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Pathways of Crime: Measuring Crime Concentration Along Urban Roadways

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Pathways of crime: Measuring crime concentration along urban roadways

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Key Messages

- Traditional calculations of the location quotient can be adjusted to better capture concentrations along road networks.
- Using this adapted measure, we found that some road types exhibit higher concentrations of specific crimes than others.
- Measuring differences in concentration along road types assists in understanding urban crime patterns over and above land use type.

Some urban spaces are associated with disproportionate numbers of criminal events, while other areas are relatively free from disorder and crime. The relationship between urban space and crime concentration has received increased attention in recent years, with the location quotient frequently presented as a tool to identify and quantify such concentration. This measure has several limitations, with one significant concern surrounding the choice of denominator with which to standardize local and global rate calculations. In response, we present a new methodological adaptation to the location quotient, improving the measurement of crime concentration along linear features. To test this adaptation, we measure how crime concentrates by road classification at both a macro and micro level within two Canadian suburban municipalities. Using transportation network data, we identify the road types that are associated with a disproportionate concentration of criminal events, and illustrate how these relationships change alongside the level of aggregation. Results support the use of the adapted location quotient, finding that criminal events concentrate along specific road types, and emphasize the importance of spatial scale in understanding local relationships between crime and the built urban landscape.

Keywords: built environment, crime concentration, location quotient, road networks, road types

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Les voies de la criminalité : mesurer la concentration de la criminalité selon les axes urbains

Certains espaces urbains sont associés à un nombre disproportionné d'événements criminels alors que d'autres secteurs sont relativement exempts de désordre et de criminalité. En conséquence, la relation entre l'espace urbain et la criminalité a de plus en plus retenu l'attention au cours des dernières années. Dans ce contexte, le quotient de localisation est fréquemment présenté comme un outil de premier plan permettant d'identifier et de quantifier la concentration d'activités criminelles. Cependant, cet indicateur comporte plusieurs limites, en particulier des questions reliées au choix du dénominateur avec lequel on normalise le calcul des taux locaux et mondiaux. En réponse à ces interrogations, nous présentons une nouvelle adaptation méthodologique du quotient de localisation, améliorant ainsi la mesure de la concentration de la criminalité sur la base de caractéristiques linéaires. Pour vérifier cette adaptation, nous mesurons la façon dont la criminalité se concentre par classification de routes aux niveaux macro et micro dans deux municipalités suburbaines canadiennes. En utilisant les données du réseau de transport, nous recensons les types de routes qui sont associées à une concentration disproportionnée d'événements criminels et nous illustrons la façon dont ces relations changent selon le niveau d'agrégation. Les résultats appuient l'utilisation d'un quotient de localisation adapté, constatant que les événements criminels se regroupent selon des axes linéaires spécifiques. De plus, il nous semble important de mettre l'accent sur l'échelle locale pour comprendre les relations entre la criminalité et l'environnement urbain, à la lumière de nos travaux.

Mots clés : environnement bâti, concentration de la criminalité, quotient de localisation, réseaux routiers, types de routes

Introduction

Over the past several decades, a significant body of research has investigated the interconnectedness of urban form and patterns of criminal activity. Such studies have identified environmental features that are associated with higher volumes of crime within specific urban settings, and across multiple urban environments. Spaces and places that attract a large number of people for typical, everyday activities are also frequently associated with more crime and disorder events (Andresen 2007).

As both police records and built environmental datasets continue to grow, integrating these sources has allowed for the development of a nuanced understanding of the environmental features that relate to local patterns of crime and disorder. Indeed, researchers within the field of environmental criminology have identified numerous links between urban form and crime, finding that commercial areas, liquor-serving establishments, parks, schools, and major roads, for example, are associated with disproportionate rates of criminal activities (Kinney et al. 2008; Johnson and Bowers 2010; Groff 2011; Weisburd et al. 2012; Groff and Lockwood 2014; Davies and Bowers 2018; Wuschke and Kinney 2018). While such studies continue to find support for high levels of crime concentration at and along specific urban features, researchers are challenged to identify appropriate metrics with which to measure such concentration (Lee and Eck 2019).

The location quotient (LQ) is one metric that has gained popularity as a simple, yet powerful measure of concentration, allowing for quick comparison of crime rates between areas (Brantingham and Brantingham 1993; Andresen 2007; Groff 2011; Wang et al. 2017). However, as a rate-based measure, the LQ is known to be sensitive to the units of aggregation, and the choice of denominator (Andresen et al. 2009). The LQ is sensitive to minor changes in crime counts within small areas, which is particularly problematic given recent trends within crime and place literature towards block-level analysis (Weisburd et al. 2012; Groff 2014; Davies and Bowers 2018). In response, this study introduces and applies a new adaptation to this existing metric, enabling the LQ to provide a measure of crime concentration along street segments. With this adapted measure, we explore the relationship between crime and the road network across multiple spatial scales, identifying unique local connections between crime events and urban form.

Background

Crime and the built urban environment

The everyday travel patterns of urban populations bring individuals away from their homes, and allow for the intersection of potential offenders, targets, or guardians in space and time. In doing so, these activities can either facilitate or prevent criminal occurrences (Cohen and Felson 1979). Such routine patterns of movement are themselves restricted by the built environment, with major transportation corridors and commercial or public locations attracting more activity and potentially, more crime (Brantingham et al. 2009; Wuschke and Kinney 2018). The routine movements of offenders and non-offenders leads to increased individual knowledge of specific activity nodes. Places such as one's home, work, or school, and recreational nodes, as well as the pathways between these locations, form an individual's activity space. This activity space, as well as the broader surrounding awareness space, is created predominantly through routine and legitimate activities. Individuals spend most of their time within their activity space, and as such, offenders typically identify targets and commit offences within it (Brantingham and Brantingham 1991; Song et al. 2017).

In recent years, a number of scholars have conducted research using the street segment as the unit of analysis (Weisburd et al. 2009; Groff et al. 2010; Weisburd et al. 2012; Groff 2014; Andresen et al. 2017; Davies and Bowers 2018). Weisburd (2015, 133) has emphasized the overwhelming concentration of crime at the street segment level, proposing the "law of crime concentration at place," and finding that when considering large metropolitan areas, half of crime events concentrate on roughly 5% of street segments. Other studies have noted that a considerable, though varied, proportion of street segments report no crime at all (Andresen and Linning 2012; Weisburd et al. 2012). Street connectivity further influences crimes at the block level, with higher levels of access associated with higher concentration of crime (Brantingham et al. 2009; Davies and Bowers 2018).

Consideration of the land use on which crime events concentrate may be insufficient in itself, particularly as road type and volume of use play critical roles in shaping crime concentration. This has been demonstrated by Spicer et al. (2016), who emphasize that crime clusters along major roads and intersections, as well as by Song et al. (2017), who demonstrate that crime concentrates where land use *changes*; these changes tend to occur along arterial roads. These studies emphasize the importance of the road segment as a unit of analysis when investigating spatial patterns of crime. Just as streets shape the movement patterns of urban residents, so too do they shape the spatial concentration of crime events.

Measuring concentration: The location quotient

A strong and growing number of academic studies have emphasized the concentrated nature of crime within urban environments. However, there continues to be significant variation in the metrics used to recognize and measure this concentration (Lee and Eck 2019). The LQ is one measure that has seen consistent use within the past three decades. LQs allow for simple comparisons between sub-areas within the same larger region (Brantingham and Brantingham 1993; Andresen 2007, 2009; Andresen et al. 2009; Groff 2011). This metric is often calculated as a ratio of the proportion of a crime in a given sub-area, in comparison to the proportion of the same crime in the greater region. It provides a locally based, standardized measure that easily identifies sub-areas with over- or under-representation of the measured crime.

LQs traditionally provide a measure of specialization of crime in one sub-region, in comparison to the area as a whole (Brantingham and Brantingham 1993). However, in recent years, LQs have been adapted as a rate ratio, where the crimes per area within a sub-region are standardized by the equivalent measure within the larger region (Groff 2011). Both methods allow for relatively simple comparisons across areas, and both methods result in a metric standardized around the value of 1.0. Sub-areas with an LQ value of greater than 1.0 display over-representation of crime in comparison to the wider region; sub-areas with an LQ value of less than 1.0 display under-representation. A sub-area with a calculated LQ value of 1.5 can be interpreted as having 1.5 times the expected proportion of the measured crime, compared to the region as a whole.

There are several challenges with this standard use of LQs, which are exacerbated when translating this measure to linear features. As LQs measure over/under-representation within sub-areas of a greater region, they require the aggregation of crime data to specific sub-units. Any point-based data that are aggregated to spatial areas are subject to the modifiable area unit problem (MAUP), whereby the patterns presented at one level of aggregation may change should the data be aggregated to different spatial units (Openshaw 1984). The units of aggregation require considerable forethought as they have the potential to influence results.

An additional challenge is that rate-based calculations associated with small areas are greatly impacted by small changes in the number of crime events. This concern is inherent in any area-based crime rate calculation, but the impact is exacerbated when the regional comparison includes spaces where criminal events are unlikely to occur, such as water features, cliffs, or areas that are otherwise difficult to access. Careful consideration of the denominators used to calculate crime rates is essential for the development of a meaningful location quotient (Andresen et al. 2009).

In response to these concerns, this study introduces and applies further adaptations of the LQ to reduce the impact of the unit of analysis. By investigating crime events along the street segment—both as a unit of analysis and as a distinct environmental feature—this study contributes to an understanding of how roads shape how and where we travel, as well as what we do. By adapting the LQ to improve measurement and comparison of crime density along linear distances, we are able to identify broad road types, and specific blocks, associated with a disproportionate amount of crime events.

Study site, data sources, and data preparation

Coquitlam, British Columbia is a municipality within Greater Vancouver that is experiencing dramatic urban development alongside rapid population growth. Canada's 2016 Census reported that Coquitlam was home to over 139,000 residents, increasing by 9.8% from 5 years prior (Statistics Canada 2019). During this timeframe, neighbouring Port Coquitlam contained less than half of the population of Coquitlam, with just under 60,000 residents. This small municipality is also experiencing population growth, though at about half of the rate of Coquitlam (Statistics Canada 2019).

Coquitlam and Port Coquitlam, together with surrounding communities, form the Coquitlam Detachment of the Royal Canadian Mounted Police (RCMP). The Coquitlam RCMP Detachment provided police records for this analysis. This initial dataset included all recorded criminal events within the BC-PRIME police records management system in Coquitlam Detachment in 2009 (n = 39,387). These data were geocoded by address, matching all events to a specific location on the RCMP's road network (created by GIS Innovations in 2008). The BC-PRIME records matched with a high success rate of 94.4%, which exceeds the recommended threshold as documented by Ratcliffe (2004) and Andresen et al. (2020).

All events occurring outside of the municipalities of Coquitlam and Port Coquitlam were removed from the matched data (424 events), as were events determined by police to be unfounded (7,215) and those identified as police statistics codes, documenting police-initiated activities including community events, interactions, and warnings (16,683 events). All events linked to the address of either the police detachment headquarters or local provincial courts were excluded from this study due to known inconsistencies associated with recording practices at such locations (82 events; Groff 2011). The final dataset contains all confirmed and matched criminal events occurring in Coquitlam and Port Coquitlam in 2009 (n = 12,786).

Data sharing agreements prevent the display of non-aggregate crime events. Therefore, Figure 1 displays a kernel density (KD) map of the spatial distribution of criminal events in Coquitlam and Port Coquitlam (KD cell size: 50.4 m; search radius: 521.4 m; mapped using 5 natural breaks; *Low Density* = KD values <63.1, and *High Density* = KD values >657.5). A number of hotspots of crime appear throughout the study area, with the most prominent appearing near the geographic centre of the site. This hotspot coincides with the Coquitlam city centre area, which is a highly-connected central node, linked by major transportation routes and housing a regional shopping mall, as well as a large local college, the city hall, and the local police detachment headquarters. This area is also illustrated at the centre of Figure 2, portraying the mix of commercial and residential land use, as well as high accessibility via many of the area's major travel routes.

Crime data were spatially joined with the local RCMP road network, which includes 776 kilometres

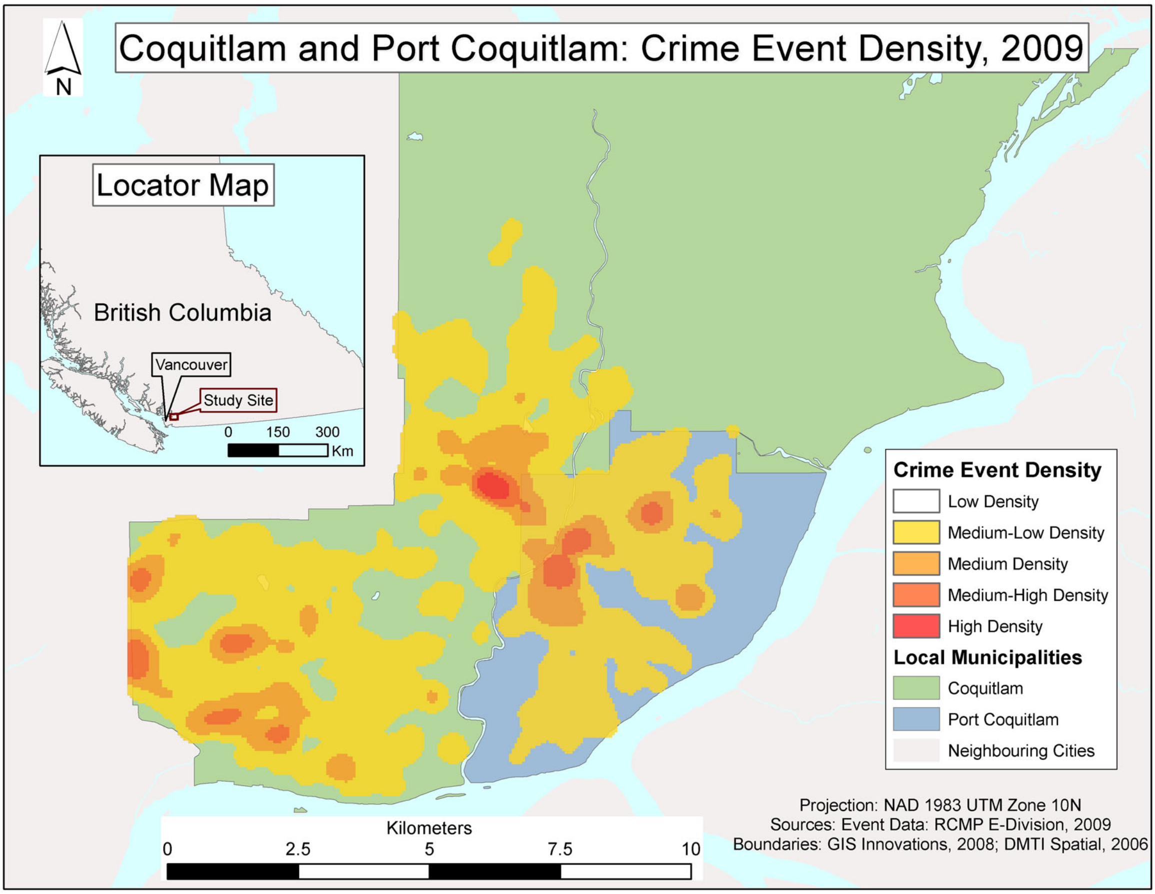

Figure 1
Study site location and crime event density, 2009.
SOURCES: RCMP E-division (2009); GIS Innovations (2008); DMTI Spatial (2006).

of categorized roadways. Each event was updated to include the ID of the block on which it occurred, as well as the road type. Road classifications include *freeway* (access-controlled, high-speed, high-volume roads; average speed (AV) = 83.8 km/h), *highway* (high-speed, high-volume roads; AV = 70.1 km/h), *arterial* (high-volume roads designed to channel traffic from collectors to highways and freeways; AV = 50.8 km/h), *collector* (roads designed to connect local streets to arterials; AV = 46.7 km/h), *local* (primarily residential roads; AV = 47.9 km/h), and *all other road types* (including restricted access roads, lanes, and ramps, for example; AV = 31.9 km/h). For 85.3% of the crime events within this dataset, the event location was recorded as a specific address, allowing for a direct link to a specific block. The remaining crimes were recorded at intersections (n = 1883), with several street segments associated with these mapped event locations. Several approaches have been used to deal with such fuzzy matches within existing studies, such as excluding intersection data (Weisburd et al. 2009, 2012), analyzing these data separately (Braga et al. 2010; Andresen et al. 2017), and allocating intersection crime proportionally to adjacent street segments (Hibdon and Groff 2014). Given that this subset of events represents a considerable proportion of the

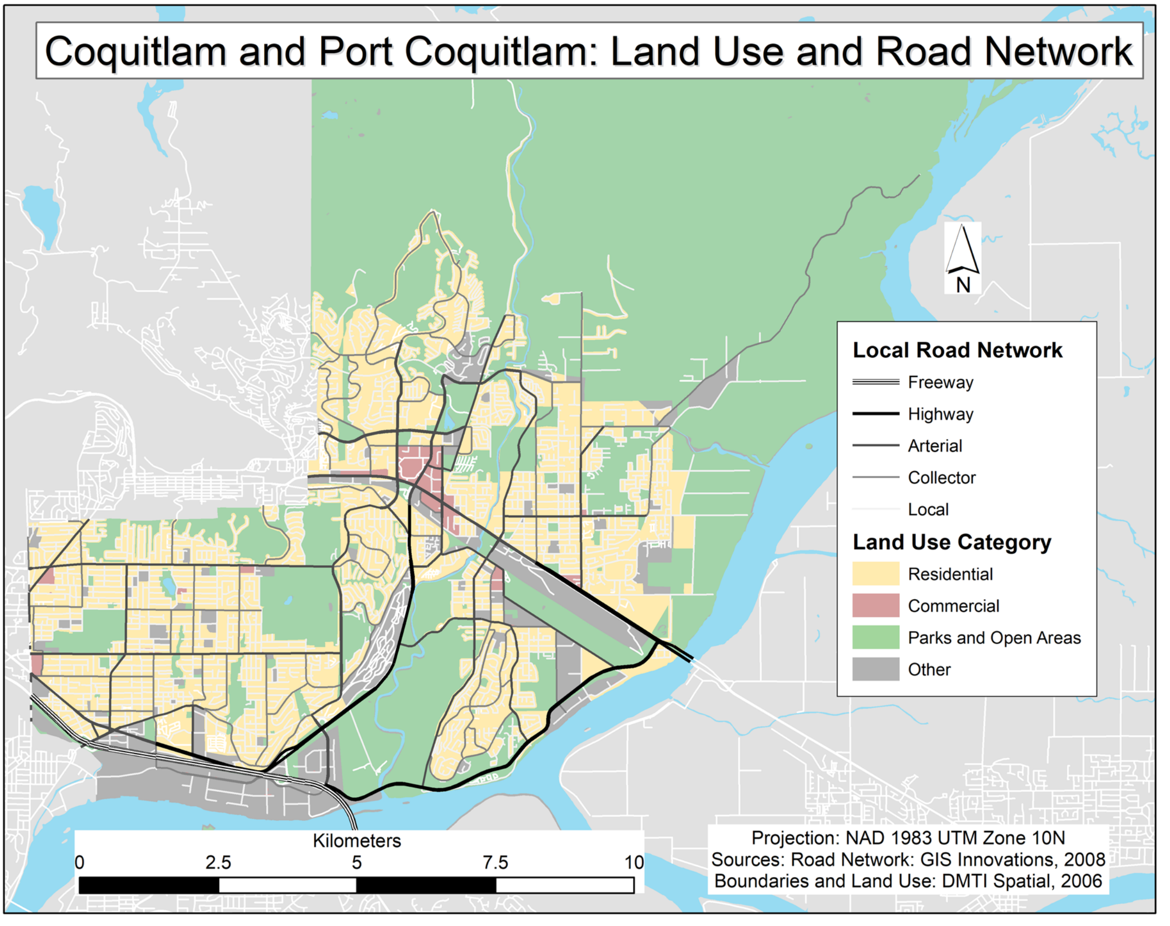

Figure 2
Coquitlam and Port Coquitlam's transportation network and land use.
SOURCES: GIS Innovations (2008); DMTI Spatial (2006).

overall crime dataset, this analysis applied ArcGIS's default spatial join, which randomly assigns each crime event to one of the connecting segments. This ensured that each event was linked to one of the blocks that it matched with.

Methodology

Adapting the LQ

This analysis introduces an adapted version of the LQ and applies this technique to identify if and how crime events vary along with road types within the study site. The conceptualization of sub-units within a region is adjusted first, as this adaptation groups crime according to the road type on which the event occurs (rather than more traditional, area-based measures). Crime rate denominators, then, are calculated as road distance, rather than area. When exploring crime along the road network, the adapted location quotient (LQ), is calculated as follows:

$$LQ = \frac{C_n/D_n}{C_N/D_N}$$

where

LQ = *Location quotient*

C_n = *Count of crimes occurring along road type n (within Region N)*

D_n = *Total distance of road type n (within Region N)*

C_N = *Count of crime within the entire Region N*

D_N = *Total distance of all road types within entire Region N*

The calculation above determines an LQ based on the rate of criminal events per distance of one road type. This value is then standardized by the region-wide rate of all criminal events per distance of all roads. This minor adaptation creates classifications that are more meaningful within the local built environment—crime is categorized not according to arbitrary geographic boundaries, for example, but according to the specific environmental feature onto which it is mapped. In choosing a distance-based denominator, it reduces the impact of larger area-based denominators that include locations where crimes cannot have occurred in the first place. Events geocoded based on road networks can only be mapped to the network, so excluding all non-road features provides a more accurate denominator.

There is no standard test to measure the statistical significance of the LQ, though related metrics are beginning to establish such measures, showing promise for wider applications (see, e.g., Wang et al. 2017). Several values have been applied as indicators of very high overrepresentation within sub-areas; these values range from 1.3 (Miller et al. 1991; Andresen 2007; Andresen et al. 2009) to 2.0 (Groff 2011). The latter value has been selected for use within this study to capture the road types with considerably higher crime rates than the area-wide norms.

Measuring crime concentration by road type

The adapted LQ was applied within this study to measure the impact that different road classifications may have on crime within Coquitlam and Port Coquitlam. This analysis was undertaken at the macro- and micro-level. At the macro-level, all records were analyzed by road type to identify the classifications with disproportionate volumes of crime. Micro-level analysis was then performed by street segment, to identify the precise street type of the 10 highest crime blocks within the study area.

Results

Macro-level exploration

This analysis begins at the macro-level, exploring the connections between road type and criminal events across the study area. Table 1a presents the initial breakdown of crime events according to the road type on which the event was mapped. Subsequent sections of Table 1 (b through g) further break down the analysis according to crime type to explore how the resulting crime concentrations shift. As emphasized in Table 1, the study municipalities report an overall average of 16.5 criminal events per kilometre of roadway; however, as shown by the LQ, this rate increases 2.9 times when considering arterial roads. Collector roads display a LQ of 1.2, indicating a slight over-representation of crime, though this does not surpass the threshold value of 2.0. The LQs of all other road classifications display under-representation of crime. While more events happen on local roads than any other classification, an LQ of 0.5 highlights that the rate of events per kilometre of local road is less than half of the comparable rate across all road types. Very few sections of roads are classified as freeways within Coquitlam and Port Coquitlam; no crime events at all are associated with this road type.

The relative values of the LQs as displayed in Table 1 remain consistent across crime categories. Arterial roads consistently display the highest LQ, showing over-representation across all crime types. Indeed, arterial LQs consistently surpass the threshold value of 2.0 in all categories except one. Rates for other federal statute violations, such as income tax, immigration, health care, and customs act violations, are higher than average across arterial, collector, and local roads, although no road type surpasses the LQ threshold value. A relatively small number of offences are classified within this grouping, and none are recorded on any other road type. Likewise, collector roads consistently have the second highest LQ, displaying a value higher than 1.0 across all crime categories, although none of the collector LQs surpass the threshold of 2.0. All other road classifications

Table 1
Criminal events by road type of event location: all crimes, and specific types (2009)

a) All Crimes

Road Type	Length (km)	Road Length (%)	Crime Events *(f)*	Crime Events (%)	Events/km	LQ
Arterial	96.44	12.43	4,541	35.52	47.08	2.86
Collector	98.88	12.74	1,911	14.95	19.33	1.17
Freeway	13.31	1.72	0	0.00	0.00	0.00
Highway	34.12	4.40	266	2.08	7.80	0.47
Local	461.05	59.41	6,011	47.01	13.04	0.79
Other	72.22	9.31	57	0.45	0.79	0.05
Total	**776.02**	**100.00**	**12,786**	**100.00**	**16.48**	**1.00**

b) Crimes Against Persons—*such* as assault, robbery, sexual assault

Road Type	Length (km)	Road Length (%)	Crime Events *(f)*	Crime Events (%)	Events/km	LQ
Arterial	96.44	12.43	464	31.06	4.81	2.50
Collector	98.88	12.74	227	15.19	2.30	1.19
Freeway	13.31	1.72	0	0.00	0.00	0.00
Highway	34.12	4.40	20	1.34	0.59	0.30
Local	461.05	59.41	779	52.14	1.69	0.88
Other	72.22	9.31	4	0.27	0.06	0.03
Total	**776.02**	**100.00**	**1,494**	**100.00**	**1.93**	**1.00**

c) Offences Against Property—*such as break and enter, arson, possession of stolen goods*

Road Type	Length (km)	Road Length (%)	Crime Events *(f)*	Crime Events (%)	Events/km	LQ
Arterial	96.44	12.43	2,126	32.76	22.04	2.64
Collector	98.88	12.74	972	14.98	9.83	1.18
Freeway	13.31	1.72	0	0.00	0.00	0.00
Highway	34.12	4.40	154	2.37	4.51	0.54
Local	461.05	59.41	3,214	49.52	6.97	0.83
Other	72.22	9.31	24	0.37	0.33	0.04
Total	**776.02**	**100.00**	**6,490**	**100.00**	**8.36**	**1.00**

d) Other Criminal Code Violations—*such as weapons, breach of probation, criminal organization*

Road Type	Length (km)	Road Length (%)	Crime Events *(f)*	Crime Events (%)	Events/km	LQ
Arterial	96.44	12.43	1,339	39.71	13.88	3.20
Collector	98.88	12.74	452	13.40	4.57	1.05
Freeway	13.31	1.72	0	0.00	0.00	0.00
Highway	34.12	4.40	47	1.39	1.38	0.32
Local	461.05	59.41	1,514	44.90	3.28	0.76
Other	72.22	9.31	20	0.59	0.28	0.06
Total	**776.02**	**100.00**	**3,372**	**100.00**	**4.35**	**1.00**

e) Controlled Drugs and Substance Act Violations—*such as drug production, importing, trafficking*

Road Type	Length (km)	Road Length (%)	Crime Events *(f)*	Crime Events (%)	Events/km	LQ
Arterial	96.44	12.43	213	37.90	2.21	3.05
Collector	98.88	12.74	82	14.59	0.83	1.15
Freeway	13.31	1.72	0	0.00	0.00	0.00
Highway	34.12	4.40	12	2.14	0.35	0.49
Local	461.05	59.41	252	44.84	0.55	0.75
Other	72.22	9.31	3	0.53	0.04	0.06
Total	**776.02**	**100.00**	**562**	**100.00**	**0.72**	**1.00**

(Continued)

Table 1
(Continued)

a) All Crimes

Road Type	Length (km)	Road Length (%)	Crime Events *(f)*	Crime Events (%)	Events/km	LQ

f) Other Federal Statute Violations—*such as violations of income tax, customs, immigration acts*

Road Type	Length (km)	Road Length (%)	Crime Events *(f)*	Crime Events (%)	Events/km	LQ
Arterial	96.44	12.43	12	18.75	0.12	1.51
Collector	98.88	12.74	11	17.19	0.11	1.35
Freeway	13.31	1.72	0	0.00	0.00	0.00
Highway	34.12	4.40	0	0.00	0.00	0.00
Local	461.05	59.41	41	64.06	0.09	1.08
Other	72.22	9.31	0	0.00	0.00	0.00
Total	**776.02**	**100.00**	**64**	**100.00**	**0.08**	**1.00**

g) Traffic Violations—*criminal traffic charges such as driving while prohibited, dangerous operation of a motor vehicle, impaired operation causing death (does not include civil offences such as speeding)*

Road Type	Length (km)	Road Length (%)	Crime Events *(f)*	Crime Events (%)	Events/km	LQ
Arterial	96.44	12.43	387	48.13	4.01	3.87
Collector	98.88	12.74	167	20.77	1.69	1.63
Freeway	13.31	1.72	0	0.00	0.00	0.00
Highway	34.12	4.40	33	4.10	0.97	0.93
Local	461.05	59.41	211	26.24	0.46	0.44
Other	72.22	9.31	6	0.75	0.08	0.08
Total	**776.02**	**100.00**	**804**	**100.00**	**1.04**	**1.00**

display LQs very near or below 1.0, indicating average or under-representation of the crime categories in question.

Micro-level exploration

As a whole, arterial roads within the study site have higher rates of crime than other road types. This concentration becomes more apparent as we focus on the specific street blocks associated with the highest counts of crime events. Table 2 provides a closer look at the highest micro-level crime concentrations within Coquitlam and Port Coquitlam, aggregated to the block level.

The 10 single blocks listed in Table 2 together account for 11.6% of all crime events within Coquitlam and Port Coquitlam. The single top street segment, labelled as *Arterial – a*, houses the area's regional shopping mall, and is located in the geographic centre of the cities (as discussed in Figures 1 and 2, above). This segment alone accounts for 3.1% of all events within the study area. While Table 2 displays only aggregate crime categories, *Arterial - a* also appears within each of the top 10 highest segments when broken down according to distinct crime type, indicating that this particular micro-level concentration is of considerable local importance (crime-specific analysis not shown in this paper, in the interest of space). The LQs for each of these top locations reveal the extreme concentration of criminal events per distance, and should be considered in comparison to the overall average for the study site as a whole; for example, the highest-density street segment reports 238.1 times the concentration of crime per road distance than the area's average.

Further insight into the local relationships between the built environment and crime emerge when exploring the details about these micro-scale hotspots. The top seven highest-crime blocks are classified as arterial roads, once again emphasizing the local relevance of this environmental feature when considering crime distributions. However, three segments, labelled as *Highway – a*, *Collector – a, and Collector - b*, also appear on the top-10 list, each reporting over 80 crime events within the year of study. This indicates that while arterial roads are certainly locally relevant in shaping the crime

Table 2
Top 10 road segments, by counts (2009, all crimes)

Road Type	Road Length (km)	% of Total Length	Count of Events	% of Total Events	Events/km	LQ
Arterial – a	0.10	0.01	396	3.10	3925.81	238.12
Arterial – b	0.31	0.04	206	1.61	662.62	40.19
Arterial – c	0.23	0.03	165	1.29	706.83	42.87
Arterial – d	0.42	0.05	133	1.04	318.79	19.34
Arterial – e	0.41	0.05	115	0.90	278.94	16.92
Arterial – f	0.17	0.02	103	0.81	596.35	36.17
Arterial – g	0.22	0.03	98	0.77	441.79	26.80
Highway – a	0.69	0.09	96	0.75	139.77	8.48
Collector – a	0.09	0.01	86	0.67	993.31	60.25
Collector – b	0.43	0.06	84	0.66	194.78	11.81
Top 10 Road Segments	**3.07**	**0.40**	**1482**	**11.6**	**482.13**	**29.24**

distributions in Coquitlam and Port Coquitlam, specific and important micro-level hotspots appear along roads classified as both highways and collectors as well.

Crime and the built environment: Discussion

The varying concentrations across the cities of Coquitlam and Port Coquitlam support the finding that crime is not uniformly distributed across the urban landscape. Previous research has identified specific features within the built environment that are frequently associated with disproportionate rates of urban crime, including mention of major roads as important elements in shaping local crime patterns. Through a novel adaptation of the LQ metric, this multi-scale analysis has helped to provide a clearer definition of *major* by identifying the road types that are associated with an over-representation of crime within the study site.

Reviewing macro-level findings

Existing research has discussed the importance of major roads in shaping the spatial distribution of crime and disorder events (Beavon et al. 1994; Johnson and Bowers 2010; Groff and Lockwood 2014). However, the definition of "major roads" themselves continues to be inconsistently defined. What constitutes a "major" road is open to interpretation and is likely to be dependent on the local environmental design. There is little consistency across existing research regarding which road classifications are to be considered as major: some studies explore highways as the unit of analysis, others incorporate a combination of several high-volume road types (see for examples, Brantingham et al. 2009; Groff and Lockwood 2014). Within Coquitlam and Port Coquitlam, not a single crime event location is recorded along the freeway, and relatively few are associated with local highways. These two categories make up a comparably small proportion of the total road distances within the study municipalities. While typically well-used, these routes include fewer intersections and exits than other road categories, and correspondingly, fewer facilities along these roads that draw individuals together. This translates into fewer opportunities to stop and access any targets that may be identified along the route. While these road classifications can certainly be thought of as major, based on road distance and associated criminal events alone, these higher-level major roads as a whole appear unlikely to be primary drivers of local crime.

In contrast, collector and arterial roads are also well-travelled, but in comparison to freeways and highways, they provide many opportunities to stop, start, identify, and access potential targets. Collectors make up 12.7% of the road network within the study site, and are associated with 15.0% of recorded crime events. Likewise, over 12.4% of the local road network is classified as arterial, and 35.5% of all criminal events fall on these streets. When focusing on the counts and percentages of crime events, as well as the rate of events per kilometre, it is clear that a considerable proportion of events occur on both collector and arterial roads. However, based on these metrics alone, the relative importance of these built environmental features is not immediately clear.

Recognizing this, we adapted a common metric that is typically used to compare differences in crime rates or types across areas. The adapted LQ provides a clear and concise method to quantify the relative importance of different road types within the study site, addressing some common concerns within area-based measures. The results allow for clear comparison between road types: LQs associated with aggregate crime along freeways and highways within the study site are 0.0 and 0.5, respectively, indicating considerable under-representation of crime along these road types. The LQ for all events along collector roads is 1.2, which is a slight, but not considerable over-representation of crime rates on these road types. Arterial roadways, however, display consistent and considerably over-represented LQ values, exceeding the threshold value of 2.0 for all crime events. These patterns are echoed when breaking down crime according to event type, with a minor reduction in magnitude (and a dip below the threshold value) when considering the few non-drug federal violations recorded within the study site. In contrast, the LQs of local and other roads within the area remain at or below the local area average, regardless of event type. These findings reiterate the results found in past research, and support the relevance of major roads, specifically arteries, in shaping the concentration of urban crime (Weisburd et al. 2012; Andresen et al. 2017).

Local-level hotspots: A micro-level analysis

This within-classification concentration brings us to the micro-level, where we see the exceptionally clustered nature of local crime, with 11.6% of reported events being associated with 10 single blocks across both municipalities (Table 2). The local importance of arterial roads is once again underscored, as each of the top seven blocks with highest counts of crime fall within this category. The LQs, calculated for each block, well exceed the threshold value of 2.0 in each case—though this is certainly expected given the high count of crime concentrated within a small road length (discussed below), it continues to emphasize the within-category clustering along arteries.

The single road segment reporting the highest counts of crime, identified as *Arterial – a* within Table 2, is attributed with 396 events in 2009. This segment reports the highest counts across multiple categories, including the highest count of property and drug crimes, the second highest count of personal crimes, and is within the top 10 segments across all other categories. This specific micro-location is an important hot street within the locale. In order to further understand what is driving crime concentration at the block, however, we need to consider the unique land use facilities that exist here. This block houses a regional shopping mall, a land use type which has been frequently identified as a crime attractor (see Figure 2) (Kinney et al. 2008; Wuschke and Kinney 2018). This highlights the importance of considering the land use and facilities that exist on the road itself. In fact, six of the seven arterial hot blocks featured within Table 2 border commercial land uses. Upon further exploration, these six locales are each associated with shopping facilities. While this indicates a likely correlation between these major nodes and arterial roads themselves, further investigation indicates that not all hot blocks follow this trend. *Arterial – c* represents a low-density residential block, located approximately one kilometre from the location's regional mall. This warrants further exploration: while the facilities on each block shape segment-level crime (Bowers 2013; Lee and Eck 2019), land use alone may not be sufficient to identify key local hotspots. Road type, particularly arterial roads, appear to be important features beyond land use itself.

Analysis at the micro-scale further reveals the complexity of local crime patterns within this area. One road segment designated as highway, and two collectors emerge within the top 10 blocks with the highest crime counts, reporting at least 84 events along each segment. This finding reiterates the importance of local-level analysis across multiple scales of aggregation. While arterial roads report high levels of crime across crime types and scales of analysis, other road types remain locally important. These non-arterial locations are not consistent hotspots across crime types: *Highway – a* is largely associated with property crime; *Collector – a* contains a mix of crimes, disproportionally categorized as crimes against person, and other; and *Collector – b* is disproportionally associated with traffic violations and drug crimes. These findings emphasize the within-category clustering present in crime distributions, and underscore the importance of exploring the environmental context through locally based analysis at multiple scales.

When considered alongside the results from the macro-level analyses, this micro-level clustering highlights that not all similar features are equally associated with local crime distributions (Bowers 2013; Groff and Lockwood 2014). While arterial roads appear at both the macro- and micro-levels as being related to consistently high concentrations of criminal events, these findings certainly do not apply to all arterial blocks. In fact, within the year of this study, there were no reported crime events along 30.2% of local arterial roads. The highly clustered nature of crime events is further evident at the citywide level: 41.1% of the total road distance across Coquitlam and Port Coquitlam have no reported crime events in 2009, and 58.0% of all blocks within the two municipalities had one or fewer crime events.

Contributions, limitations, and future research directions

This paper has contributed to the existing body of research exploring crime within the context of the urban built environment. In proposing adaptations to the LQ, this research addresses several existing limitations associated with rate-based measures, while continuing to provide clear and straightforward identification of crime concentrations. The process of geocoding address-level data results in a single point placed proportionally along a road network. This provides a concrete limit to the potential locations in which geocoded points may be placed. Rather than systematically excluding large area-based features such as parks, waterways, and steep terrain that otherwise inflate denominators (McCord and Ratcliffe 2009), this adaptation excludes *areas* entirely, considering only the linear road distances on which events can be matched. This adaptation reduces the impact of a large denominator that would otherwise over-inflate the rate-based LQ calculation. In doing so, the adapted LQ provides a standardized metric to measure relative concentrations of crime at the block level and along road networks.

Testing this adaptation allowed for a locally informed definition of criminogenic major roads. In addition, in applying the LQ across both crime categories and spatial scales of analysis, this metric has demonstrated value in measuring the clustered nature of crime. Applying the LQ within this study has revealed that, in many ways, Coquitlam and Port Coquitlam are consistent with their larger urban counterparts and neighbouring municipalities. Arterial roads are the sites of considerable counts and rates of crime. Crime events concentrate along these high-crime roads, with further concentration at the micro-scale emphasizing the impact of single high-crime blocks. This finding further emphasizes within-category crime concentration, and stresses the need for analysis at multiple spatial scales (Kinney et al. 2008; Wuschke and Kinney 2018). Moreover, these analyses show that road type is important across a variety of crime classifications. While previous research indicates that land use is important in understanding spatial distributions of crime (Wuschke and Kinney 2018), these results suggest that arterial roads, themselves, are important environmental features to consider.

While supporting existing research, this study has several limitations, providing direction for further investigation. The LQ measure incorporated within this study helps to address several existing limitations with traditional interpretations of the metric; however, some areas remain to be addressed. While the use of length-based distance measures reduces the artificial inflation of high-crime sub-areas, the adapted LQ continues to be a rate-based measure, requiring that discrete events be aggregated to specific sub-units. This continues to leave the measure susceptible to the MAUP. However, in conducting analyses across multiple scales, this helps to identify inconsistencies and shifts in patterns that may emerge due to aggregation concerns, and is a helpful practice to continue. However, the measure does not yet have a consistently-applied significance metric (McCord and Ratcliffe 2009). Given promising developments within related measures (Wang et al. 2017), this area is deserving of continued research.

This study explored crime both in aggregate, as well as by broad category, in fitting with the multi-level analytical approach presented herein. It is likely that new concentrations will emerge with the inclusion of more nuanced crime categories (Andresen and Linning 2012). Further, this study assigned crime recorded at intersections to one of the adjacent road segments, which necessarily incorporated some uncertainty into the analysis. Further research is needed to test alternative methods to account for crime in such fuzzy locations. In addition, findings from this study identify key environmental features based on the location of the crime event itself, matching a single event with its associated road type. Finer-resolution data would facilitate identification of specific facilities driving crime patterns (Lee and Eck 2019), while broader explorations would facilitate understanding of wider local impact that such built environmental elements have on crime and disorder within their surrounding urban region. By exploring the specific association of key environmental features and crime both at the local level and in the immediate surroundings, a more complete understanding of the relationship between the local built environment and crime can emerge. This exploration could then include the effects of both road type and land use to identify their individual effects.

Conclusion

Crime is not uniformly distributed across urban spaces. Key features within the urban landscape are frequently found to be related to higher counts and rates of disorder and crime events. Past research has identified that major travel routes attract high volumes of both motivated offenders and suitable targets, and as such, may be associated with higher levels of crime. While there has been a wide breadth of research identifying the types of environmental features associated with high volumes of crime, there has been a call for further locally based analyses to determine the applicability of such findings across wider urban settings (see Groff 2011; Groff and Lockwood 2014; Wuschke and Kinney 2018). This paper contributes a methodological adaptation to the LQ, to better account for crime concentrations along linear features. Findings from this analysis emphasize major roads as the site of a considerable proportion of crime, and further define major roads within the local context as arterial routes. This research emphasizes the need for analysis at multiple scales of aggregation, as nuanced patterns and concentrations emerge with each level of analysis.

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