CT maximum</th>
<th>Total, all CTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arson</td>
<td>2</td>
<td>0</td>
<td>9</td>
<td>170</td>
</tr>
<tr>
<td>Assault</td>
<td>68</td>
<td>0</td>
<td>948</td>
<td>7459</td>
</tr>
<tr>
<td>Auto theft</td>
<td>211</td>
<td>0</td>
<td>3589</td>
<td>23263</td>
</tr>
<tr>
<td>Breaking and entering</td>
<td>118</td>
<td>0</td>
<td>497</td>
<td>13024</td>
</tr>
<tr>
<td>Drug incidents</td>
<td>8</td>
<td>0</td>
<td>355</td>
<td>917</td>
</tr>
<tr>
<td>Homicide</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Prostitution</td>
<td>19</td>
<td>0</td>
<td>428</td>
<td>2064</td>
</tr>
<tr>
<td>Robbery</td>
<td>11</td>
<td>0</td>
<td>174</td>
<td>1251</td>
</tr>
<tr>
<td>All sexual offences</td>
<td>4</td>
<td>0</td>
<td>17</td>
<td>440</td>
</tr>
<tr>
<td>Shoplifting</td>
<td>23</td>
<td>0</td>
<td>614</td>
<td>2839</td>
</tr>
<tr>
<td>Theft</td>
<td>102</td>
<td>0</td>
<td>1716</td>
<td>11254</td>
</tr>
</tbody>
</table>

#### Rate of incidents per 1,000 residential population

<table>
<thead>
<tr>
<th></th>
<th>CT average</th>
<th>CT minimum</th>
<th>CT maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total incidents</strong></td>
<td>101</td>
<td>0</td>
<td>998</td>
</tr>
<tr>
<td>Offence</td>
<td>CT average</td>
<td>CT minimum</td>
<td>CT maximum</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>Total violent incidents</td>
<td>19</td>
<td>0</td>
<td>245</td>
</tr>
<tr>
<td>Total property incidents</td>
<td>82</td>
<td>0</td>
<td>872</td>
</tr>
<tr>
<td><strong>Selected offences</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arson</td>
<td>0.29</td>
<td>0</td>
<td>1.42</td>
</tr>
<tr>
<td>Assault</td>
<td>12.94</td>
<td>0</td>
<td>129.28</td>
</tr>
<tr>
<td>Auto theft</td>
<td>39.51</td>
<td>0</td>
<td>539.46</td>
</tr>
<tr>
<td>Breaking and entering</td>
<td>22.76</td>
<td>0</td>
<td>74.70</td>
</tr>
<tr>
<td>Drug incidents</td>
<td>1.46</td>
<td>0</td>
<td>42.15</td>
</tr>
<tr>
<td>Homicide</td>
<td>0.02</td>
<td>0</td>
<td>0.40</td>
</tr>
<tr>
<td>Prostitution</td>
<td>3.38</td>
<td>0</td>
<td>57.35</td>
</tr>
<tr>
<td>Robbery</td>
<td>2.23</td>
<td>0</td>
<td>37.14</td>
</tr>
<tr>
<td>All sexual offences</td>
<td>0.77</td>
<td>0</td>
<td>4.24</td>
</tr>
<tr>
<td>Shoplifting</td>
<td>4.89</td>
<td>0</td>
<td>92.29</td>
</tr>
<tr>
<td>Theft</td>
<td>19.25</td>
<td>0</td>
<td>257.93</td>
</tr>
</tbody>
</table>

**Rate of incidents per 1,000 ambient population**
Though it is no surprise that there are census tracts with zero reported crimes once the analysis focuses on crime categories with a low number of offences city-wide, the presence of zero reported crimes for census tracts within the broad classifications of violent and property crime may be problematic. This may be particularly true if there are a large number of such census tracts. However, there are only four census tracts with zero reported violent crime and three census tracts with zero reported property crime. These census tracts have residential population counts that range from 5100 to 20,000 (violent crime) and 5100 to 11,000 (property crime), despite their small size. Additionally, the first census tracts in Vancouver to report a positive number of crimes do have low counts: 10 crime incidents (violent crimes) and 2 crime incidents (property crimes). Consequently, the analysis is carried out with little concern for bias.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total property incidents</strong></td>
<td>144</td>
<td>0</td>
<td>1353</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Selected offences</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arson</td>
<td>0.08</td>
<td>0</td>
<td>0.97</td>
</tr>
<tr>
<td>Assault</td>
<td>4.99</td>
<td>0</td>
<td>90.14</td>
</tr>
<tr>
<td>Auto theft</td>
<td>15.07</td>
<td>0</td>
<td>250.06</td>
</tr>
<tr>
<td>Breaking and entering</td>
<td>7.93</td>
<td>0</td>
<td>104.67</td>
</tr>
<tr>
<td>Drug incidents</td>
<td>0.56</td>
<td>0</td>
<td>18.61</td>
</tr>
<tr>
<td>Homicide</td>
<td>0.01</td>
<td>0</td>
<td>0.26</td>
</tr>
<tr>
<td>Prostitution</td>
<td>0.67</td>
<td>0</td>
<td>10.89</td>
</tr>
<tr>
<td>Robbery</td>
<td>0.86</td>
<td>0</td>
<td>27.61</td>
</tr>
<tr>
<td>All sexual offences</td>
<td>0.25</td>
<td>0</td>
<td>2.91</td>
</tr>
<tr>
<td>Shoplifting</td>
<td>1.69</td>
<td>0</td>
<td>35.04</td>
</tr>
<tr>
<td>Theft</td>
<td>7.57</td>
<td>0</td>
<td>97.89</td>
</tr>
</tbody>
</table>
In order to provide a reference of locations in Vancouver for those not familiar with the City, Map 1 provides the locations of the central business district, the Downtown Eastside, and the major thoroughfares, referred to below.

Despite the complete lack of crime in a small handful of Vancouver CTs, inspection of Map 2 (violent crimes) shows that the distribution of crime in Vancouver is far from random or uniform—similar results have been found in other Canadian studies (Wallace, Wisener and Collins, 2006; Fitzgerald, Wisener and Savoie, 2004; Savoie, Bédard and Collins, 2006).

The spatial pattern of violent crime as shown in Map 2 is most apparent. Violent crime is concentrated in Vancouver’s central business district, the Downtown Eastside and its surrounding areas, along the major thoroughfares, and, to some extent, on the east side of the city. This pattern of crime concentration in the central business district (and the Downtown Eastside that is on its border) has been a well-known fact in criminological research for more than 75 years (see Shaw & McKay, 1931; Schmid 1960a, 1960b; Brantingham and Brantingham, 1984); has long been apparent in Vancouver (Macdonald, 1992) and has been documented recently for other Canadian cities (see Heisz, 2005).

The distribution of property crime is not shown because it is more difficult to discern due to the sheer volume of property crime in Vancouver—the Vancouver CMA has more property crime incidents than either of the Toronto or Montreal CMAs, despite the fact that the Toronto CMA has 2.35 times the population of the Vancouver CMA and the Montreal CMA has 1.75 times the population of the Vancouver CMA. However, property crime does reveal a very similar pattern to that of Map 2: property crime is concentrated in Vancouver’s central business district, the Downtown Eastside and its surrounding areas, the major thoroughfares, and the east side of the city.

| Map 1: Vancouver’s major thoroughfares and locations, 2001 |
Map 2: Distribution of violent crime incidents, Vancouver, 2001
Based on 10056 violent crime calls for service.

Source: Vancouver Police Department Calls for Service Database.

Turning to the hot spot maps of violent and property crime (Map 3 and Map 4), however, the hottest spots for violent and property crime are somewhat different. The hot spot for violent crime is in the Downtown Eastside, one of the oldest areas of the city. This area is well-known for its problems with drugs, prostitution, and the highest rate of HIV infection in the western world (Babineau, 2005). This area is a classic “zone in transition” according to social disorganization theory: a place with low social cohesion and high crime.

Property crime, Map 4, has its hot spot right in the central business district. The Downtown Eastside is a place of intense property crime, but no more so than many other areas of the city such as most of Broadway, a major thoroughfare that runs east-west. This spatial pattern is most likely driven by the spatial pattern of automotive
theft, the highest volume property crime (see, also, Weigman & Huan, 1992). Though the maps showing the location of hot spots for selected types of offences within the city are provided in an appendix, there are some results worth noting. First most of the sub-categories within property and violent crime do follow the spatial patterns outlined above. However, there are a few notable differences.

Prostitution (Map 19) is the first different pattern of note. Though there is some concentration of prostitution in the Downtown Eastside, the hot spots for prostitution in 2001 are along Kingsway, another one of Vancouver’s major thoroughfares, which is a traditional area for street prostitution in Vancouver. The second crime classification to note is sexual assault (Map 23). The highest concentration of sexual assault is in the Downtown Eastside, but this crime has a number of other hot, or at least warm, spots throughout the city. A similar situation occurs with shoplifting (Map 25). Wherever there are a large number of commercial outlets acting as crime generators (Brantingham and Brantingham 1993, 1994, 1995) there are hot spots of shoplifting. This appearance could be confirmed using land use data as in previous hot spot studies of cities in Canada (see Wallace, Wisener and Collins 2006; Fitzgerald, Wisener and Savoie, 2004; Savoie, Bédard and Collins, 2006). Land use data were not available to us for the purposes of this project.

Map 3: Kernel density distribution of violent crime incidents, Vancouver, 2001
Based on 10056 violent crime calls for service.

Source: Vancouver Police Department Calls for Service Database.

Map 4: Kernel density distribution of property crime incidents, Vancouver, 2001
Based on 47711 property crime calls for service.

Source: Vancouver Police Department Calls for Service Database.

The distribution of hot spots in Vancouver changed significantly when examined using the risk-adjusted hot spot method discussed in the methodology section below. The population at risk, the ambient population, used for the calculation of the risk-adjusted hot spot method is also discussed in the methodology section below. Aside from the presence of a slightly higher crime density in violent crime, the majority of the spatial distinctions between violent crime (Map 5) and property crime (Map 6) disappeared.

Map 5: Kernel density distribution of violent crime incidents and population at risk,
Vancouver, 2001
Based on 10056 violent crime calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory.

Rather than there being any areas that can be identified as hot spots, some areas are simply a little warmer than others. Though there is still a spatial pattern observable on each of these maps, controlling for the ambient population at risk has significantly altered the analysis. Examination of the full population at risk changes our understanding of the intensity of crime.

This result is even more apparent when observing the relative-risk hot spot maps for the more detailed crime categories. In a number of cases: arson (Map 8), homicide (Map 18), sexual assault (Map 24), and theft (Map 28), the hot spots have all but
disappeared. This illustrates the importance of analyzing the appropriate data (absolute versus relative measures), as shown further in the following sections.

Map 6: Kernel density distribution of property crime incidents and population at risk, Vancouver, 2001

Based on 47711 property crime calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory.

3. Neighbourhood characteristics and crime: descriptive analysis
Spatial, or environmental/ecological/neighbourhood, studies of crime date back to the early nineteenth century (Glyde, 1856; Guerry 1833; Quetelet 1842). However, contemporary studies of the relationship between neighbourhoods and crime have their roots in the work of Shaw (1929) and Shaw and Mackay (1931, 1942).

The research work of Shaw and Mackay (1942) led to development of social disorganization theory. The primary findings of this research have been that neighbourhood poverty and/or social deprivation, population instability, and ethnic heterogeneity have strong relationships with the spatial distribution of criminal activity (Ackerman, 1998; Cahill and Mulligan, 2003; Harries, 1974). The underlying assumption is that these neighbourhood conditions lead to a collapse of informal social control within the neighbourhoods and a consequent rise in delinquent and criminal activity by residents. Most of the recent empirical work in this tradition has used variables such as income levels, unemployment rates, the number or percent of rental units, the percent of single-parents, the degree of ethnic mix, and the percentage of college graduates (Andresen, 2006a, 2006b; Cahill and Mulligan, 2003; Davies, 2006; Harries, 1995; Sampson and Groves, 1989; Stark, 1996).

Another theoretical framework that is commonly employed in neighbourhood analyses of crime is routine activity theory (Cohen and Felson, 1979). Cohen and Felson (1979, 588) “hypothesize that the dispersion of activities away from households and families increases the opportunity for crime and thus generates high crime rates”. Therefore, the changes in the socio-demographic and socio-economic characteristics of the population in a neighbourhood, in part, drive the crime rate. These changes may occur across time, as studied by Cohen and Felson (1979), or may be changes that occur across space (see Miethe and McDowall, 1993; Miethe and Meier, 1990; Miethe, Stafford and Long, 1987; Phipps, 2004; Rountree, Land and Miethe, 1994; and Sampson and Lauritsen, 1990). Generally speaking, age, ethnicity, and marital status have proved to be the most powerful predictors of victimization in the routine activity theory framework (Cohen, Kluegel and Land, 1981; Gottfredson, 1986; Cohen and Cantor, 1980).

This section of the analysis explores the relationship between these and other socio-economic, population, and dwelling characteristics (based on the two theoretical frameworks briefly outline above) and the 2001 rates of violent and property crime in Vancouver census tracts (CTs). For the purposes of tractability in the analysis and comparability with the past studies of the spatial distribution of crime in Canadian cities, total violent and property crime rates are employed rather than the varied
individual offence types shown in Table 1. All of the characteristics employed in the following analysis are sourced from the 2001 Census, as outlined in the Methodology section below.

In order to examine the relationship between the various neighbourhood characteristics and crime, the present analysis follows that undertaken by Wallace, Wisener and Collins (2006), Fitzgerald, Wisener and Savoie (2004), and Savoie, Bédard, and Collins (2006) to maximize comparability between studies of various Canadian cities. As such, the 110 CTs are separated into high crime and low crime areas: 28 CTs are labelled as high crime (the top 25 percent of CTs for both violent and property crime), with the remaining 82 CTs being labelled as low crime. It should be noted that this separation may be artificial, only indicating those CTs that have relatively high and low crime rates and that there is much variation within each of these two categories.

There are many significant differences between the high and low crime neighbourhoods that are consistent for both violent and property crime. However, not all of these differences are expected given the predictions of social disorganization and routine activity theories. Most of these deviations from expectations, however, are understandable within the particular context of Vancouver. The comparison of high and low crime rate neighbourhoods is first undertaken using crime rates calculated using the residential population of each CT (the conventional approach) and then the comparison is done using crime rates calculated using the ambient population of each CT.

**Figure 2. Demographic characteristics in neighbourhoods with high and lower resident-based rates of violent crime, Vancouver, 2001**

* differences between high-crime and lower-crime means are statistically significant at: $p < 0.01$.

**Notes:** High-crime = CTs falling into the highest 25% (28) of crime rate neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 residential population; $n = 110$ Census Tracts.

**Sources:** Vancouver Police Department Calls for Service Database, 2001 and Census, 2001.
**Figure 3. Demographic characteristics in neighbourhoods with high and lower resident-based rates of property crime, Vancouver, 2001**

* differences between high-crime and lower-crime means are statistically significant at: \( p < 0.01 \).

**Notes:** High-crime = CTs falling into the highest 25% (28) of crime rate neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 residential population; \( n = 110 \) Census Tracts.

**Sources:** Vancouver Police Department Calls for Service Database, 2001 and Census, 2001.

Figure 2 (violent crime) and Figure 3 (property crime) show the relationship between the demographic characteristics of neighbourhoods and crime. When the variables are significant for both violent and property crime, the differences between high and low crime areas are consistent. In line with expectations, high violent crime areas have a greater proportion of recent movers (24 versus 17 percent) and those who have never been married (45 versus 33 percent). Contrary to expectations, however, those same high crime areas have lower proportions of young males (5 versus 6 percent) and fewer people of visible minority status (41 versus 47 percent). Although the difference for young males is statistically significant, it is of low magnitude. In order to understand the result with respect to visible minority status, as well as recent immigrants, one needs to know the context of these population groups in the Vancouver context. As Andresen (2006b) has found for Vancouver in 1996, these populations (many of which are from Hong Kong and Taiwan) tend to settle in relatively well-off neighbourhoods that have low crime rates (also see Ley, 1999 and Ley and Smith, 2000).

**Figure 4. Socio-economic characteristics in neighbourhoods with high and lower resident-based rates of violent crime, Vancouver, 2001**
* differences between high-crime and lower-crime means are statistically significant at: $p < 0.01$.

**Notes:** High-crime = CTs falling into the highest 25% (28) of crime rate neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 residential population; $n = 110$ Census Tracts.

**Sources:** Vancouver Police Department Calls for Service Database, 2001 and Census, 2001.

Turning to the socio-economic characteristics in Figure 4 (violent crime) and Figure 5 (property crime), the patterns are again similar for both crime categories: all but one of the results is in line with theoretical expectations. High crime areas have more people (on average) receiving government assistance (16 versus 10 percent), more people without a completed high school education (11 versus 9 percent), a higher unemployment rate (12 versus 7 percent), a lower average family income ($54 000 versus $75 000), and more people classified as low income (6 versus 5 percent). Contrary to the findings in Montreal, post-secondary completion is higher in high crime areas, significantly so for property crime. This measure of post-secondary education is broader than that used by Savoie, Bédard and Collins (2006), including graduates from vocational and technical programs. The result is curious, but may be related to *gentrification* in high crime neighbourhoods, discussed below.

**Figure 5. Socio-economic characteristics in neighbourhoods with high and lower resident-based rates of property crime, Vancouver, 2001**

* differences between high-crime and lower-crime means are statistically significant at: $p < 0.01$.

**Notes:** High-crime = CTs falling into the highest 25% (28) of crime rate neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 residential population; $n = 110$ Census Tracts.

**Sources:** Vancouver Police Department Calls for Service Database, 2001 and Census, 2001.

Housing characteristics, once again, show similar results for both violent crime (Figure 6) and property crime (Figure 7). Three of the variables have results consistent with
expectations: indicators of housing stress are generally associated with high crime neighbourhoods. The one result that does not conform to this expectation must be understood within the local Vancouver context.

High crime areas have more people that spend a large portion of their income on shelter (23 versus 12 percent); have fewer owner-occupied homes (27 versus 51 percent); have more dwellings in need of major repair (11 versus 8 percent), and have generally lower dwelling values ($221 000 versus $378 000)

The potential curiosity amongst this set of indicators is that high crime areas have fewer old houses (30 versus 36 percent). There are two reasons for this result. First, the wealthiest areas of Vancouver consist of many old houses that are not replaced as they age, but are restored because they are large and current city by-laws would not permit them to be replaced with similar sized houses. Second, many of the old working class neighbourhoods in Vancouver, that have many of the remaining older houses, have been bought up and restored by professionals in a process called *gentrification* (Ley, 2003). These houses tend to have relatively high values because of the cost of the restoration process as well as some on-going land speculation pressure that has yet to subside.

**Figure 6. Housing characteristics in neighbourhoods with high and lower resident-based rates of violent crime, Vancouver, 2001**

* differences between high-crime and lower-crime means are statistically significant at: \( p < 0.01 \).

**Notes:** High-crime = CTs falling into the highest 25% (28) of crime rate neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 residential population; n = 110 Census Tracts.

**Sources:** Vancouver Police Department Calls for Service Database, 2001 and Census, 2001.

**Figure 7. Housing characteristics in neighbourhoods with high and lower resident-based rates of property crime, Vancouver, 2001**
* differences between high-crime and lower-crime means are statistically significant at: $p < 0.01$.

**Notes:** High-crime = CTs falling into the highest 25% (28) of crime rate neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 residential population; $n = 110$ Census Tracts.

**Sources:** Vancouver Police Department Calls for Service Database, 2001 and Census, 2001.

Exploration of the violent and property crime rates based on ambient population in relation to the demographic, socio-economic, and dwelling characteristics of neighbourhoods identifies patterns that are very similar to those found using standard resident-based crime rates. Generally speaking, the same patterns hold for the ambient-based crime rates although the strengths of these relationships change slightly with some becoming stronger and others becoming weaker. The most notable change involves the ambient-based property crime rate. Average family income is no longer statistically different between the high and low crime areas, whereas there is statistically significant difference between them using the resident-based property crime rate ($62,000 versus $72,000). This is likely a result of the coarse nature of the classification of property crime, but it does show the difference that a crime rate calculation can make (see Andresen, 2006a; Boggs, 1965; and Harries, 1991 for further discussion of this issue).

**Figure 8. Demographic characteristics in neighbourhoods with high and lower ambient-based rates of violent crime, Vancouver, 2001**

* differences between high-crime and lower-crime means are statistically significant at: $p < 0.01$.

**Notes:** High-crime = CTs falling into the highest 25% (28) of crime rate neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 ambient population; $n = 110$ Census Tracts.

**Sources:** Vancouver Police Department Calls for Service Database, 2001 and Census, 2001.
Figure 9. Demographic characteristics in neighbourhoods with high and lower ambient-based rates of property crime, Vancouver, 2001

* differences between high-crime and lower-crime means are statistically significant at: $p < 0.01$.

Notes: High-crime = CTs falling into the highest 25% (28) of crime rate neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 ambient population; n = 110 Census Tracts.


Figure 10. Socio-economic characteristics in neighbourhoods with high and lower ambient-based rates of violent crime, Vancouver, 2001

* differences between high-crime and lower-crime means are statistically significant at: $p < 0.01$.

Notes: High-crime = CTs falling into the highest 25% (28) of crime rate neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 ambient population; n = 110 Census Tracts.


Figure 11. Socio-economic characteristics in neighbourhoods with high and lower ambient-based rates of property crime, Vancouver, 2001

* differences between high-crime and lower-crime means are statistically significant at: $p < 0.01$. 
Notes: High-crime = CTs falling into the highest 25% (28) of crime rate
neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 ambient
population; n = 110 Census Tracts.


Figure 12. Housing characteristics in neighbourhoods with high and lower
ambient-based rates of violent crime, Vancouver, 2001

* differences between high-crime and lower-crime means are statistically significant
at: $p < 0.01$.

Notes: High-crime = CTs falling into the highest 25% (28) of crime rate
neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 ambient
population; n = 110 Census Tracts.


Figure 13. Housing characteristics in neighbourhoods with high and lower
ambient-based rates of property crime, Vancouver, 2001

* differences between high-crime and lower-crime means are statistically significant
at: $p < 0.01$.

Notes: High-crime = CTs falling into the highest 25% (28) of crime rate
neighbourhoods; lower-crime = remaining 75% (82); rate per 1,000 ambient
population; n = 110 Census Tracts.


4. Neighbourhood characteristics and crime: multivariate analysis
Although most of the variables analyzed in the previous section showed either expected relationships or unexpected relationships that could be understood using local knowledge of Vancouver, such analyses are limited since these variables may not have much of an independent effect on crime rates, after considering other variables. As such, a multivariate analysis is also undertaken to control for the independent effect of each variable in the above analysis.

Following the lead of Savoie, Bédard and Collins (2006), the crime rate variables in this analysis are transformed by their natural logarithm. All of the independent variables used in the multivariate analysis are also transformed into the natural logarithms of their counts. The resulting parameters estimated in the regressions below can then be interpreted as elasticities (see Kennedy, 2003). Elasticities measure the degree of sensitivity between the dependent and independent variables: a one percent increase in an independent variable leads to a b-percent increase (or decrease if the parameter is negative) in the dependent variable.

4.1. Statistical modelling and spatial autocorrelation

Multicollinearity is not used as a criterion for removal of variables from the statistical analysis in this study. In this we differ from the practice followed in several prior Canadian crime mapping studies (Wallace, Wisener and Collins, 2006; Fitzgerald, Wisener and Savoie, 2004; and Savoie, Bédard and Collins, 2006). Multicollinearity is not a problem in a statistical analysis, a priori, and removing highly collinear variables or variables that have high variance inflation factors may result in parsimonious models that suffer from statistical bias. Multicollinearity does not bias estimated coefficients, does not affect the coefficient of determination, and does not violate any of the ordinary least squares assumptions (see Kennedy 2003, p. 206). However, multicollinearity may increase the standard error of a regression coefficient, causing it to be insignificant when a significant relationship is known to exist. Removing variables through the inspection of bivariate correlation tables or variance inflation factor analysis is problematic. This is apparent in Table 2.

Table 2 shows the bivariate correlations between all of the natural logarithms of the independent variables used in the regression analysis. The highest bivariate correlation exists between visible minorities and ethnic heterogeneity, $r = 0.99$. Additionally, the variance inflation factor for either of these variables is over 500, far greater than the usual critical threshold of 10. Despite this high degree of collinearity and multicollinearity, both of these variables are retained in 3 of the 4 statistical models reported below. This simply means that despite the high correlation between
these variables, there is still enough independent variation to warrant the inclusion of both variables in the models. As such, rather than removing variables from the analysis, a priori, a general-to-specific method is employed for the final model selection: for each crime rate, the statistical model begins with all independent variables; parameters are tested for significance (p-value = 0.10) and removed if insignificant; the final models for each crime are reported, displaying the remaining statistically significant independent variables in each case.

In the present context using spatial data, the use of ordinary least squares regression is problematic because of the likely presence of spatial autocorrelation. As a result, ordinary least squares most often violates the assumption of independent normal residuals. The estimated parameters within ordinary least squares remain unbiased, but the variance of the errors is unknown so proper statistical testing cannot take place. Consequently, spatial statistical procedures have been developed to control for spatial autocorrelation. Spatial regression (the spatial error model, in particular) is one such procedure that accounts the spatial autocorrelation to ensure parameter estimation is unbiased and variance is known.

Spatial autocorrelation is modelled using fifth- and sixth-order queen’s contiguity, including all lower-order neighbours—this high order was necessary to remove the spatial autocorrelation in the reported statistical models. Contiguity is defined as a spatial relationship of tangency. If two census tracts touch, even at the corners of each census tract, they are considered contiguous. All estimation is performed using the spatial error model and GeoDa 0.9.5i, a spatial statistical freeware package developed by Luc Anselin and his co-workers at The Spatial Analysis Laboratory (SAL) in the Department of Agricultural and Consumer Economics at the University of Illinois, Urbana-Champaign: <http://sal.agecon.uiuc.edu/geoda_main.php>.

An alternative spatial model is also available within GeoDa, the spatial lag model. However, the spatial lag model only controls for spatial autocorrelation in the dependent variable. When using socio-demographic and socio-economic variables, positive spatial autocorrelation is most often present: contiguous neighbourhoods tend to have similar property values, for example. Consequently, controlling for spatial autocorrelation is much easier if the spatial error model is used so that the spatial autocorrelation in both the dependent and independent variables is considered.

4.2. Results of the Multivariate Analysis
The results from the multivariate analysis are presented in Table 3. It includes the results for violent crime and property crime, both calculated as residential- and ambient-based crime rates. Though a coefficient of determination, or $R^2$, is not available in the spatial regression procedure, another measure is provided for model fit that is the squared correlation between predicted and actual values. As shown in Table 3, the model fit values for each of the four models are of moderate value, ranging from 0.55 - 0.69, with the ambient-based crime rates having the highest model fit values. All models retain 8 or 10 independent variables.

When significant, all estimated parameters are consistent in sign for all crime rates. Most variables also have their expected signs in relation to crime. Recent movers have a moderate positive impact on the ambient-based violent crime rate, implying the lack of social cohesion in neighbourhoods with high turnover. Those who have never been married have a substantial effect on all four crime rates. Visible minorities now have a strong positive impact on all four crime rates but ethnic heterogeneity has a negative effect on three of the four crime rates. This differs from the descriptive analysis, above, as visible minorities are now positively associated with crime. It appears as though ethnic heterogeneity is where the wealthier Vancouver immigrants are having their impact on neighbourhood crime rates. Once the heterogeneity of an area is controlled for, visible minorities have their “expected” effect on crime. The primary difference between these variables is that an area with a high degree of visible minorities may be ethnically homogeneous.

Post-secondary education is statistically significant for the resident-based violent crime rate only and that relationship is negative, as would be expected. The unemployment rate is positively associated with both violent crime rates. Low income is positively associated with the resident-based property crime rate, but spending more than 30 percent of one’s income on shelter (another traditional measure of poverty) is negatively associated with the resident-based property crime rate. This latter relationship may be related to the rapid increases in property values in Vancouver (in excess of 20 percent in recent years) without corresponding increases in incomes that force people to spend large portions of their income on mortgage payments or rent. Finally, the average dwelling value of a CT is negatively related to all four crime rates.

Contrary to expectations, young males, as in the descriptive analysis above, have a moderate negative effect on crime, but only on the resident-based property crime rate. The percentage of income within a CT coming from government assistance is negatively associated with all four crime rates. This result is counter to much research
on the spatial analysis of crime because the poor tend to steal from the poor. Higher proportions of residents who have not completed high school decrease all crime rates. Dwellings in need of major repair also decrease ambient-based crime rates, but this result may be due to the gentrification process, discussed above. Lastly, and most significantly, average family income in a CT increases all four crime rates. This is likely an interaction effect with the average dwelling value variable: wealthier areas, measured by both dwelling value and income have lower crime, but within those areas that have high crime, the people who have relatively more income are more attractive targets. This interaction, however, is not tested in the present analysis. As with the visible minority – ethnic heterogeneity relationship, this unexpected relationship and the explanatory hypothesis we suggest need further research.

**Table 2**

**Bivariate correlations of independent variables (natural logarithms), Vancouver census tracts, 2001**

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# Hot spots of crime in Vancouver and their relationship with population characteristics

<p>| Notes: | * p &lt; 0.05; ** p &lt; 0.01. |
| Table 3 | |
| <strong>Spatial autoregressive models for violent and property rates, Vancouver, 2001</strong> | | |
| | Violent crime rate | Property crime rate |
| | Resident-based | Ambient-based | Resident-based | Ambient-based |
| Recent movers | | 1.13* | | |
| Males, 15 - 24 | | | -1.75** |
| Never married | 3.15** | 2.36** | 5.77** | 5.38** |</p>
<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient 1</th>
<th>Coefficient 2</th>
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<tr>
<td>Visible minority</td>
<td>0.67**</td>
<td>5.53*</td>
<td>6.43*</td>
<td>12.01**</td>
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<td>Ethnic heterogeneity</td>
<td>-38.41*</td>
<td>-34.68</td>
<td>-78.17**</td>
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<td>Government assistance</td>
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<td>No high school</td>
<td>-1.21**</td>
<td>-1.33**</td>
<td>-1.97**</td>
<td>-2.39**</td>
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<td>Post-secondary</td>
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<td>Unemployment rate</td>
<td>0.50</td>
<td>0.79*</td>
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<tr>
<td>Average family income</td>
<td>4.63**</td>
<td>6.32*</td>
<td>8.95**</td>
<td>9.94**</td>
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<tr>
<td>Low income</td>
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<td></td>
<td>0.95*</td>
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<tr>
<td>&gt; 30% Spending on shelter</td>
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<td>-1.35*</td>
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<tr>
<td>Average dwelling value</td>
<td>-1.27**</td>
<td>-1.81**</td>
<td>-1.64**</td>
<td>-2.88**</td>
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<tr>
<td>Dwellings in need of major repair</td>
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<td>-0.44*</td>
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<td>Model fit</td>
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<td>0.60</td>
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<td>Spatial dependence (p-value)</td>
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<td>0.32</td>
<td>0.34</td>
<td>0.28</td>
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<tr>
<td>Queen’s contiguity order</td>
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**Notes:** * p < 0.05; ** p < 0.01; regression models include intercept; all estimated coefficients are elasticities.
**Sources:** Vancouver Police Department Calls for Service Database, 2001 and Census, 2001.

**5. Discussion**

This study has offered information about the spatial distribution of crime in the city of Vancouver using a combination of statistical analyses and crime mapping based on Geographic Information System (GIS) technology. The results of the analysis, ranging from descriptive to inferential to crime-mapping techniques, have shown that in Vancouver, like in other cities under investigation in Canada, crime is neither randomly nor evenly distributed across space. Rather, with a few exceptions, crime is concentrated in the central business district and surrounding areas that have suffered from demographic, socio-economic, and dwelling characteristics that are conducive to crime.

As shown in Winnipeg, and Regina, most of the crime in Vancouver is concentrated in or near the central business district. But similar to findings in Montreal, there are some crimes that exhibit multiple hot spots.

The descriptive bivariate results showed statistically significant differences for most neighbourhood characteristics in a comparison of high crime and low crime neighbourhoods. Consequently, as with many previous studies, this suggests that crime is more common in those neighbourhoods whose residents are at a disadvantage with regard to both social and economic resources. Neighbourhoods that are classified as high crime typically have higher population turnover, more single people, fewer immigrants and visible minorities, higher unemployment, lower family income, and more renters. These factors in and of themselves do not create crime, but they do create more opportunity for crime. Social disorganisation theory predicts that such neighbourhoods will exhibit lower levels of social cohesion and thereby make criminal acts easier. Such neighbourhoods also encourage routine activities that take people and property away from their homes, leaving them vacant and providing criminals with more targets. Consequently, particular neighbourhoods do not create more criminals, they merely create more criminal opportunities (Felson, 2002). These results were consistent for both property crime and violent crime, for both residential- and ambient-based crime rates.

The multivariate results, however, do differ from the bivariate results in some instances. The results are consistent across all crime rates, so only the general patterns will be discussed here. Most of the multivariate results are of no surprise
given past research on the geography of crime. Recent movers, single people, visible minorities, and low income are all related to increases the prevalence of crime, whereas post-secondary education and average dwelling values are related to decreases in crime. Of those variables, the greatest magnitude parameters were with single people and visible minorities. Though these variables cannot be controlled through policy, their presence in a neighbourhood may guide crime prevention and reduction initiatives.

However, it is the unexpected results that are of particular interest here. In the bivariate results, neighbourhoods with more recent immigrants, more visible minorities, and a greater degree of ethnic heterogeneity are related to low crime areas. However, in the multivariate results, though a high degree of ethnic heterogeneity was still negatively related to crime, visible minorities were strongly and positively associated with crime, particularly property crime using both the residential- and ambient-based crime rates. This seemingly contradictory finding may be understood by taking into account where these variables manifest themselves. Though a detailed analysis of these variables is beyond the scope of this study, some of the wealthier (and low crime) areas of Vancouver are ethnically heterogeneous and some of the areas of Vancouver with a high proportion of visible minorities are close to the high crime areas of the city. Two prime examples are Kerrisdale and Chinatown. Kerrisdale, though not the most ethnically heterogeneous area in Vancouver, does have a large contingent of wealthier immigrants and is a low crime neighbourhood. Chinatown, by definition, contains a large percentage of visible minorities and is contiguous to the Downtown Eastside. Though this does not explain this result, this is clearly an avenue for future research.

The second unexpected result was the positive relationship between average family income and crime. As was hypothesized above, it is expected more detailed analysis would show that this is a product of the crime levels experienced by relatively wealthier sub-areas within high crime neighbourhoods. The gentrification process, for instance, can distort average income values for a census tract while creating spatial juxtapositions of intense relative deprivation.

Although this sort of analysis cannot address social disorganisation or collective efficacy directly, the results of this neighbourhood analysis of crime in Vancouver is not inconsistent with the collective efficacy hypothesis that the level of social capital, defined as “social interactions and standards which facilitate decisions toward formal and informal collective measures in the interest of individuals and the community”
varies negatively with crime rates (Bursik, 1986, Sampson and Raudenbush, 1999; Savoie, Bédard and Collins, 2006, 39). This should really come as no surprise because, in essence, collective efficacy is the inverse of social disorganization. However, using the term collective efficacy allows us to use crime prevention and reduction programs to build the positive dimensions of society rather than trying to constantly get rid of the negative dimensions. Also, as stated by Shaw and McKay (1942) and Sampson and Groves (1989), the variables used in the present analysis do not have direct relationships with crime. Rather, variables such as unemployment, visible minorities, and income tend to foster or inhibit social organization / collective efficacy. In other words, a poor neighbourhood with high unemployment and many visible minorities need not be a high crime area. Building social organization / collective efficacy may not be an easy task for crime prevention and reduction programs, but it will likely be far easier than eliminating poverty, unemployment, and other aspects of social disorganization that may be controlled by public policy.

6. Limitations and future research areas

As with the previous studies of crime in Canadian cities, the present study has focussed on the distribution of crime and neighbourhood characteristics in one year, 2001. Because we only focus on one year, rather than investigating changes over time in both crime rates and neighbourhood characteristics, the inference presented here is limited. However, this is a common limitation of spatial analyses of crime. Since the work of Shaw and McKay (1942), very little work has been done to investigate the spatial-temporal dimensions of crime simultaneously (see Weisburd et al., 2004 for a notable exception). This is simply because of research budgets and the availability of address-level-crime-specific police data that spans many years. This type of crime data will begin to accumulate in Canada through various comprehensive police information systems such as BC PRIME and RCMP PROAS as well as the new version of the Incident-Based Uniform Crime Reporting Survey (UCR2). This gathering of data is also occurring in the United States, with the development of databases such as that at chicagocrime.org that collects crime data for the City of Chicago, Illinois. As these databases accumulate crime data and further censuses are conducted, a valuable resource will be available for spatial crime analysis. This will be particularly true for Canada because it performs the census every five years.

With regard to Vancouver, this type of analysis will be particularly interesting not just for the most recent 2006 Census, but for the 2011 Census as well. Vancouver is once
again on the verge of international attention with the 2010 Winter Olympics. Understanding factors related to change over time, for the Downtown Eastside in particular and the rest of the city in general, is important for developing crime prevention and reduction strategies as well as for the evaluation of current and future programs.

Another limitation, and opportunity for that matter, with this study is that it only uses police data to measure and understand the spatial distribution of crime in Vancouver. Though extant victim and offender surveys are not sufficiently detailed for use in crime analysis at city level, much less the neighbourhood level, the development of such surveys would prove most useful to improving our understanding of the spatial distribution of crime in Vancouver. The “dark figure” of crime is reported to be 2 to 3 times the official crime rate and may differ spatially from the official crime rate. If fine grained victimization data were available, it too would be important for developing crime prevention and reduction strategies as well as for the evaluation of current and future programs.

The combination of temporal address-level-crime-specific crime data and multiple sources of that crime data will provide the basis from which research investigating the relationship between crime and neighbourhoods can flourish. This research would then be able to be used as the foundation from which continuously improving crime prevention and reduction policies can be formulated and evaluated.

7. Methodology

7.1. Data sources

_Vancouver Police Department Calls for Service Database_

The data used to calculate the crime rates for Vancouver is the Vancouver Police Department (VPD) Calls for Service (CFS) Database generated by its Computer Aided Dispatch (CAD) system. The CFS Database is the set of requests for police service made to the VPD directly or from calls allocated to the VPD through the 911 Emergency Service. The information contained within the CFS Database includes both the location, and the complaint code/description for each incident. For all reported crimes, there is an initial complaint code and a complaint code filed by the officer on the scene. In all cases, the code supplied by the officer is taken to be correct. The advantage of the CFS Database is its raw form. It should be noted that these data are a
proxy for actual criminal activity data because a CFS does not necessarily imply that a crime has taken place. Few CFS are subsequently unfounded however.

Note that these crime counts will differ from those published through the Uniform Crime Reporting (UCR1) system. UCR1 counting rules over-emphasize the relative frequency of violent crimes against the person and under-emphasize the relative frequency of all other types of crimes. The crime definitions used in the Vancouver CAD system for police operational purposes are also somewhat different from the crime definitions into which they are subsequently sorted for UCR1 purposes.

Census of Population

On May 15, 2001, Statistics Canada conducted the Census of Population to produce a statistical portrait of Canada and its people. The Census of Population provides the population and dwelling counts not only for Canada but also for each province and territory, and for smaller geographic units, such as cities or districts within cities. The Census also provides information about Canada’s demographic, social and economic characteristics.

The detailed socio-economic data used in this study are derived from the long form of the Census, which is completed by a 20% sample of households. These data exclude the institutional population, that is, individuals living in hospitals, nursing homes, prisons and other institutions.

Ambient Population

The LandScan Global Population Database, provided by Oak Ridge National Laboratory, is a 24-hour ambient population estimate, at the resolution of 30 arc seconds by 30 arc seconds (latitude and longitude), approximately one square kilometer. This estimate measures how many people are expected to be in a given square kilometer at any time of the day and all days of the year through the incorporation of diurnal and seasonal population movements.

The LandScan database assigns each one square kilometer cell a value based on its relative attractiveness to people pursuing work, shopping, and recreational activities. The census population of sub-national units is then re-distributed based upon each cell's attractiveness to the population (Dobson, 2003; Dobson et al., 2003). The final database is an estimate of the population at the one kilometer by one kilometer scale that “integrates diurnal movements and collective travel habits into a single measure” and its “purpose is to distribute populations based on their likely ambient locations.
integrated over a 24-hour period for typical days, weeks, and seasons” (Dobson et al., 2000: 849 - 850).

The redistribution of the census population is undertaken using a probability coefficient based on road proximity, slope, land cover, and nighttime lights. Transportation networks (roads, rail, water, and air) are all excellent indicators of populations, particularly the road network density, which is positively related to population density; slope enters the calculations because human settlements are typically located on relatively flat terrain; land cover (desert, water, wetlands, ice, urban, etc.), due to suitability for human settlement, is an important factor (Dobson et al., 2000); and “[n]ighttime lights are the best available global indicator of where people live, work, and play, and the amount of light emitted is roughly proportional to the number of people” (Dobson, 2004: 577).

7.2. Description of variables

Crime variables

A long-established fact in the criminological literature is that the distribution of criminal incidents is concentrated at or near the city centre (Shaw & McKay, 1942; Schmid, 1960a, 1960b). Consequently, these areas, that tend to have low residential populations but high daytime populations, tend to have crime rates that are inflated because the true population at risk has not been taken into consideration (Andresen, 2006a; Boggs, 1965; Harries, 1991).

To better measure the crime rates for Vancouver CTs, crime rate calculations are calculated using both the residential population at risk and the ambient population at risk for comparison.

- Violent offence rates. Violent offences include assault, fight, hold up, homicide, robbery, stabbing, and sexual assault.
- Property offence rates. Property offences include arson, automotive theft (theft from and theft of), breaking and entering, and theft. In the VPD CFS Database there is no distinction between theft over $5000 and theft under $5000.

2001 Census of Population variables

Population characteristic variables

- Males aged 15 to 24 as a percentage of the total neighbourhood population. This age group is at highest risk of offending. This is a long-standing criminological fact as
well as being found with recent research (Andresen, 2006a; Hirschi and Gottfredson, 1983).

- Percentage of single persons in the neighbourhood, defined as single persons aged 15 and older who have never been married has a positive relationship with crime through routine activities (Cohen and Cantor, 1980; Cohen, Kluegel and Land, 1981).

- Percentage of the neighbourhood population immigrating to Canada between 1991 and 2001. Depending on the location, the existence of an existing social framework for immigrants to associate with, they may or may not be able to initially get involved in social participation within their neighbourhood, which is related to higher crime. This is an old fact in the criminological literature dating back to Shaw and McKay (1942), though more recent research has confirmed this relationship (Morenoff, Sampson, and Raudenbush, 2001; Sampson, Raudenbush and Earls, 1997; Sampson, 1997).

- Percentage of visible minority residents in the neighbourhood, one measure of ethnic diversity, is positively associated with crime (Cahill and Mulligan, 2003).

- Ethnic heterogeneity. The degree of ethnic mix has been found to be positively associated with crime (Cahill and Mulligan, 2003). Ethnic heterogeneity is measured using an index that ranges in value from one to one hundred, with one representing no ethnic mix and 100 representing a perfectly even mix of ethnic groups.

\[ \text{Ethnic heterogeneity} = \sum_{i=1}^{n} p_i \]

where \( p_i \) is the proportion of ethnic group \( i \) and \( n \) is the number of ethnic groups.

- Percentage of lone-parent families among economic families living in private households, as a measure of family disruption is positively associated with crime (Tseloni et al., 2002).

- Percentage of persons who have moved. Includes persons who, on Census Day, resided at an address other than the one where they were living one year earlier. Population turnover also has a long-standing positive relationship with crime because of greater difficulty in establishing neighbourhood cohesion (Shaw and McKay, 1942).

Socio-economic variables

The results from the Montreal, Regina, and Winnipeg research projects all showed significant differences between the socio-economic characteristics of high crime and low crime neighbourhoods: high crime neighbourhoods were characterized by reduced access to socio-economic resources (Wallace, Wisener, and Collins, 2006; Fitzgerald, Wisener, and Savoie, 2004; Savoie, Bédard, and Collins, 2006). Additionally a number
of other research studies covering both Canada and the United States have shown that socio-economic status is significantly related to crime (Andresen, 2006b; Morenoff, Sampson, and Raudenbush, 2001). Consequently, the following socio-economic variables are used in the current study:

- Percentage of population receiving government transfer payments, including employment insurance benefits; Old Age Security benefits, including the Guaranteed Income Supplement and the spouse’s allowance; net federal supplements; Canada and Quebec pension plan benefits; the Canada Child Tax Benefit; New Brunswick, Quebec, Alberta and British Columbia family allowances; the goods and services tax credit; workers’ compensation benefits; social assistance; and provincial or territorial refundable tax credits.
- Percentage of neighbourhood population aged 20 years and older without a secondary school diploma.
- Percentage of neighbourhood residents aged 20 and older who have obtained a post-secondary certificate, diploma, or degree.
- Percentage of neighbourhood population in private households with low income in 2000. Low income refers to private households that spend 20% more of their disposable income than the average private household on food, shelter and clothing. Statistics Canada’s low-income cut-offs (LICOs) are income thresholds that vary according to family and community size. Although LICOs are often referred to as poverty lines, they have no official status as such.
- Neighbourhood unemployment rate for population aged 15 and older participating in the labour force.
- Average household income in thousands of dollars.

Dwelling characteristic variables

- Percentage of dwellings constructed before 1961. The age of dwellings may be related to higher crime rates through the perception of physical disorder and decay and is also a characteristic of the “zone in transition” in a city that is a high crime area (Kelling and Coles, 1998; Shaw and McKay, 1942).
- Percentage of dwellings in need of major repairs. This variable refers to whether, in the judgement of the respondent, the dwelling requires any repairs (excluding desirable remodelling or additions). Major repairs refer to the repair of defective plumbing or electrical wiring, structural repairs to walls, floors or ceilings, etc. This variable is associated with higher crime rates in the same manner as the percentage of older dwellings. (Kelling and Coles, 1998; Shaw and McKay, 1942).
• Percentage of households spending more than 30% of total household income on shelter, including both owner-occupied and tenant-occupied households. This is a measure of housing affordability. The 30% figure is based on research indicating that when the shelter costs of low income households exceed 30% of their income, their consumption of other life necessities is reduced. Shelter expenses include payments for electricity, oil, gas, coal, wood or other fuels, water and other municipal services, mortgage payments, property taxes, condominium fees and rent. Decreased housing affordability within a neighbourhood is another indicator of socio-economic disadvantage.

• Percentage of owner-occupied dwellings in the neighbourhood. This variable is another measure of population turnover that is positively associated with crime (Harries, 1974; Ackerman, 1998; Shaw and McKay, 1942). The percentage of owner-occupied dwellings, however, captures neighbourhood stability and should be negatively associated with crime.

• Average dwelling value. The average dwelling value measures two dimensions of neighbourhoods. First, it is a measure of relative poverty that is positively associated with crime (Harries, 1995). And second it measures the suitability of a target, particularly for break and enter. More expensive homes are more likely to have more lightweight consumer durables to be stolen that are desirable (Cohen and Felson, 1979).

7.3. Geocoding

Wallace, Wisener and Collins (2006), Fitzgerald, Wisener and Savoie (2004), and Savoie, Bédard and Collins (2006) have all covered many of the aspects of geocoding, but there are a few notes we would like to add here.

Geocoding point locations of crimes (or any phenomena for that matter) always provides the potential for error. By their very nature, geocoding algorithms have issues regarding their accuracy (see Ratcliffe, 2001), but these procedures are not always able to find the specific addresses of some point locations even when these issues are not of any particular concern. At times, addresses are recorded incorrectly, only a 100-block is given, or the street network may be out of date. To deal with questions of the reliability of geocoded spatial point data, Ratcliffe (2004) ran simulations to find a minimum acceptable hit rate (perfect match). This hit, or success, rate was deemed to be 85 percent. The geocoding procedure used in the present analysis had a 93 percent match rate for all crime in Vancouver—all crimes were geocoded from one data set.
With such a high success rate in geocoding, all analysis is performed without concern for any bias.

### 7.4. Mapping hot spots: kernel density analysis

Kernel density analysis is one of many methods to understand the spatial distribution of crime data. The advantage of kernel density analysis is that it allows for the examination of criminal incident point data across neighbourhood boundaries and to see natural distributions and the areas where these incidents are concentrated. Kernel estimation was originally developed to estimate probability density from a sample of observations (Bailey and Gatrell, 1995). When applied to spatial point data, kernel density analysis allows for the creation of a smooth map of density values such that the density at each point on the map represents the concentration of points in the surrounding area.

In order to undertake this procedure, a rectangular grid is placed over the study area—technically any grid that does not have “holes” in it can be used. From each of the grids, measured from the centre of a grid cell, all points within the bandwidth are used to calculate the density. The bandwidth is the radius of the circle drawn around the centre of each grid cell. Using each of those points captured, the density value is calculated. Depending on the type of density calculation, each point may contribute equally to the density calculation or disproportionately depending on how far the point is from the grid centre. In the present analysis, a quadratic kernel is used that gives more weight to points closer to the centre of the grid cell.

To be consistent with previous studies, the grid cell size is specified at 100 square metres and the radius of the circle used is 1000 metres—the higher the radius, the smoother the image produced. Dual kernel density analysis is similar to that of a crime rate, such that it analyzes the distribution of two sets of point variables simultaneously. Consequently, the dual kernel density standardizes the distribution of crime based on some population at risk. In the present analysis the population at risk is the ambient population. In order to be able to create a dual kernel density, the ambient population needed to be converted into a point file, which was easily done using GeoDa. All kernel density analysis was undertaken using CrimeStat III, a spatial statistics program for the analysis of crime incident location. CrimeStat III is statistical freeware available from the United States National Institute of Justice.

In addition to the legend categories that range from low to high intensity, the maximum intensity value for each crime is included in the legend. This inclusion is
critical for the interpretation of the maps because some crime in Vancouver, homicide for example, though representing some “hot spots” has an incredibly low maximum intensity, 0.03 for the single kernel. Other crimes, such as automotive theft, have a rather high maximum intensity, 33.96 for the single kernel. The same legend could not be used for all crimes because of the extreme variation, so each of the hotspots must be interpreted as relative to each crime, not as an absolute measure across crime types.

8. Bibliography


**Appendix: Single and Dual Kernel Density Maps**

**Map 7: Single Kernel Density Distribution of Arson, Vancouver, 2001**
Map 8: Dual Kernel Density Distribution of Arson, Vancouver, 2001
Based on 170 arson calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory.

Map 10: Dual Kernel Density Distribution of Assault, Vancouver, 2001
Based on 7459 assault calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory

Map 12: Dual Kernel Density Distribution of Automotive Theft, Vancouver, 2001
Based on 23263 automotive theft calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory.

Map 14: Dual Kernel Density Distribution of Break & Enter, Vancouver, 2001
Based on 13024 break & enter calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory

Map 16: Dual Kernel Density Distribution of Drug Offences, Vancouver, 2001
Based on 917 drug offence calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory.

Map 17: Single Kernel Density Distribution of Homicide, Vancouver, 2001
Map 18: Dual Kernel Density Distribution of Homicide, Vancouver, 2001
Based on 12 homicide calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory

Map 20: Dual Kernel Density Distribution of Prostitution, Vancouver, 2001
Based on 2064 prostitution calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory.

Map 22: Dual Kernel Density Distribution of Robbery, Vancouver, 2001
Based on 1251 robbery calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory.

Map 23: Single Kernel Density Distribution of Sexual Assault, Vancouver, 2001
Map 24: Dual Kernel Density Distribution of Sexual Assault, Vancouver, 2001
Based on 440 sexual assault calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory.

Map 26: Dual Kernel Density Distribution of Shoplifting, Vancouver, 2001
Based on 2839 shoplifting calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory.

Map 28: Dual Kernel Density Distribution of Theft, Vancouver, 2001
Based on 11254 theft calls for service.

Source: Vancouver Police Department Calls for Service Database and Oak Ridge National Laboratory.

Footnotes

1. The ambient population is the relevant population at risk for all violent crimes, but may not always be appropriate for property crimes. For example, the ambient population is a good measure of the population at risk of automotive theft because of the automotive culture in North America: where there are people, there will be cars. However, for a property crime such as break and enter, the ambient population may not be the appropriate population at risk; rather, the number of dwelling units may be more appropriate—the appropriateness of the population at risk is context
dependent. Nevertheless, the ambient population is used as the population at risk for all crimes in this study for consistency.  

2. The results for dwelling values are not shown in Figures 6 and 7.  

3. The exception is ethnic heterogeneity $b$ value. Ethnic heterogeneity is an index, not a count. The interpretation of the value of the estimated parameter is the same, but the magnitude of the parameter will not have any particular interpretation.  

4. As well as its more modern cousin, neighbourhood efficacy theory.