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Temporal and geographic clustering of residential structure fires: A theoretical platform for targeted fire prevention

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ABSTRACT

Environmental criminology theory has established that crime is non-random across time and space, instead clustering in specific, predictable ways. This has resulted in the development of theories that have helped generate a suite of highly effective, targeted crime prevention tools. Although access to high-quality temporal and spatial fire event data has improved in recent decades, the nexus between spatial/temporal clustering, theory, and targeted fire prevention remains largely unexplored. To address this, the current paper compares the temporal and spatial distributions of residential structure fire and residential burglary within a North American city over a three year period. This analysis reveals (a) overlapping spatial clustering for these two incident types, and (b) distinct temporal patterns; all of which can be explained by the logic underpinning environmental criminology theory. The extrapolation of these findings to targeted fire prevention is discussed with respect to the opportunity this presents for the fire service.

1. Introduction

The temporal and spatial clustering of crime and disorder events has been well documented in recent decades. Environmental criminology theories (such as routine activity theory and crime pattern theory) have repeatedly emphasized that criminal events are unevenly distributed across urban areas, influenced by physical and social landscapes in a non-random way. These environmental theories have helped to hone spatial and temporal research, explaining why crime patterns may emerge as they do, which has led to the development of highly successful, targeted approaches to crime prevention, such as problem-oriented policing and situational crime prevention. Despite this successful connection of analysis, theory, and prevention for crime, over the same period of time there has been comparably less research focusing on analysis of fire event data [1–3]. Recent trends indicate this is changing, likely driven by improved access to high-quality spatial fire data [2], which has led several authors to emphasize the importance of understanding more about the distribution of fire events [3–6].

This paper aims to extend the existing literature by examining the relevance of environmental criminology theory for understanding the temporal and spatial distributions of residential structure fire calls in addition to residential burglaries. To summarise the findings of this analysis, it reveals that residential fires and burglaries occur in the same places but at different times: a combination of patterns that can be explained by the relevant environmental criminological theories. By exploring the temporal and spatial patterns of fire events within a theoretical context, this research aims to bridge the divide between investigating *where* and *when* fires occur, to understanding how this information can be linked to theory. This in turn can drive targeted fire prevention practice.

1.1. The non-random nature of spatial and temporal patterns

1.1.1. Crime in space and time

It is no longer a controversial claim that there is a non-random nature to the distribution of crime across time and space. Crime is not randomly distributed across the urban landscape, but rather, occurs at specific, predictable times [7,8] and places [9]. While patterns often depend on event type, crimes tend to cluster in the warmer months [10–12]. Further, crimes vary by day of week and hour of day: some crime types tend to cluster on weekends and evenings, while others occur more often during weekdays [13]. In addition to this, the physical and social environment is

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repeatedly found to relate to the distribution of criminal events, with a small number of places associated with a large percentage of the overall crime [14,15]. Certain types of land use are associated with higher volumes and rates of criminal activity, with commercial land uses and recreational spaces often reporting higher proportions of crime [15,16]. Criminal events further cluster *within* land use types, with some spaces hosting high levels of crime, while other locations remain relatively crime free [9,14–17]. This micro-scale variation is typically present across land use categories, and across neighbourhoods [14,15,18,19]. This variation may be due in part to the social and economic characteristics of specific areas; urban structure alone does not determine a local crime rate [20]. Areas with higher rates of unemployment, female-headed families, and low-income households, as well as neighbourhoods with more vacant properties, older properties, and properties in need of repair, are also often associated with higher crime rates [14,17,21].

1.1.2. *Fire in time and space*

In a similar way there is a newer, but growing, body of research that demonstrates fire experiences cluster with respect to victims and building type. Recently, Corcoran and colleagues [2] have called for further analysis of fire patterns in a variety of geographic settings in order to determine whether there are commonalities in fire risk across urban areas. From the level of the individual fire-related casualty, research findings do indicate that fire risk is increased for the very old, the very young [22–26], and the socially disadvantaged [1,25–29]. In addition to this, from a dwelling perspective, fire risk has also been demonstrated to increase as a function of characteristics such as building age and construction type [22]. As it stands, there is not obvious theoretical framework to parallel those developed for crime that accounts for these fire-specific patterns.

1.2. *A theoretical basis to explain clustering: Environmental criminology*

Environmental criminology focuses on the clustering of criminal events within the context of the surrounding spatial and temporal environment [30–32]. It is founded on the principle that the built environment shapes and influences the activities and social patterns of residents and inhabitants. The theories and approaches developed within the environmental criminology framework have been applied to help understand and explain spatial and temporal patterns of human behaviour and urban phenomenon, both criminal and non-criminal in nature [e.g., [33]]. With this in mind, these theories may contribute to a further understanding of the distribution of fires. Two environmental perspectives that may be particularly relevant when exploring different fire events are routine activity theory and crime pattern theory.

1.2.1. *Routine activity theory*

Developed by Cohen and Felson [7], routine activity theory describes crime as a normal event, to be considered and studied in the same light as other everyday occurrences. According to the theory, the daily routines of urban residents in modern society create regular patterns of movement and activity. These predictable patterns result in a spatio-temporal convergence of motivated offenders with suitable targets; when this intersection occurs in the absence of a capable guardian, a crime may occur [7]. Changes in the routine activities of populations over time can explain shifts and changes in crime patterns.

A semantic shift may facilitate the application of routine activity theory to explain clustering of fire events. A motivated offender, while applicable in fire situations such as arson or vandalism, is not a universal requirement for fire occurrences. Rather, a trigger is required; this may be a motivated individual, but may also be a variety of other ignition sources. Further, the routine activity approach includes a broad definition for a suitable target, encompassing both people and objects, among other targets. When extending the theory to fire events, a susceptible target is of interest: a car, building, structure or other subject with some risk of ignition. Finally, the capable guardian element applies well to both crime and fire occurrences. An available and capable guardian may intervene and prevent a crime occurrence; likewise a capable guardian may notice a fire (or fire risk) and take steps to extinguish (or prevent) it. Alternatively, given that (a) a large percentage of residential fires are caused by cooking, inattentive use of heating equipment, and misuse of matches, candles, and cigarettes, and (b) as mentioned above, particular, vulnerable demographics in society are higher risk of having residential fires, it is possible that a more appropriate component may be the *presence* of an *incapable* guardian.

Routine activity theory aids in understanding crime event patterns by dictating that the convergence of the three essential elements occurs at predictable times and locations. Likewise, it can be posited that there is an increased chance for fires to occur when a trigger and a susceptible target intersect in time and space in the absence of a capable guardian (or the presence of an incapable one). It can be hypothesized that the sites of convergence are not uniformly distributed across the urban landscape, but like criminal activity, are clustered in meaningful ways.

1.2.2. *Crime pattern theory*

Crime pattern theory further emphasizes the non-random distribution of criminal activities. Pattern theory presents a series of rules which help to define both individual and group decision-making processes, movement patterns and methods for target selection — all of which occur within, and are constrained by, the physical urban form [34,35]. The theory proposes that individuals develop an awareness space through their daily activities. This space includes the areas surrounding home, work, school, shopping and entertainment sites, as well as the routes used to travel between these nodes [36]. The physical and social environment is particularly important in shaping the distribution of criminal events: the locations and routes frequented by large numbers of individuals form part of many peoples' awareness spaces – including both targets and offenders – and as such, these locations are predictably associated with increased numbers of criminal occurrences.

When shifting the focus from crime to fire, pattern theory may contribute to a further understanding of the clustered nature of some types of fires. Pattern theory has been useful in explaining the distribution of arson and deliberately-set fires, emphasizing the importance of offender home locations, other anchor points, and major travel routes in target selection [e.g., [37–39]]. When extending beyond deliberate ignitions, pattern theory offers insight into the importance of urban form in shaping the spatial and temporal distribution of human activity [34]. In contributing to an understanding of the relationship between the environment and human behaviour, pattern theory in a revised form may help to provide context to the spatial and temporal distributions of fire events. For example, cooking fires are more likely to occur at times of day when people are home and preparing food, and fires resulting from Christmas trees are more likely to occur in December and January.

1.3. *From theory to practice: Targeted prevention*

It extends beyond the focus of this paper to comprehensively review the full range of successful applications of targeted crime prevention grounded in environmental criminology theory. However, to provide some context, two key approaches to targeted prevention will be briefly discussed. The first is problem-oriented policing (POP) and the second is situational crime prevention (SCP).

POP is a framework for developing strategies to counter crime which combines a diverse set of approaches into a focused course of action [40]. This concept was first proposed by Goldstein [[41]: 236] with the underlying premise that, “policing should fundamentally be about changing the conditions that give rise to recurring crime problems and should not simply be about responding to incidents as they occur or trying to forestall them through preventative patrols” [as summarized by Ref. [40]]. Goldstein advocated that to achieve this shift in focus, policing practices need to meet a number of objectives, including: (a) being more specific about the nature of individual problems, involving research, analysis, and interpretation of current and previous police responses, (b) assess the adequacy and effectiveness of these approaches within the context, (c) undertake a comprehensive exploration for novel, alternative responses to existing problems, and (d) select the most suitable response (s) and implement them.

The SARA (Scanning, Analysis, Response, and Assessment) mnemonic, which was first proposed by Eck and Spelman [presented in 1987 at a Police Executive Research Forum in Washington, D.C., and referenced by [42]: 186], builds on Goldstein′s propositions and provides a formalised framework for capturing the crucial components of POP. Clarke and Eck [40] discuss the principles that underlie each of the components of SARA: (a) *Scanning*: Examination of existing information to identify relevant patterns (a.k.a., *problems*) in a category of incidents that are routinely addressed; (b) *Analysis*: Undertake a comprehensive analysis of these specific problems with a view to identifying the contextual factors that contribute to their causes; (c) *Response*: This requires two main activities: (i) generate creative, prevention-focused strategies for intervening at a preliminary stage in the causal chain with a view to reducing the likelihood of problems emerging (thinking beyond the traditional focus of the criminal law where relevant), and (ii) building functioning partnerships with non-policing stakeholders that maximise the likelihood of collaborative, multifaceted prevention efforts being successful; and (d) *Assessment*: In order to truly utilize a POP approach, it is essential to complete the SARA steps by evaluating the outcome of the POP strategy, with a view to using this additional outcome information as a driver for the next iteration of the prevention process. A Campbell systematic review of POP concluded that, “POP as an approach has significant promise to ameliorate crime and disorder problems broadly defined” [[43]: 164].

SCP is a framework for reducing criminal opportunity that can work in partnership with POP. Clarke [[44]: 178–180] outlines three fundamental assumptions of SCP: (a) when crime occurs it is the result of an appropriate interaction between situation and motivation; (b) crime arises as a result of a choice; and (c) opportunity mediates the occurrence of crime. Building on the theoretical basis provided by environmental criminological theory and with these assumptions in mind, the SCP framework has developed over time into a set of 25 techniques that are categorized into five overarching styles: increasing effort, increasing risk, reducing rewards, removing excuses, and reducing provocations e.g., [44,45].

As with the theoretical perspectives discussed above, these crime prevention toolkits will not translate directly to fire prevention. However, the logic and structure that underlies them does. Provided it can be demonstrated that there is meaningful predictability in the temporal and geographic clustering of fire that can be explained through a theoretical framework, it is reasonable to assume the problem-focused frameworks provided by SCP and POP will be useful in addressing fire problems.

1.4. Research aims and expectations

As discussed previously, recent research has demonstrated that fire clusters in meaningful ways. In addition to this, criminological research has demonstrated clustering of crime types, which has helped develop theory, and in turn has driven highly-effective, targeted crime prevention techniques. This research builds on what is known about the predictability of crime and the explanatory role that environmental criminology theory has played in understanding (and subsequently, responding to) crime. The aim here is to extend the existing literature, which examines the clustering of fire events, by relating these patterns to the theoretical perspectives that help interpret crime, with a view to demonstrating the relevance of targeted prevention.

This will be achieved by analysing the patterns of residential burglary and residential structure fire events across time and space within a large North American city, and exploring the capacity for environmental criminological theory to explain these trends. It is expected that there will be a consistent fit for the logic that explains the predictability of both crime and fire activity. Furthermore, it is anticipated that there is likely to be some meaningful overlap between the patterns that emerge from the police and fire data. It is expected that fire will cluster because (a) previous exploratory research has demonstrated this to be the case, and (b) risk has been shown to be influenced by fixed characteristics of individuals and buildings. From previous research it appears there is an overlap in the underlying factors driving the patterns for fire and crime, therefore, it is expected the spatial clustering will coincide for these two types of incident. However, given the variations in routine activities and building use, it is expected that there will be differences in the temporal patterns for fires and burglary, with fires often ‘caused’ by inattentive individuals (the presence of an incapable guardian), as opposed to burglaries which are thought to be prevented due to the presence of a capable guardian.

2. Study area and data

2.1. Study area

Surrey, British Columbia (BC), is part of the Vancouver Census Metropolitan Area, and is one of Canada′s largest and most rapidly growing cities. Covering a total of 314.7 km^2, the 2011 Canadian Census reports that Surrey has a population of 468,251: an 18.6% growth since the previous census period (as compared to the national average growth rate of 5.9%) [46]. This urban area is experiencing rapid physical redevelopment, growth, and population expansion [47]. The city is bordered on the north by the Fraser River and on the south by the United States, and includes a variety of land uses: from high-density residential areas and commercial zones, to open areas, parks and farmland. Fig. 1 provides an overview of the land use and road networks for Surrey, which provides useful reference for the interpretation of subsequent maps presented here.

2.2. Data for analysis

Data for this project was provided by both the Surrey Fire Services (SFS) and the Royal Canadian Mounted Police (RCMP). The residential structure fire (henceforth referred to as *fire*) data was taken from all official fire incident reports submitted to the BC Office of the Fire Commissioner for appropriately coded events

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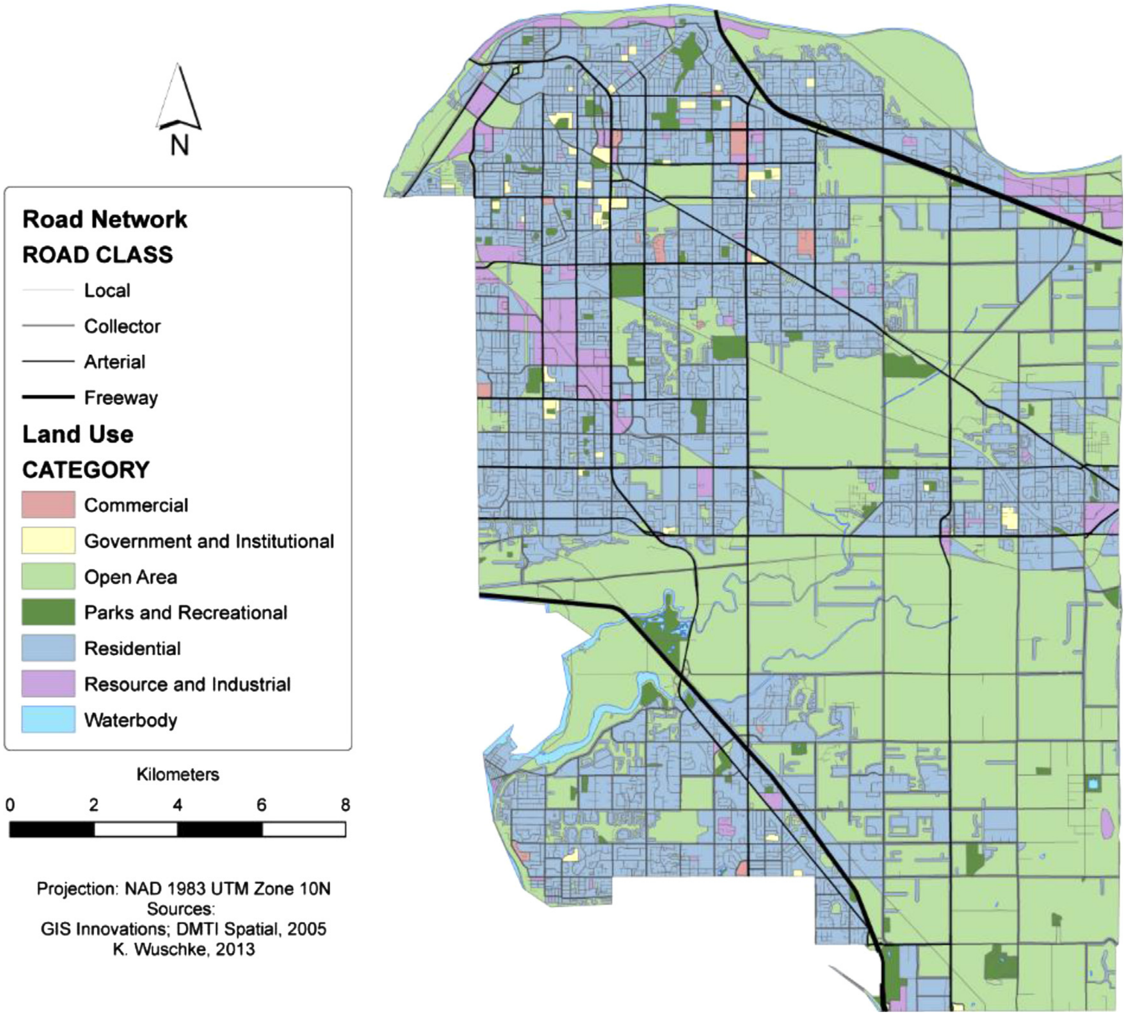

Fig. 1. City of Surrey land use and road types.

occurring within the City of Surrey between 2004 and 2006 ($n=933$). The residential burglary (referred to as *burglary*) data was extracted from the total number of criminal events recorded by the RCMP between 2004 and 2006 occurring in Surrey ($n=9143$). Both the fire and burglary datasets included event dates, timestamps and address information. These two data types were selected as they share a common unit of analysis: the household.

In preparation for spatial analysis, data were cleaned and geocoded onto Surrey's road network using the reported event address. Both the fire and burglary datasets geocoded with a success rate of 98%, which is well above the established minimum successful geocoding rate required to maintain spatial accuracy [85%, e.g., [48]]. These data sets were then spatially joined to the 2006 Canadian Census spatial dissemination area (DA) boundaries, which are the smallest spatial areas for which all Census information is reported. DAs typically contain a residential population of between 400 and 700 individuals and remain geographically stable over time. Data aggregation necessarily generalizes spatial patterns, preventing individual-level interpretation and leaving data analysis susceptible to the modifiable areal unit problem (MAUP), meaning that point data aggregated to a different spatial level or different spatial units may display different patterns [49,50]. In order to explore the impact of different levels of aggregation, data was also joined and analysed at the census tract (CT) level, which is the next level of spatial aggregation of census data. However, the small spatial size and relatively uniform population counts across DAs makes this unit of aggregation the best available choice to ensure event location anonymity and to facilitate areal comparisons across datasets. Surrey was divided into 559 DAs and 78 CTs in 2006.

3. Method

This study began by exploring spatial patterns of fire and burglary event data and followed with corresponding analyses of the temporal patterns of both of these event types. The spatial patterns of fire and burglary events were analysed using ESRI's ArcGIS 10. Event counts by DA were input into ESRI's Hot Spot Analysis tool, found in the Spatial Statistics toolbox. This tool calculates the Getis-Ord Gi* statistic for each area, outputting a *Z*-score which identified areas with statistically significant (e.g., $|Z| > 1.96$) clusters of high counts (and low counts) of events. In this analysis, counts of events were selected as input rather than rates. A primary goal of spatial analysis of event data is to aid in resource allocation and proactive planning [3,4]. Identifying locations with high occurrence volumes was of particular operational interest, and with this goal in mind, the count itself was an appropriate measure [51,52]. The output from the hot spot analysis tool was mapped at the DA-level as well as at the CT-level. The temporal analysis explored fire and burglary incidents broken down by hour of the day, day of the week, and month of the year, with data displayed using circular plots to accurately

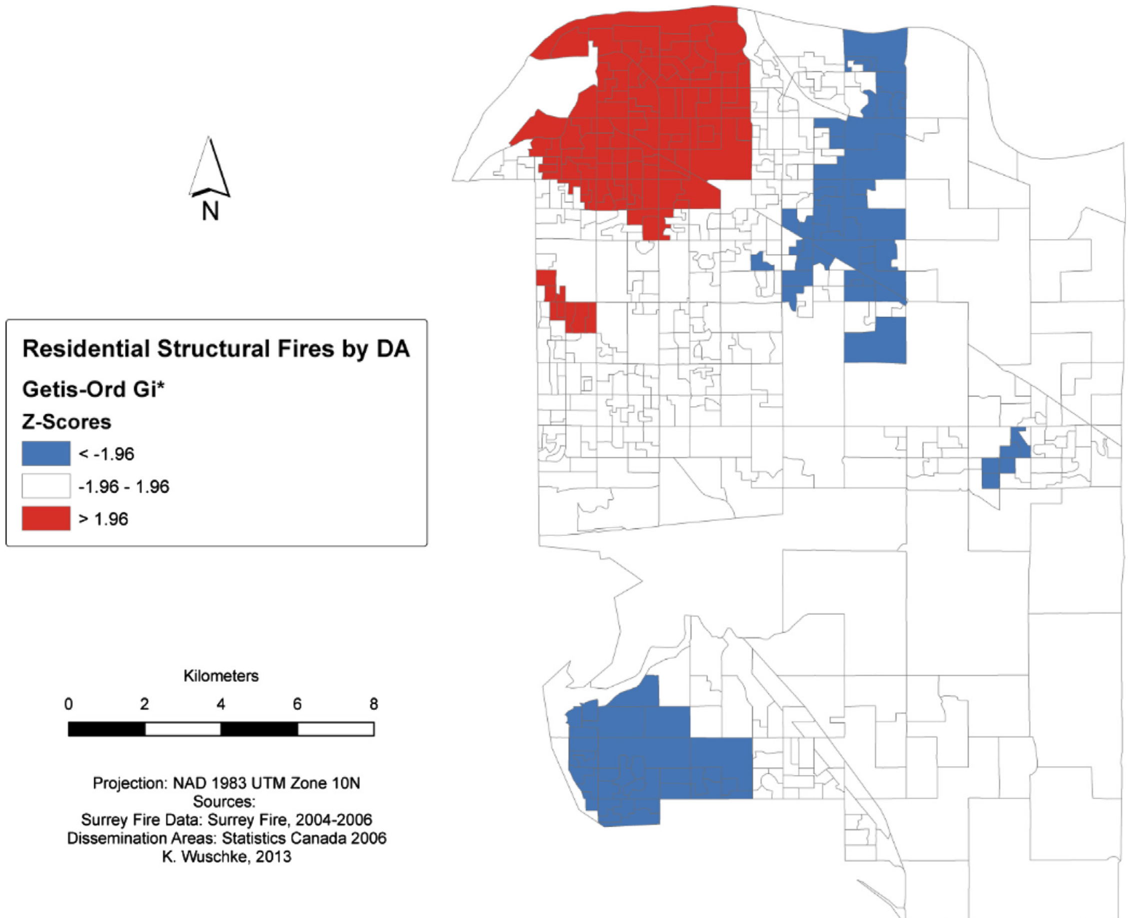

Fig. 2. Spatial patterns of fires by dissemination area. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

visualize the continuous nature of these temporal categories [4]. This method of display allows for quick identification of times with more (or fewer) events than expected. The circular plots further allow for ease of comparison, both between fire and burglary data in this analysis, and among different studies.

4. Results

4.1. Spatial analysis

As was expected based on previous analysis of the spatial clustering of fires, Moran's I identified significant clustering of fires at a global level across DAs ($Z=10.68$, $p<.0001$). At a local level, the geographic clustering of fires, displayed in Fig. 2, reveals a large, significant hotspot of fire events (displayed in red) in the north-west portion of the map, indicating the presence of DAs with Getis-Ord Gi* Z-values greater than 1.96. Areas in the north, south-west, and a small portion of the east of the city were identified as significant cold spots (Getis-Ord Gi* Z-values <1.96, represented by the DAs shaded in blue). Areas without colour in Fig. 2 exhibit no apparent significant spatial clustering of values. To attempt to control the influence of the MAUP, the same analyses were undertaken at the CT level, and the pattern remained constant: Moran's $I=0.20$, $Z=5.90$, with significant clustering at a local level.

Also in accordance with previous research findings, Moran's I demonstrated significant global-level clustering of burglaries across DAs, $Z=21.09$, $p<.0001$ (Fig. 3). Using the same colour coding as with fires to indicate significant hot and cold spots, Fig. 3 demonstrates an elevated incidence of burglary in the city's north-west and central-west, and significant cold spots in the north, east, and south-west. The only additional areas of significance unique to the burglary patterns involve the prominent hotspot in the geographical centre of the city (an area largely comprised of acreages, farmland, and suburban residential neighbourhoods, and divided by several major transportation routes), and a new cold spot appearing along the western municipal border. As with the fire data, these analyses were repeated at the CT level, and equivalent results were produced: Moran's $I=0.23$, $Z=6.89$, and significant clustering at a local level.

To extend this analysis beyond previous research and to formally explore the cross-dataset clustering, the Getis-Ord Gi* Z-scores calculated for each DA for the fire and burglary data were ranked and then the Spearman's Rho correlation was computed. This correlation produced a significant result, $\rho=0.78$. To address the potential influence of the MAUP, the same calculation was computed at the CT level, returning and equivalent result, $\rho=0.92$. To help characterise this calculation graphically, Fig. 4 displays the significant hot and cold areas for burglary (cross-hatching and diagonal lines, respectively) superimposed on the significant hot and cold areas for fire (represented in red and blue).

As discussed previously, certain household-level characteristics have been demonstrated to be related to elevated residential fire frequency. One of these, household socio-economic disadvantage, was selected to further examine the spatial clustering of fire. The

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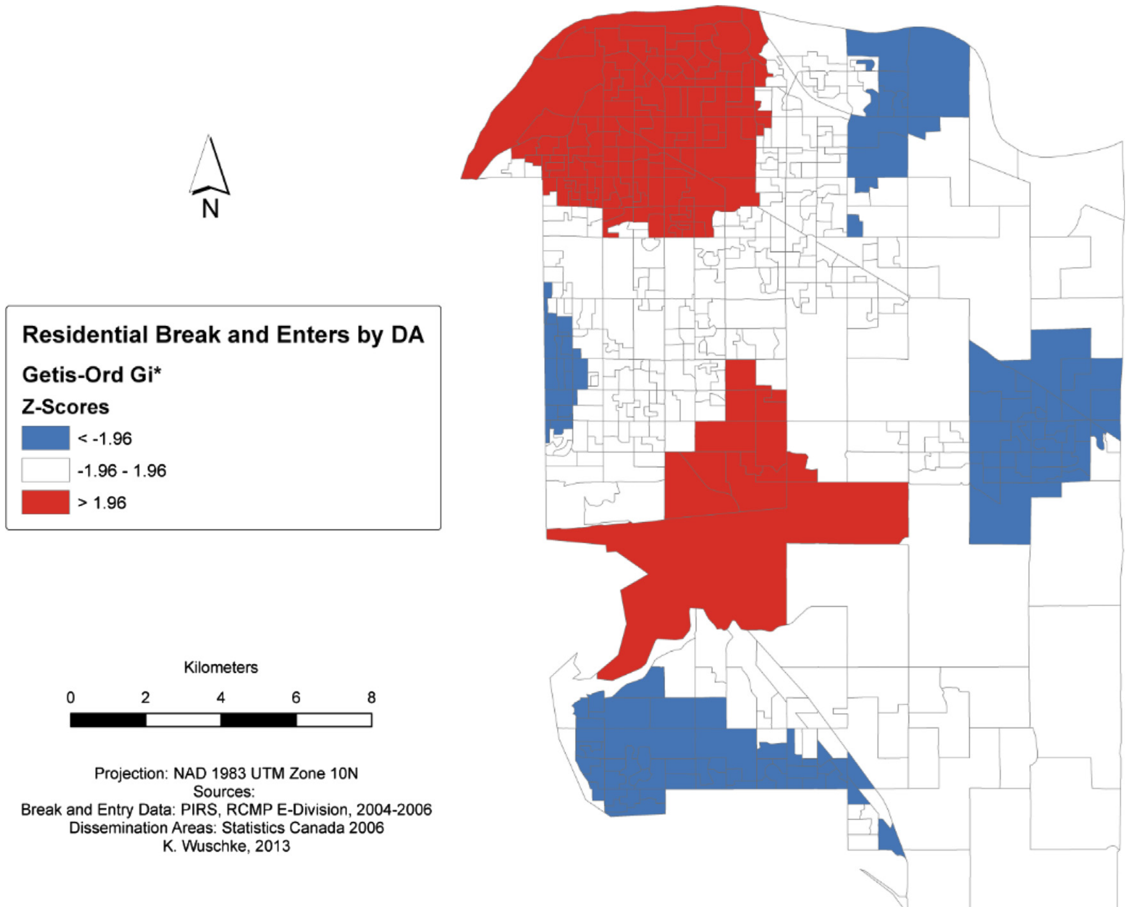

Fig. 3. Spatial patterns of burglaries by dissemination area. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

metric selected for this was the Vancouver Area Neighbourhood Deprivation Index (VANDIX), which is an aggregate index of seven variables from the 2006 Canadian Census (average income, home ownership, single parent family, proportion with no high school education, proportion with a university degree, employment ratio, and unemployment rate) [53]. In developing the VANDIX, variables were selected and weighted based on input from provincial Medical Health Officers who were asked to identify the key indicators that best characterize health and socio-economic outcomes in BC [54]. The spatial relationship between DAs with extreme VANDIX values (e.g., Getis-Ord Gi* values where $|Z|>1.96$) and fire is displayed in Fig. 5, with fire hot and cold spots again represented by red and blue, respectively, and the highly disadvantaged areas shaded with cross-hatching and the significantly less disadvantaged areas shaded with diagonal lines. In its own right, the VANDIX displays significant global clustering at the DA level (Moran's $I=0.32$, $Z=32.50$) and significant local-level clustering. Correlation between the rank orders of the VANDIX DA values and those for DA-level fire incidents again returned a significant result: $\rho=0.84$.

4.2. Temporal analysis

The next component in this analysis is to examine the relative trends for fire and burglary across time. Fig. 6 displays circular plots depicting the hourly, daily, and monthly patterns for fires and burglaries. From a descriptive perspective, fires increased between about 1 pm and 8 pm, appear relatively evenly distributed across day of the week, and increased slightly in June and October. In comparison, burglary appears to increase between 8 am and 7 pm, is less frequent on weekends, and relatively more frequent in March, August, and December.

Beyond these ostensible explanations, circular statistical analyses were undertaken to examine the strength of the patterns observed here, both within fire and burglary in isolation, and also between the temporal distributions of the two. By way of a quick overview, circular statistics provide a way of analysing data that circles back on itself in its distribution (such as time), the properties of which are a mean vector which can be defined based on direction (θ) and magnitude/length (r). In this case, θ ranges from 0° to 359° and r ranges from 0.0 to 1.0, giving an indication of the relative dispersion of the distribution (where completely random dispersion would produce $r=0.0$) [55].

The first type of circular statistic that was computed was Rayleigh's test, designed to indicate whether a circular distribution is random or non-random. Within fire, Rayleigh's test indicated significant clustering for time of day ($Z=24.24$, $p<.001$, $\theta=181.1^\circ$, $r=.16$), but not for day of week or for month of year, signifying there was no reliable sample mean direction for either of these. In comparison, within burglary events, Rayleigh's test indicated significant clustering for all three temporal divisions: hour of day ($Z=167.54$, $p<.001$, $\theta=180.6^\circ$, $r=.14$), day of week ($Z=13.23$, $p<.001$, $\theta=180.2^\circ$, $r=.04$), and month of year ($Z=11.53$, $p<.001$, $\theta=359.7^\circ$, $r=.04$).

In addition to this, Watson's U^2 test provides a non-parametric test to indicate whether the distributions of two sets of circular data are significantly different. Examination of the relationship between the fire and burglary indicate significant differences in the shapes of the distributions across hour of day ($U^2=0.39$, $p<.001$), day of week ($U^2=1.58$, $p<.001$), and month of year ($U^2=0.59$, $p<.001$).

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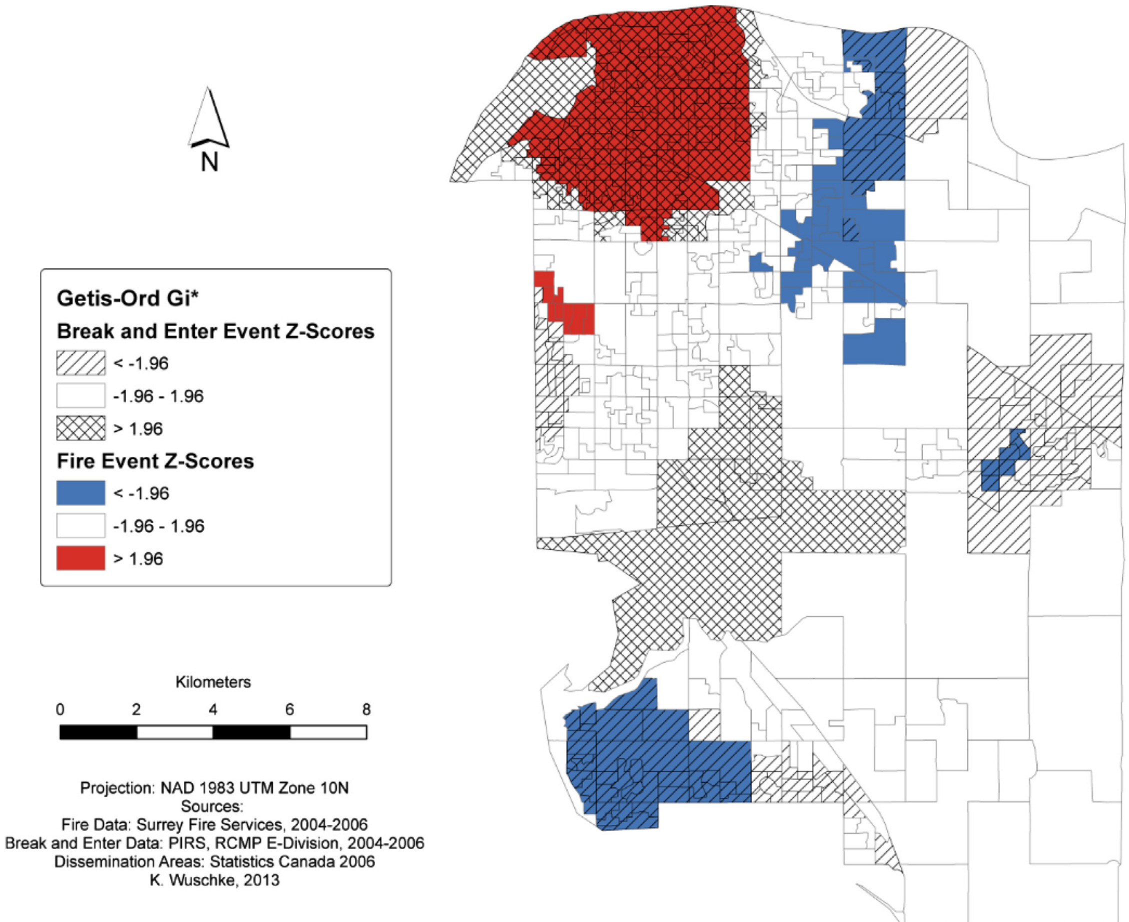

Fig. 4. Spatial pattern overlaps of fires and burglaries by dissemination area. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

5. Discussion

5.1. Overview of results

Overall, the burglary data clustered across time and space in a manner that is entirely consistent with previous criminological research and can be explained through environmental criminological theory. There were specific areas that experienced high volumes of burglary and others where burglary was a rare occurrence. Fire data similarly demonstrated spatial clustering, which is consistent with previous research into this area. From a theoretical perspective, the relationship between these fires and disadvantage was as expected, given the body of evidence suggesting elevated fire risk for disadvantaged citizens. Given disadvantage is also a high-level predictor of crime victimisation, the significant spatial correlation between burglary and fire was also understandable.

From a routine activities perspective, the differing temporal patterns for burglary and fire can also be understood in a manner consistent with a common theoretical base. Temporal burglary patterns can be understood with respect to the absence of a capable guardian (elevated frequency during the working day) and the variations in building use associated with summer months (leaving windows/doors unlocked) and increased opportunities around Christmas time. Fire, however, is more frequently the result of the presence of an incapable guardian, with elevated risk when people are home due to cooking/heating accidents (and lower when residents are home, but asleep), and not significantly different as a result of day of the week or month of the year.

5.2. From theory to practice

Given the overlap and patterns and the capacity for the theoretical frameworks to provide reasonable explanations for fire and burglary, the next step is to make the move from theory to targeted fire prevention practice. There is potential to utilise this awareness of non-random variations in risk to drive operational decision-making with respect to allocation of fire prevention resources (utilising the structure of SARA and examining the potential application of the 25 SCP techniques). The logic of these findings has been used to drive effective fire prevention strategies in high-risk areas of communities and to help focus limited resources on areas identified as having the greatest risks [3–6,56]. Specific to fire, SFS have already demonstrated the effect this approach can have, implementing a door-to-door targeted fire-prevention and public education campaign in the city that resulted in significant reduction in the rates of residential fires and a simultaneous significant increase in the frequency of working smoke alarms in the event of fires [56]. From a joint operational perspective, SFS have also worked in partnership with the RCMP to conduct door-to-door visits in high-risk areas for cooking fires and burglary, with police delivering a message to avoid leaving doors and windows open when the house is unattended, and the fire service emphasising the risks associated with cooking. One-year follow-up analysis to this campaign revealed a 19% reduction in the annual rate of residential structure fires in the area and a 64% decrease in the number of residential burglaries [57]. These two agencies are also working collaboratively on other areas of overlap including the police testing smoke alarm presence and

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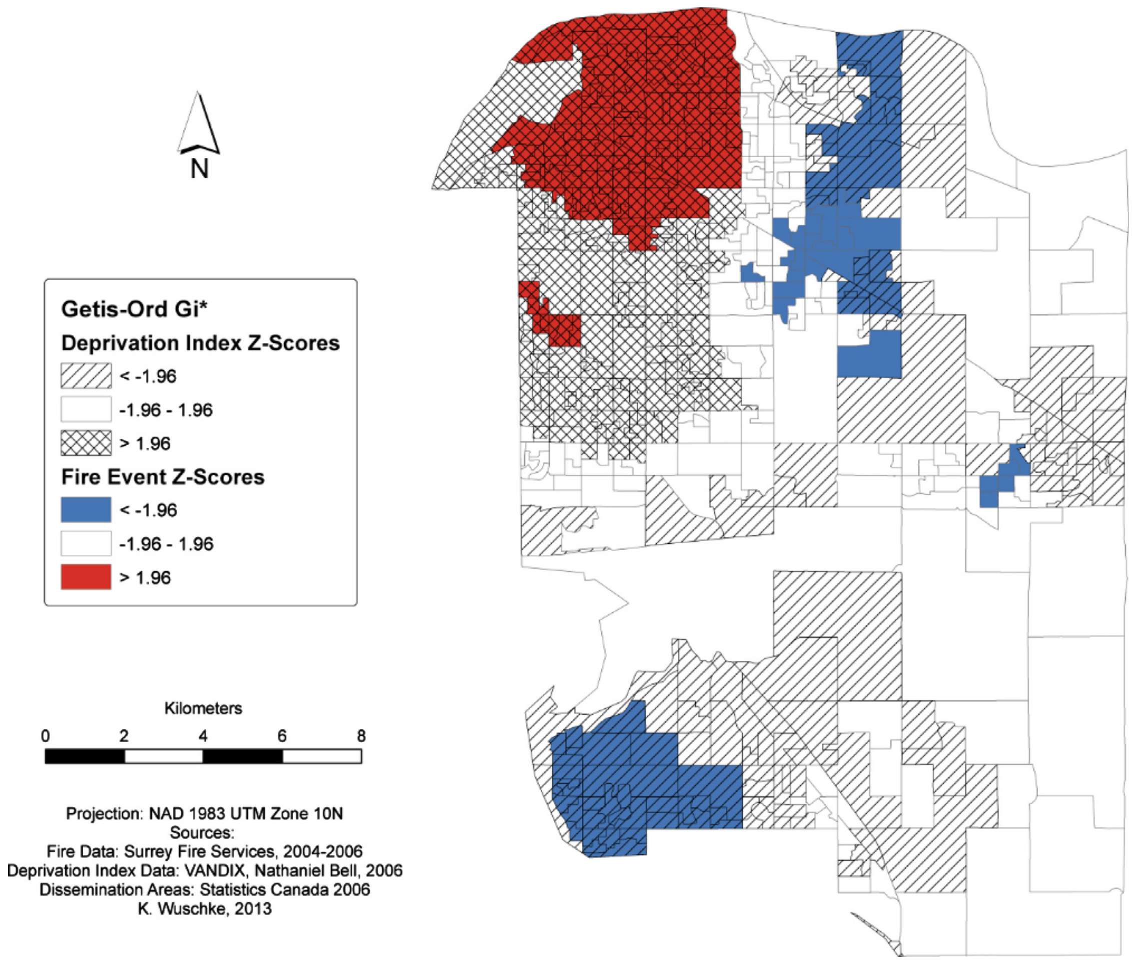

Fig. 5. Spatial pattern overlaps of fires and deprivation index scores by dissemination area. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

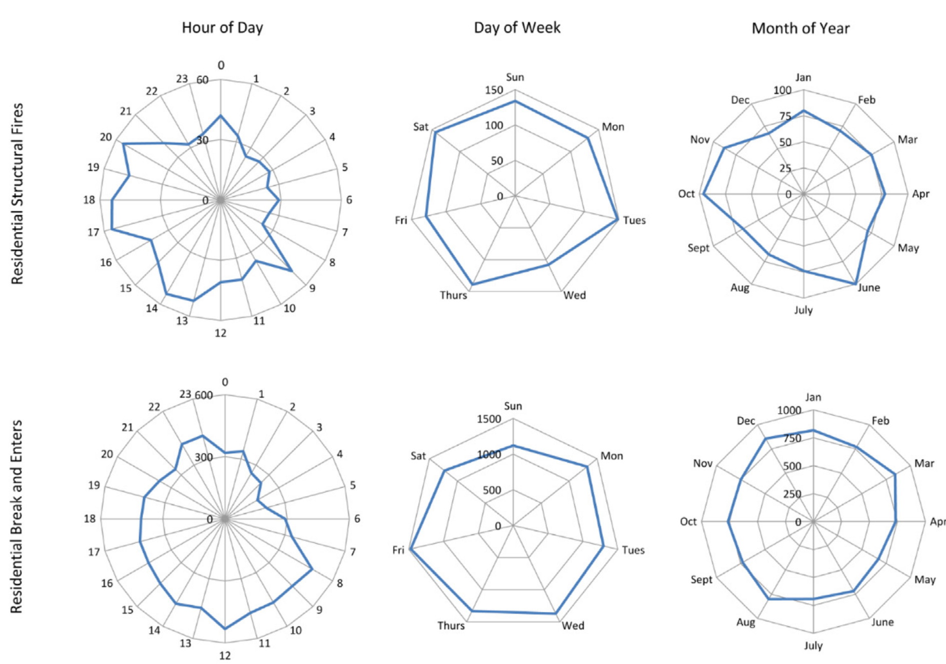

Fig. 6. Temporal patterns of fires and burglaries.

functionality where possible, and the fire service staying alert for abandoned buildings, human trafficking, indoor marijuana grow operations, elder abuse, and child abuse. The logic of these efforts is to target fire and police prevention efforts towards the highest-risk areas of the community, focusing limited resources to maximise the return on investment.

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6. Conclusion and future directions

Fires, like crimes, are not uniformly distributed across time and space, and instead occur in a predictable and non-random manner. The importance of understanding the distributions of fire events has been repeatedly emphasized within recent academic literature. With a clearer understanding of residential fire patterns, limited resources may be allocated for maximum benefit, and fire prevention activities can be targeted on areas identified as having the most need [2–6,28,56]. While progress has been made in fire event analysis, there continues to be calls for further spatial and temporal investigations across different geographic settings [2]. This research heeds this call by exploring the temporal and spatial patterning of fire events within the context of environmental criminology theory. Environmental theories have aided in crime analysis and police resource allocation for targeted prevention by providing consistent explanations for the temporal and spatial clustering of crime and disorder events within urban areas.

This work is a beginning in the development of theoretical understanding for the clustering of fire across time and space. These findings need to be augmented by additional research to examine the apparent overlap in fire and police service delivery. As well, there would be value in continuing to explore the relationship between socio-economic neighbourhood characteristics and individual victim characteristics for both fire and crime events. Finally, given the diverse range of calls for service that fire departments typically respond to, there would be value in expanding this investigation to include the wider range of services provided by fire departments, such as other types of fires, motor vehicle accidents, and emergency medical response. As with all other examples of successful approaches to targeted crime prevention, the greatest impact of this approach will be achieved by being specific about the type of problem that is being addressed and being persistent about achieving a solution.

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