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The decline and locational shift of automotive theft: A local level analysis

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ABSTRACT

Purpose: Investigate the changes in the spatial patterns of auto theft in Vancouver, British Columbia during a time of a significant crime drop.
Methods: Geo-referenced auto theft data, 2003 and 2013, is analyzed considering crime concentrations at the street segment level, kernel density estimation, and a nonparametric spatial point pattern test that identifies the similarity in spatial point patterns.
Results: Auto theft in Vancouver has dropped significantly, but does not appear to have a stable crime pattern. Specific and limited areas account for the crime drop in auto theft rather than occurring at all places. These places appear to be related to target suitability and, therefore, opportunity.
Conclusions: The crime drop for auto theft in Vancouver has occurred in particular places. This provides support for the implementation of situational prevention efforts.

Introduction

Crime occurs more in some places and not in others (Eck & Weisburd, 1995). By identifying where crime is clustering and why, prevention efforts can be targeted to these places. Crime is on the decline in Canada and determining where and why specifically it is declining is imperative to investing in what works. Limited funds are available for prevention efforts (Waller, 2006). Thus, what funding is available should be used for strategies that work in the micro-places that need it most. Micro-level studies of crime and place address how the local structure and character of places can lead to crime. Much of this research has addressed 'crime' in general, rather than particular types of crime (for an exception see Braga, Hureau, & Papachristos, 2010, 2011). However, one could assume that different types of crime, which have different causes, should be spatially concentrated in different ways.

The rate of auto theft specifically in British Columbia (BC) and in Canada dropped substantially over the past several years. Auto theft counts have dropped by more than 67% in Canada since 2003 (Statistics Canada, 2013). However, the theory and policy explanations for this striking decline are highly contentious (Farrell & Brantingham, 2014). A key theoretical and related policy question is whether the same explanation is true for all these types of crime declines or whether separate explanations or policies are required by crime type. This study examines how the concentration of spatially clustered and declining auto theft events in Vancouver occurred between the years of 2003 to 2013.

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Literature review

The international crime drop and Canada

According to the International Crime Victims Survey (ICVS) data, crime rates almost universally peaked in the 1990s, but then began to steadily decline (van Dijk, van Kesteren, & Smit, 2007). The decline was first observed in the United States (Blumstein & Wallman, 2006; Zimring, 2007). Similar declines soon followed in several other countries in Europe, as well as Australia, New Zealand and other developed countries (Farrell, Tilley, Tseloni & Mailley, 2011; Tonry, 2005; van Dijk et al., 2007). Several theorists in the United States attributed this decline to an improvement in policing and increase in imprisonment,[2] while other claimed that the positive effects of welfare-state programs on 'high risk for crime' families were responsible (review see: Levitt, 2004; Knepper, 2009, 2012; Farrell, 2013). However, improved policing and increased imprisonment were applicable primarily to the United States. In many of the declining crime rate countries, there were substantial differences in such areas.

Others have attributed the crime drop in Canada, and internationally, to an improvement in security technologies (Farrell & Brantingham, 2014; Farrell, Tseloni & Tilley, 2011). Specifically, home and vehicle security improvements would have reduced opportunities for crime, particularly property crime, that sustained the largest decline (Farrell, Tilley, et al., 2011; Tseloni, Mailley, Farrell, & Tilley, 2010; van Dijk, 2008). Beginning in the late 1970s and early 1980s, security-focused situational approaches to crime prevention were popularized by opportunity theorists. By the 1990s these prevention approaches were introduced widely into national crime prevention policies (Knepper, 2009). This is

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the only international policy trend that coincides with the decline in crime. Thus, no other criminological theory has been able to effectively explain the significant and almost universal decline in crime in the last twenty years (Farrell, Tilley, & Tseloni, 2014; Tseloni et al., 2010).

The rise and decline in auto theft

In order to analyze the decline and spatial distribution in auto theft, it is important to understand why it was a problem in the first place. In 1962, auto theft occurred at a rate of 200 per 100,000 persons in Canada (Pottie-Bunge, Johnson, & Baldé, 2005). By 1996, auto theft peaked at a rate of almost 600 per 100,000 persons. However, after 1996, the rate of auto theft began to decline, albeit slowly (Pottie- Bunge et al., 2005). This pattern is consistent with other countries (Brown & Thomas, 2003; Clarke & Harris, 1992; Fujita & Maxfield, 2012). Several authors argue that the observed increase in auto-theft can be explained by an increase in the number of automobiles available and, thus, the opportunities for auto theft (Farrell, Tseloni, et al., 2011; Mayhew, 1990; Wilkens, 1964). This perspective is consistent with routine activities theory.

A change in the routine activities of North American's led to a rise in auto theft. The routine activities of North Americans required more mobility. Consequently, there was an increase in the production and consumption of automobiles (Farrell, Tilley, et al., 2011). Areas with greater road density are subject to more traffic and particularly more street parking and have been shown to have high rates of auto theft (Copes, 1999). Furthermore, there was an increase in the population living outside of the city and commuting to work. This led to improvements in public transportation (Barclay, Buckley, Brantingham, Brantingham, & Whinn-Yates, 1996; Davis, 2006). However, many commuters still needed to drive to public transportation hubs and, in turn, park-and-ride parking lots were created. These parking lots were unguarded for several hours of the day, becoming excellent targets for motivated offenders (Barclay et al., 1996). An increase in suitable targets, combined with a lack in capable guardianship, increased the opportunities for auto theft.

But now auto theft is on the decline, as with other crime types around the world. As discussed below, there is no exception in Vancouver with a drop in auto theft of 84%, 2003 to 2013. Because auto theft is reliably reported (for insurance purposes) with reporting rates as high as 95% (Wallace, 2003), very little data are expected to be missing from any given analysis. Thus, analyzing the spatial trends in auto theft over time, in a large urban center, may help address crime decline hypotheses without the data limitations of other less reported crime types.

Crime and place

As with any form of analysis, one of the first choices to make is in regard to the unit of analysis. Recent research in the crime and place literature has consistently shown the importance of considering the micro-place because of spatial heterogeneity within larger spatial units (Weisburd, Bruinsma, & Bernasco, 2009): crime has been found to cluster at certain places or 'hot spots' (Sherman, Gartin, & Buerger, 1989), certain crimes cluster at particular places (Weisburd & Green, 1994), and crime hot spot trajectories can vary from block to block (Groff, Weisburd, & Yang, 2010). Moreover, the identification of hot spots has led to targeted crime prevention (Sherman & Weisburd, 1995). For example, target hardening, surveillance, increased community police presence and the implementation of legitimate activity generators have been shown to reduce crime in micro-places (Budd, 1999; Casteel & Peek-Asa, 2000; Eck, 1997, 2002; Feins, Epstein, & Widom, 1997; Kelling & Sousa, 2001; Knights & Pascoe, 2000; Lester, 2001; Poyner, 1993; Saville, 2009; Sherman et al., 1989; Skogan, 2006; Sorensen, 2003; Tseloni, Wittebrood, Farrell, & Pease, 2004).

Crime and place researchers have since demonstrated the consistency of high crime or high victimization areas over time (Braga et al., 2010, 2011; Curman, Andresen, & Brantingham, 2015; Ignatans & Pease, 2014; Weisburd, Bushway, Lum, & Yang, 2004). Similar to Sherman et al. (1989), Weisburd et al. (2004) found that very few street segments in Seattle (around 5%) accounted for 50% of crime; this pattern has been replicated in many cities across the United States and around the world (Andresen & Linning, 2012; Melo, Matias, & Andresen, 2015; Weisburd, 2015; Weisburd & Amram, 2014). More importantly this literature has demonstrated the stability of crime in these micro-places over time. Curman et al. (2015) replicated Weisburd et al. (2004) and found that in the city of Vancouver most street segments experienced stable crime trends over time. Ignatans and Pease (2014) looked at the distribution of victimization of households across time in Britain. They found that while the most victimized households benefited from the overall decline in crime over time—in that these houses experienced less victimization in general—the proportion of total victimization for these houses was increasing. These authors contributed spatial and temporal quantitative analysis to the field of crime and place. However, different types of crime over time still have yet to be examined.

The current study uses open-source property crime data from the Vancouver Police Department to address how has the concentration of spatially clustered and declining auto theft events in Vancouver occurred between the years of 2003–2013. As mentioned above, auto theft is of particular interest because it is one of the most commonly reported crimes (Wallace, 2003). No other crime, with the exception of homicide, has such a high level of reporting and, thus, the findings should be representative of the actual phenomena. In the case of auto-theft, reporting rates are extremely high because a report must be made in order to collect insurance monies. Theft from auto will also be considered as some have claimed a partial displacement from theft of auto to theft from auto may have occurred in recent years as a result of security (Brown, 2015).

Table 1
Descriptive statistics

Year	Auto theft count	Year	Auto theft count
2003	6337	2009	1886
2004	6084	2010	1467
2005	5035	2011	1100
2006	3689	2012	1152
2007	3330	2013	1000
2008	2416		

Data and methodology

Data

The city of Vancouver is the eighth largest municipality in Canada with a population just over 600,000 people. The data for this study are from open source police incident data from the Vancouver police department. These data span the years 2003 to 2013, inclusive. The types of property crime coded in this data set include: theft of a motor vehicle over $5000 and theft of a motor vehicle under $5000. Motor vehicle theft is an indictable offense and can be defined as depriving an owner, temporarily or permanently, of his or her property — in this case a motor vehicle (*Criminal Code*, 1985, RSC, s. 322 (1); 333.1(1)). Theft of auto, both under and over $5000, are combined to understand patterns in auto theft in general. The figures in Table 1 show that auto theft has declined in Vancouver from 6337 events in 2003 to 1000 events in 2013 a decline of 84.22%.

These data are at the 100-block level for privacy reasons. However, in order to geocode the data, exact addresses on these street segments were produced using a random number generator.[3] The vast majority of street segments in Vancouver fall upon the traditional grid network meaning that most street segments are relatively short and somewhat equal in size. There are a total of 11,730 street segments. Each segment is considered separately in this analysis. The street network is also stable over the eleven years of the study period.

Methodology

In order to identify where auto theft in Vancouver was concentrated and how that concentration differed from 2003 to 2013 we considered two statistical methods. The first was the identification of hot spots and used two techniques. Kernel density estimation was used to demonstrate the magnitude per unit area of theft of auto for each year in the study. A kernel density is useful for getting a general idea of where crime clusters because it smoothes over surfaces that may not be experiencing any crime. However, because auto theft locations were geocoded to the street segment, at a random place along that street segment, all kernel densities were estimated with varying output grid sizes; this had no impact on the location of the hot spots that were identified.

The second technique was the Getis-Ord or Gi* statistic that is associated with hot spot analysis (Chainey & Ratcliffe, 2005), and identifies which spatial clusters are statistically significant of either high values (hot spots) or low values (cold spots). This analysis was conducted for each year to determine if the identified kernel densities were statistically significant. These analyses were conducted by calculating the volume of auto theft in each dissemination area in Vancouver.[4] Because of the larger size of the spatial unit, the identified hotspots are not as fine-grained as those identified in the kernel density maps.

Following the hot spot analyses, we analyzed the change in auto theft on the street segments in these areas. Both spatial analysis techniques indicated a locational shift in auto theft from 2003 to 2013. In order to determine the change from 2003 the areas that were the densest were examined. In 2003, there were two large clusters of auto theft. In 2013, there were three small clusters. The street segments within these areas were selected and the number of auto thefts in each area were spatially joined and counted for the two years. This analysis can be found in Table 2.

In order to determine whether a statistically significant spatial shift in auto thefts occurred, we used Andresen's (2009) spatial point pattern test. This test identifies the degree of similarity between two datasets—see Andresen (2010), Andresen and Linning (2012), Andresen and Malleson (2011, 2014), and Tompson, Johnson, Ashby, Perkins, and Edwards (2015) for a variety of applications. In this context, the spatial point pattern test is appropriate to assess a potential locational shift in auto theft because it will verify if there has been a spatially homogeneous auto theft reduction in Vancouver, or if the crime drop in auto thefts only occurred in particular places. The spatial point pattern test can be summarized in the following steps: 1) identify one data set as the base (here it was 2003 auto thefts) and calculate the percentage of points within each spatial unit under analysis (street segments); 2) the other data set is deemed the test data (2013 auto thefts), and 85% of the test data are randomly sampled (with replacement) to calculate the percentage of points within each spatial unit under analysis—85% is based on the research by Ratcliffe (2004); 3) repeat this sampling process 200 times[5]; 4) calculate a 95% nonparametric confidence interval by calculating 200 percentages of points within each spatial unit of analysis from step 3 and, for each spatial unit of analysis, rank these percentages removing the top and bottom 2.5%; 5) if the base data set value within a spatial unit of analysis (2003 auto thefts in a street segment) falls within the 95% nonparametric confidence interval, that spatial unit of analysis if classified as similar; and 6) repeat step five for all spatial units of analysis. Further details are available in Andresen (2009) and Andresen and Malleson (2011).

A global Index of Similarity, S, can be calculated to measure the degree of similarity between the base and test data sets. The similarity index ranges between 0 (no similarity) and 1 (perfect similarity) and can be calculated by:

$$S = \frac{\sum_{i=1}^{n} s_i}{n},$$

where s_i is equal 1 if the pattern of two datasets are similar and 0 otherwise (this similarity is defined by step 5 described above); and n is the number of areas. Consequently, the similarity index measures the percentage of areas that have a similar spatial point pattern. In the literature cited above, a rule of thumb threshold for S has been used to indicate similarity. However, this “similarity” should not be considered in a dichotomous manner; rather, this value should be used as a guide. The threshold was identified in a similar to multicollinearity in a regression context. O'Brien (2007) has stated that a variance inflation factor (VIF) of approximately 5 to 10 or greater indicates multicollinearity that may be problematic in a regression context. In the context of correlation, this is equivalent to a range of 0.80 to 0.90. Therefore, in the results below, we consider an S-Index value of 0.80 to indicate similarity between two spatial point patterns. An important benefit of the spatial point pattern test is that the output can be mapped, that facilitates interpretation. This mapped output is particular instructive for our analysis below. A graphical user interface (GUI) was developed for the application of the spatial point pattern test that is freely available at the following web site: https://github.com/nickmalleson/spatialtest.

Results

The Kernel density analysis in Fig. 1 demonstrates two main hot spots (1 and 2) of auto theft. These are located in the downtown core in areas defined as Downtown or ‘Yaletown’ (hot spot 1) and the West End (hot spot 2). However, by 2013 (Fig. 2) the hot spots shifted to the Downtown Eastside, with three relative hot spots emerging (3, 4, and 5). Note that the scale changed substantially from 2003 to 2013 to reflect the 84 percent decline in auto theft. This means that the 2013 hot spots are only hot relative to elsewhere in 2013 and not relative to 2003.

The output from the Getis-Ord Gi* hot spots for 2003 and 2013 are shown in Figs. 3 and 4, respectively. Though much more of the downtown area shows as a hot spot in 2003 (Fig. 3), because of the larger

Table 2
Change in hot spots, Vancouver, 2003–2013

	2003		2013		Change over time		
	Total auto theft Count = 6337		Total auto theft Count = 1000		Proportion change	Raw count proportional change	Percentage change
	Raw count	Proportion of total auto theft	Raw count	Proportion of total auto theft	Change from 2003–2013	% Decline in crime count 2003–2013	% Change in proportion
Hot spot 1 (2003)	373	5.89	37	3.7	−2.19	−90.08%	−62.82
Hot spot 2 (2003)	209	3.29	22	2.2	−1.09	−89.47%	−66.87
Hot spot 3 (2013)	50	0.79	20	2.0	+1.21	−60.00%	+153.16
Hot spot 4 (2013)	71	1.12	21	2.1	+1.02	−29.58%	+87.5
Hot spot 5 (2013)	67	1.06	21	2.1	+1.04	−31.34%	+98.11
Total auto theft	770	12.15	121	12.10	−.05	−84.29%	−3.2

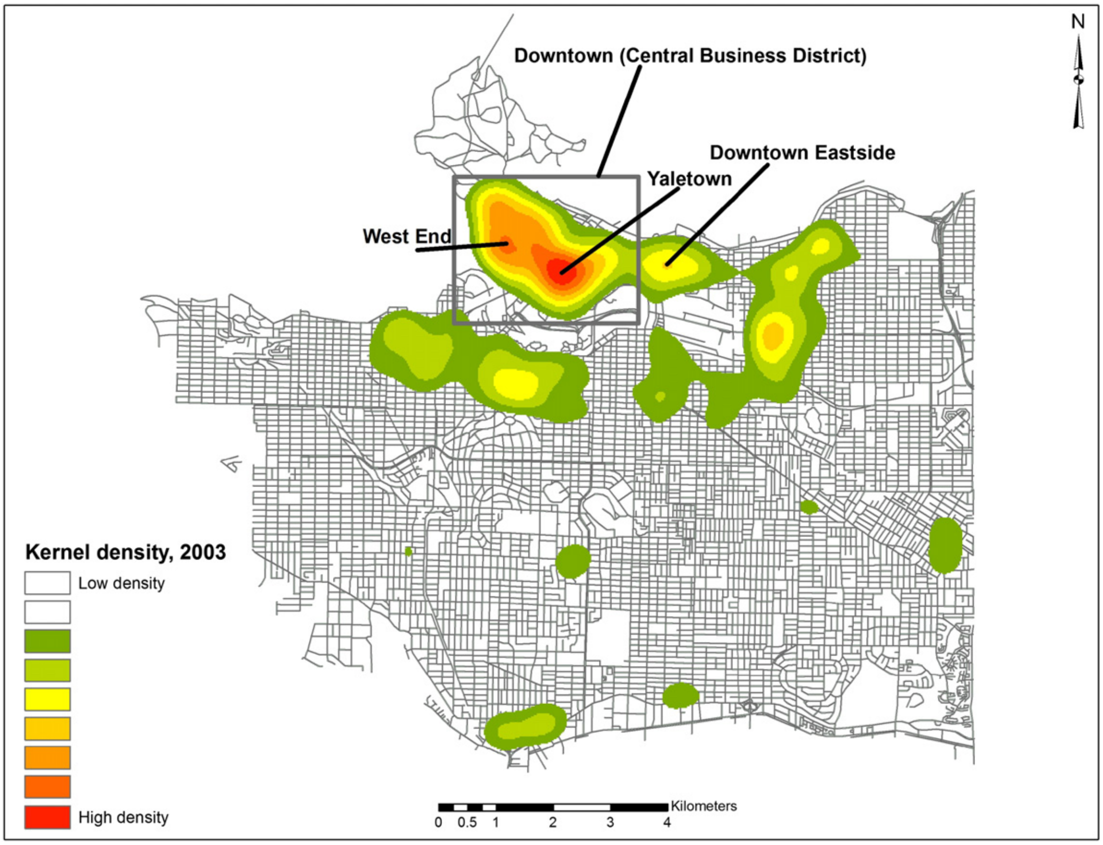

Fig. 1. Kernel density map, auto theft, Vancouver, 2003.

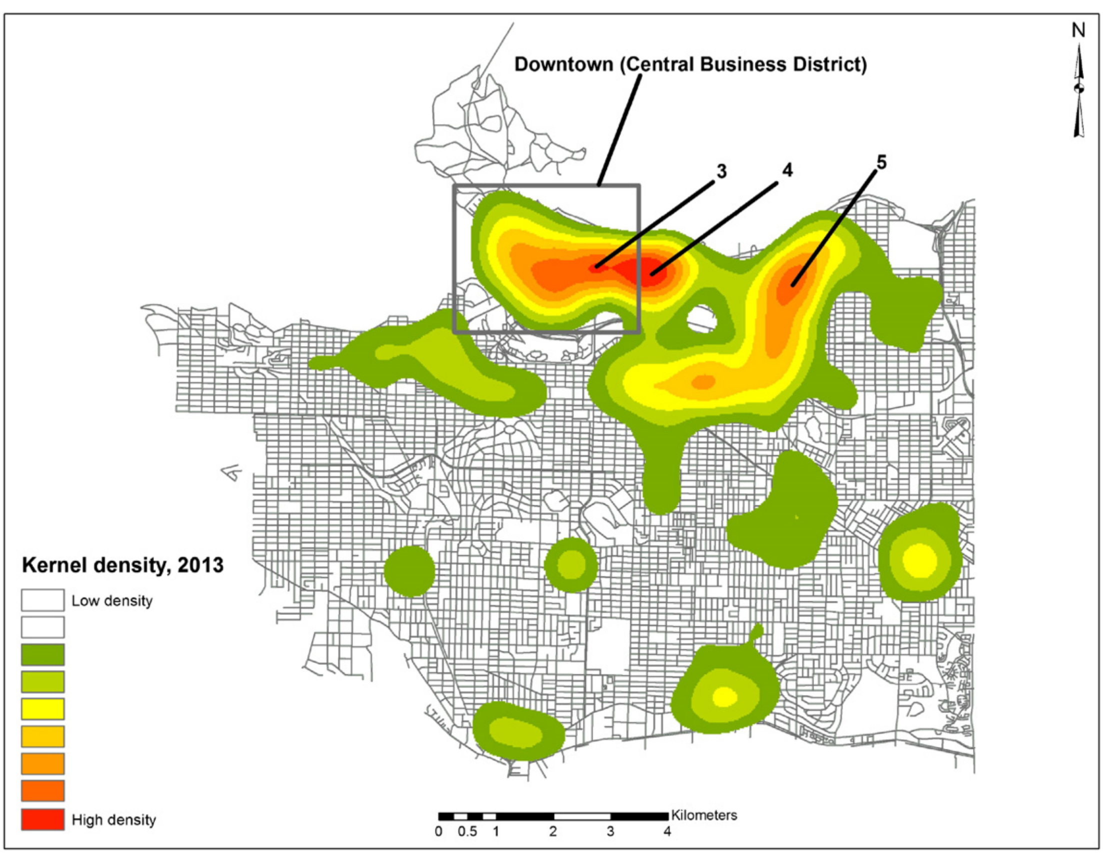

Fig. 2. Kernel density map, auto theft, Vancouver, 2013.

spatial units of analysis, the same general pattern emerges: downtown Vancouver is a hot spot for auto theft and so is the Downtown Eastside, but to a lesser extent. Fig. 4, representing 2013, still shows that there is a hot spot for auto theft in the downtown area, but there is a clear eastward shift and apparent expansion into the Downtown Eastside. The results of the Getis-Ord Gi* clearly support that the change in the hot spots for auto theft from 2003 to 2013 using kernel density estimation is a shift into the Downtown Eastside. Of course, in the context of the crime drop, the 'expansion' of the hot spot mostly reflects a slightly slower rate of decline of auto theft in these areas, as described next.

Table 2 demonstrates the change in auto theft counts in these hot spots from 2003 to 2013. The first two hot spots from 2003 are located in the central business district and the West End, respectively. In 2003 these areas had counts of auto theft events totaling 373 for hot spot one and 209 for hot spot two. By 2013 counts of auto theft in these areas had declined substantially, −90.08% for hot spot one and −89.47% for hot spot two, a −62.82% and −66.87% change in proportion, respectively. In 2013, three relatively dense hot spots around the Downtown Eastside emerged. However, auto theft had declined so much by this time that the raw counts for these three hot spots totals only 62, a substantial decrease from the counts in these areas in 2003. Although this is a decline from the total auto theft in these areas in 2003, proportionally these areas account for substantially more auto theft in 2013. Hot spot three (2013) increased by 153.16% proportionally, hot spot four increased 87.5% and hot spot five increased 98.11%.

The spatial point pattern test, Fig. 5, shows statistically significant declines (green), in the street segments that had auto theft in the years 2003 and 2013. In the central business district, Fig. 6, most street segments have either experienced statistically significant declines or no statistically significant change. However, 18 street segments in this area show statistically significant increases (red)—22 if including the edge of the Downtown Eastside. While a few dispersed street segments in the downtown core demonstrate a statistically significant increase, minor clustering appears in the street segments that correlate with the hot spots observed in Fig. 2. This test demonstrates that not only were declines in auto theft statistically significantly concentrated in the downtown core, but that the shift in hot spots to the Downtown Eastside was a statistically significant shift.

The global parameter produced by the spatial point pattern test was 0.729 when including all street segments (with and without auto theft) over the 11 years and 0.646 when excluding street segments without any auto theft. Thus, when including all street segments, 72.9% had stable proportional patterns of auto theft over eleven years and 27.1% fluctuated. However, when including only street segments that experienced auto theft, 64.6% were stable proportionally and 35.4% fluctuated in the intervening decade. This demonstrates only moderate spatial stability over time (with $S = 0.80$ considered as stable, as discussed above). This finding squares will with the hot spots of auto theft having shifted over time.

Discussion

The study examines spatial change across a most major drop in auto theft in Vancouver between 2003 and 2013. The results of the kernel density analysis and the spatial point pattern test demonstrate that auto theft in Vancouver is spatially concentrated. This is consistent with Sherman et al. (1989) who found that a large portion of crime in a city occurs in a relatively small amount of hot-spot areas. However, in Vancouver, the location of spatial concentration for auto theft shifted over time. In 2003, auto theft events were concentrated in the most expensive areas of the city. This makes sense as the most expensive cars, or the most desirable cars, are located there. By 2013, auto theft events were concentrated in the Downtown Eastside, once deemed "Canada's poorest postal code" and a socially disorganized neighborhood well known for high rates of crime across time (Andresen, 2014; Kumagai & McGuire, 2012). This shift requires explanation.

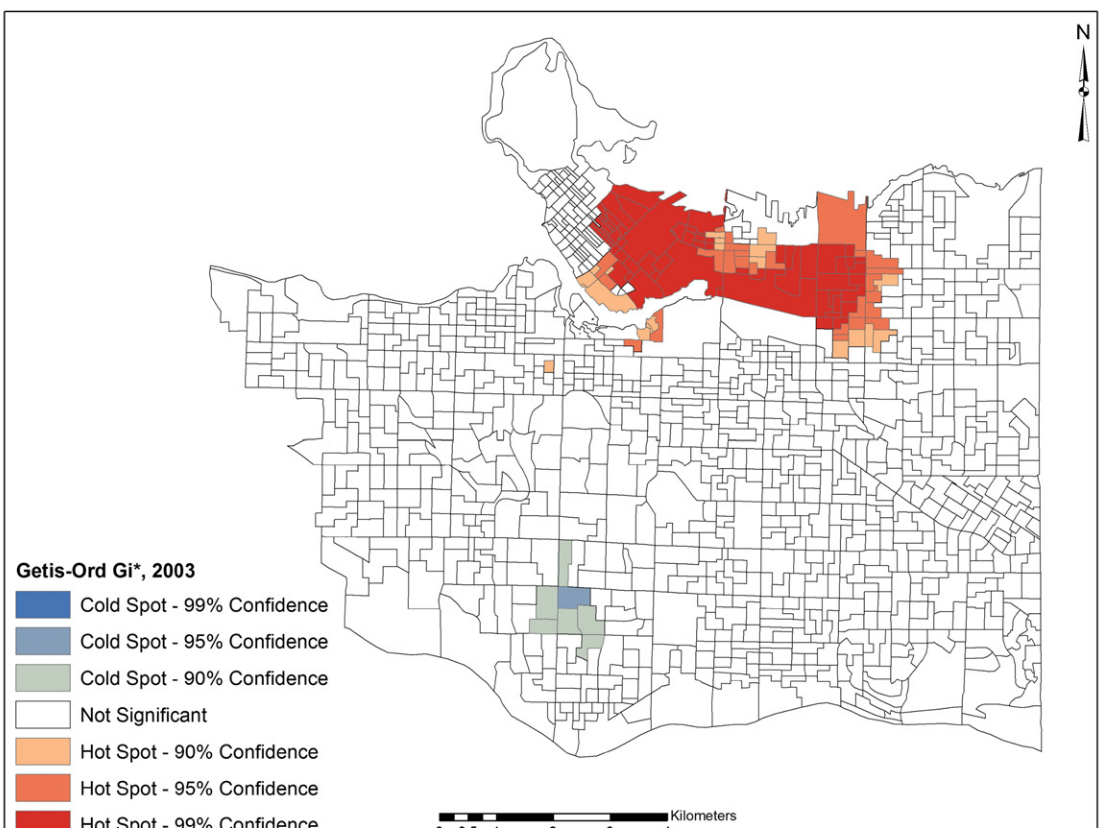

Fig. 3. Getis-Ord Gi*, auto theft, Vancouver dissemination areas, 2003.

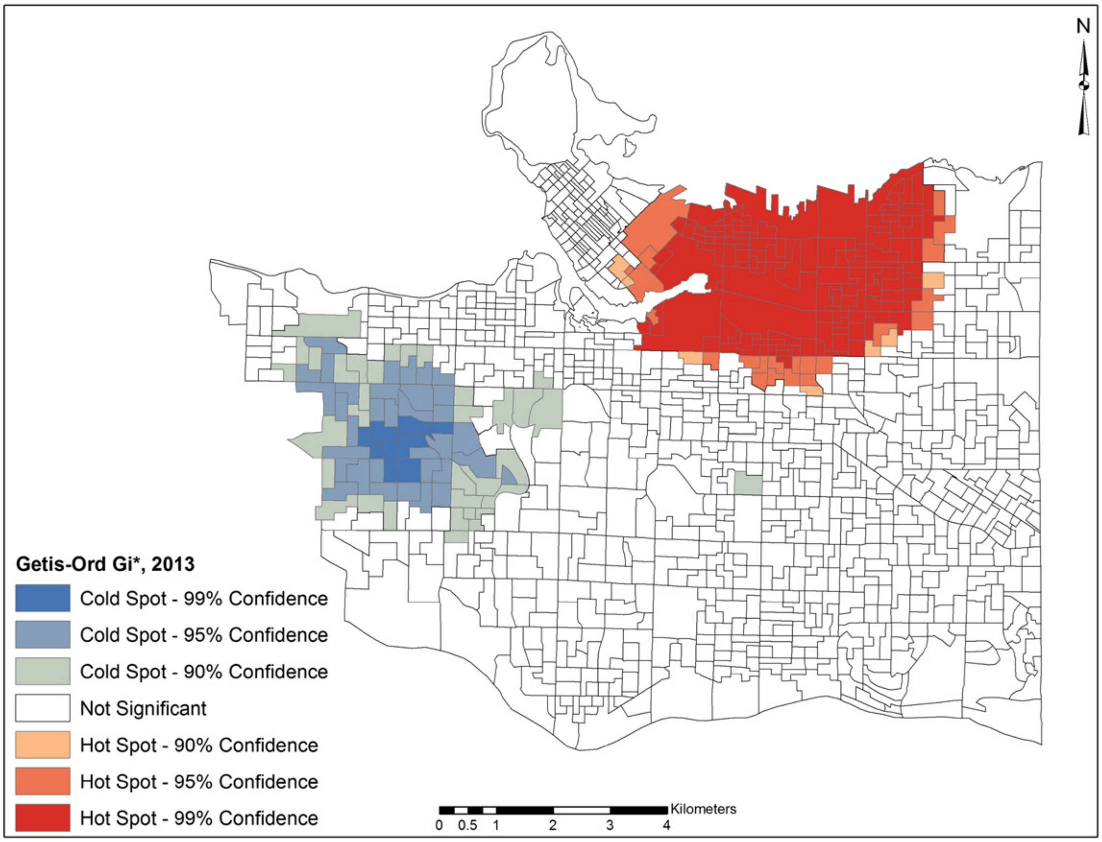

Fig. 4. Getis-Ord Gi*, auto theft, Vancouver dissemination areas, 2013.

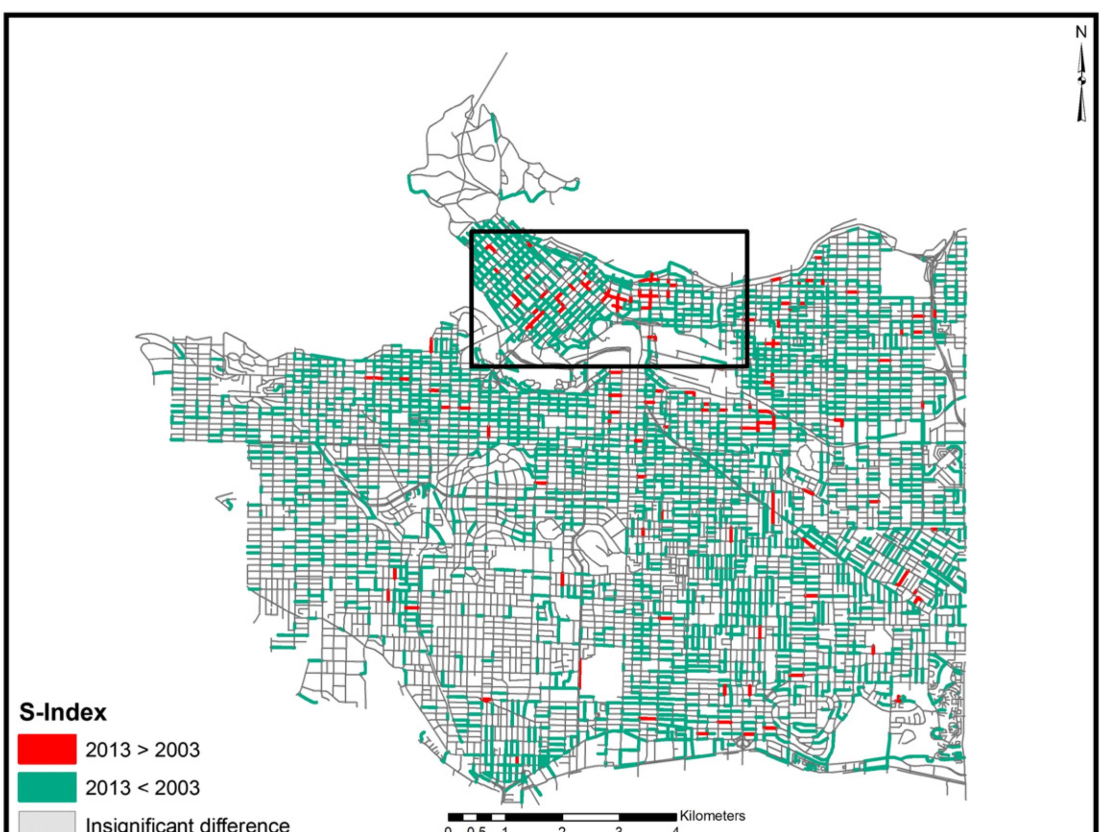

Fig. 5. Spatial point pattern test, Vancouver, 2003–2013.

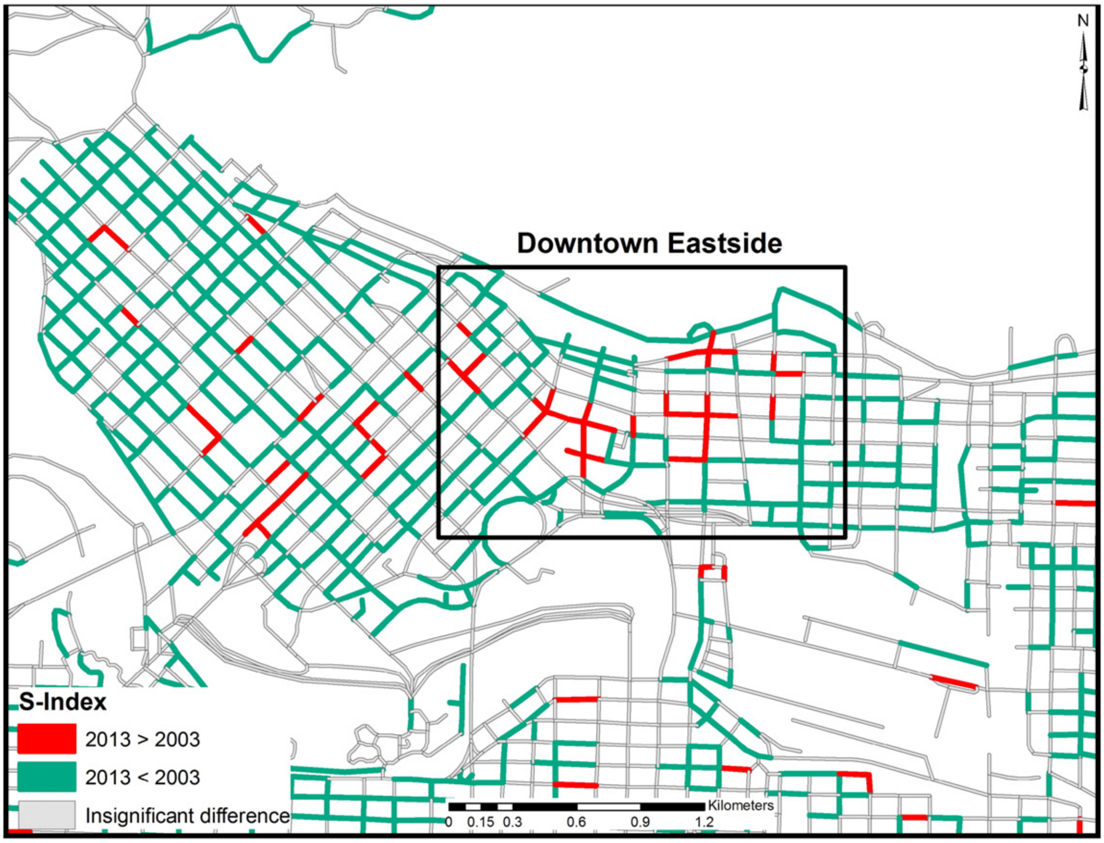

Fig. 6. Spatial point pattern test 2003–2013, statistically significant change in central business district and Downtown Eastside.

The security hypothesis offers an interpretation consistent with the shift in auto theft location. The most desirable cars would still be located in the central business district and the West End. However, legislation in 2007 made electronic immobilizers mandatory for all cars in Canada, and was anticipated by earlier security improvements to some models. Electronic immobilization refers to a device, located in the car key that is necessary to turn the engine over and start the car. If the key containing the electronic chip is not placed in the ignition, the car is unable to start (CBC News, 2007). Though introduced into several cars years earlier, these devices became mandatory in Canada in 2007 (CBC News, 2007). This legislation was introduced much later than several other countries (Brown & Thomas, 2003; Kriven & Ziersch, 2007; van Ours & Vollaard, 2013). However, in Winnipeg, as a result of an intensive and well-funded auto-theft reduction strategy, electronic immobilizers became mandatory a few years earlier. Winnipeg witnessed a significant decline in auto-theft before the rest of Canada (Linden & Chaturvedi, 2005). It may be that auto-theft declined so substantially in the central business district and the West End because these individuals could afford to buy or lease new more secure cars sooner. Arguably, individuals living in the Downtown Eastside do not have the means to purchase or lease new cars on a regular basis and, thus, the cars in these areas would be older and would not have the electronic immobilizers making them more suitable targets. Spatial variation in the impact of improved vehicle security could also be caused by factors such as changing land use in some specific street segments. Processes of gentrification and the fall and rise of particular businesses might affect local ambient vehicle populations and parking patterns. Again, further research would be needed to refine the precise manner in which land use change influences the number of available vehicles.

The difference in spatial concentration of auto theft over time reveals the importance of crime specific analyses. Place-based prevention strategies that target “high-crime” areas without addressing which types of crime are concentrated in what particular areas may fail to address specific crime opportunities in these areas. The findings also support the possibility that national and international declines in auto theft may be a result of changes in security measures. In that context, retrofitting of electronic immobilizers in remaining older cars may reduce auto theft further, although overcoming efforts to circumvent security improvements is likely to have a longer-term payoff.

No study is without limitations. While this is useful to understand spatial trends across the city, it does not provide specific answers as to why crime is occurring in these places, or why spatial concentration has shifted. We have claimed that security measures are a possible explanation, particularly because auto theft seems to demonstrate a different spatial trend over time, when compared to other crimes, which are spatially stable in the crime and place literature. However, this is no substitute for neighborhood safety audits (Doran & Burgess, 2012; Saville, 2009) that address place-based opportunities for auto theft, such as unsupervised parking garages or unsupervised motivated offenders.

The quality of the data is always subject to limitations as well. Police-recorded data are subject the issue of non-reporting. As previously mentioned, auto theft is the most commonly reported crime. However, the data span eleven years from the same city and the same reporting source (the Vancouver Police Department). While the issues of the dark figure of crime span across all police recorded data, the internal reliability of the data should be strong.

Future research on auto theft might progress upon the work developed here. Localized qualitative data on street segments that experienced major reductions in auto theft might facilitate study of the role of environmental design. Similarly, examining consistent cold-spots could provide information about place-based protective factors. Measures of the number of parking spots and auto concentration on each street would improve denominators in the analysis. Replication of the analysis in other cities is required to determine whether the finding apply generally. Additional information on the model and age of stolen cars might indirectly shed further light on the role of security because previous analyses suggest the average age of stolen vehicles would increase (Brown & Thomas, 2003).

Future research on other crime types might replicate aspects of the spatial approach used here. Both residential and commercial burglary may have experienced similar shifts in their spatial patterns that may be linked to income. Better quality door locks, windows, construction materials, and alarm systems are going to be more expensive and will, at least initially, be more prevalent in more affluent areas (Tilley et al., 2011). If that is the case then it might be expected that residential and commercial burglary spatial patterns have also shifted to less affluent areas in the city within the context of a crime drop.

Conclusion

The study considered the spatial concentration of auto theft on street segments in Vancouver. Findings demonstrate that auto theft is statistically significantly spatially clustered, but that the location of this spatial concentration is not stable over time. Thus, this analysis emphasizes the importance of crime specific spatial concentration analyses. The general findings are consistent with what would be expected if the decline in auto theft is due to improvements to vehicle security in Canada. We conjecture that specific aspects of spatial variation in the rate of decline is due to two related factors: spatial variation in the rate of replacement of older vehicles with more secure new ones plus variable change in the ambient vehicle population due to land use change (such as business development and gentrification). Thus the present study indicates need for further research in these areas and in relation to other crime types.

Notes

[1] Graham Farrell acknowledges the contribution of grants RES-000-22-2386, ES/K003771/1, ES/K003771/2 and ES/L014971/1 from the Economic and Social Research Council.

[2] Levitt (2004) found that prisons had the strongest effect on the crime decline in the United States.

[3] Addresses were provided in the following format: 100-block Main Street. In order to geocode such a spatial location to a street network a specific address is necessary. A number from 1–99 was added to each address, using a random number generator, to facilitate geocoding. Consequently, no inference can be made at a level lower than the street segment.

[4] A dissemination area is equivalent to the census block group in the United States Census of Population.

[5] The spatial analysis literature often uses 50 repeated samples (Davis & Keller, 1997). However, early experimental research on Monte Carlo simulations showed that as few as 20 repeated samples provided good results (Hope, 1968). As noted in step 3, we use a 200 repeated random sample for convenient cut-off values for the 95% nonparametric confidence intervals.

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