Market Rental Housing Affordability and Accessibility to Rapid Transit in Montreal and Vancouver

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ABSTRACT

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Housing affordability is a major issue in much of urban Canada, and particularly in the largest metropolitan areas. While measurements and rankings of housing affordability are widely publicized, they typically do not capture variations in affordability within metropolitan areas, where prices may vary significantly between, for instance, central cities and outer suburbs. One factor that can affect housing prices is access to mass transit, and rail rapid transit in particular, but existing research has not considered how this may impact affordability. From an ethical stance of redistributive equity, if housing is less affordable in transit-accessible places, low income people will be less able to access the rapid transit system and will be less well-off in comparison to middle and high income groups. This thesis applies a residual income approach – which considers housing affordable if it leaves a household with enough income to cover other basic needs – to data gathered from online rental listings in Montreal and Vancouver. It then examines how affordable market rental housing is distributed spatially within each city, and with respect to household composition and income. Looking through these "lenses," the picture of affordability is different for different types of households. Indeed, for certain household types, no affordable housing was identified. At the metropolitan scale, housing was less affordable within rapid transit catchments in both cities, while at the level of urban/suburban zones, the results were mixed. The methods therefore present a nuanced measure of affordability that can be adapted in other contexts.

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Table of Contents

List of Tables

List of Figures

1. Introduction

Housing affordability has been an issue of popular concern in many Canadian cities, with indices such as the Royal Bank of Canada's (RBC) quarterly *Housing Trends and Affordability* (Wright & Hogue, 2015) and libertarian think-tank Demographia's annual survey of housing affordability in 378 metropolitan areas in nine industrialized countries[1] (Cox & Pavletich, 2015) garnering widespread attention in the national media (e.g., *CBC News*, 2015a, 2015b; *CTV News*, 2014; Perkins, 2014a, 2014b; Posadzki, 2015a, 2015b). According to these reports, and reiterated by media coverage, affordability is particularly strained in Toronto and Vancouver, although generally less of a concern outside these centres. Demographia goes so far as to claim – despite its limited selection of countries – that Vancouver has the world's second-most expensive housing (after Hong Kong), and the most expensive housing in North America as of 2015; Toronto also ranks as "severely unaffordable." Despite media attention on Vancouver and Toronto, Demographia also rates Montreal as "seriously unaffordable," and affordable housing is a central concern of local activists (e.g., Bernstien, 2015; *Front d'action populaire en réaménagement urbain* [FRAPRU], n.d.). Indeed, housing affordability is a challenge for many people across Canada as a whole.

While high housing prices are an indicator of a strong market economy in many Canadian cities – and the growing benefits of a location in some key centres – housing affordability stress serves as an indicator of households at risk of becoming homeless (Skaburskis, 2004). Numerous studies establish a link between tight housing markets – in which vacancies are low and rents are high – and homelessness (O'Flaherty, 1995; Park, 2000; Quigley, Raphael & Smolensky, 2001). While most households do not experience the extreme outcome of homelessness, a large number experience housing affordability stress, often with serious negative impacts. It may leave families with inadequate income to cover other essentials (Kutty, 2005; Stone, 2006), with potentially deleterious effects on long-term and short-term health (Kirkpatrick & Tarasuk, 2007; Pollack, Griffin & Lynch, 2010), or cause them to incur debt to pay for them (Shipler, 2004). Furthermore, rising housing costs coupled with easy access to mortgage credit has led to an expansion in household debt in Canadian cities, resulting in increased economic vulnerability at

[1] Australia, Canada, Hong Kong, Ireland, Japan, New Zealand, Singapore, the United Kingdom, and the United States.

a variety of geographic scales from the household to the metropolitan area (Walks, 2013; see also Crouch, 2009).

Broadly speaking, housing affordability refers to "the challenges each household faces in balancing the cost of housing, on the one hand, and its non-housing expenditures, on the other, within the constraints of its income" (Stone, 2006, p. 151). In practice, this has been quantified in a variety of ways, producing a number of standards for what is considered "affordable" housing (Stone, 2006). These different approaches often reveal considerably different distributions of the problem within society (Lerman & Reeder, 1987; Stone, 1993).

According to neoclassical economists, housing unaffordability results from an excess of demand over supply. This could explain the situation in Canada, where supply of low-cost housing has been limited since the 1970s and 1980s, as private-sector rental housing construction declined sharply due to rent control policies and the removal of tax incentives, and gentrification removed low-cost housing from the market (Fallis, 1990; Leone & Carroll, 2010). Since the 1990s, government subsidization of non-market housing has been curtailed, as well (Leone & Carroll, 2010). Supply may also be constrained by land use regulations and restrictions, which may have distributional consequences in that their negative effects are greatest for the lower end of the housing market (Brueckner, 2000; Glaeser & Gyourko, 2003; Malpezzi & Green, 1996). On the demand side of the equation, expansion of international finance and mortgage markets has allowed housing prices to be bid upward in cities connected to the global economy, independent of regional or local labour market conditions (Ley, 2010; Rolnik, 2013; Walks, 2013). Indeed, income inequality has also increased in Canadian cities as a result of processes of globalization and economic restructuring, including deindustrialization and other labour market changes, such as low-income earners increasingly taking jobs with lower annual pay, even while overall wealth has increased (Bolton & Breau, 2012; Chen, Myles & Picot, 2012; see also Bunting, Walks & Filion, 2004). As a result, some households do not have sufficient income to generate market demand and are thus ignored by the market (Hulchanski, 2005).

Many of these changes are tied to neoliberalism, either in that they are the direct result of neoliberal policies, or are set within a neoliberal policy context. Harvey (2005, p. 2) defines neoliberalism as "a theory of political economic practices that proposes that human well-being can best be advanced by liberating individual entrepreneurial freedoms and skills within an institutional framework characterized by strong private property rights, free markets, and free

trade." These ideas rose to prominence in the late 1970s in response to increasing unemployment and severe inflation under the existing welfare state system. The seductive appeal to notions of freedom legitimizes and conceals the effect of neoliberal policies everywhere, which, despite geographically-contingent variations in "actually-existing neoliberalism" (Brenner & Theodore, 2002), has been to increase the wealth and income of economic elites, often with detrimental effects on the rest of the population. This has led Harvey (2005) to argue persuasively that it is inherently a political project aimed at restoring capitalist class power. This has occurred through two (not necessarily temporally separate) phases identified by Peck and Tickell (2002). The first involves the "roll-back" of the Keynesian welfare state – for example, the decline in subsidies for non-market housing cited above – while the second entails the "roll-out" of new policies and institutions conducive to the neoliberal project – such as the generalization of gentrification as urban policy around the globe (Smith, 2002).

Consistent with neoliberalism is the ideal of homeownership. Of course, such an ideal long pre-existed the rise of neoliberalism, but it has taken on added importance in such a context. In addition to normalizing private property, proponents often see it as a way of providing "asset-based welfare;" that is, allowing individual owners to grow and store wealth so that (in theory) they are able to take care of their own well-being without state involvement (Forrest, 2011). The increased importance of mortgages in extending this vision, coupled with the deregulation of financial markets, is a major component in the financialization (increasing importance of finance rather than production) of the global economy. The predominant beneficiaries of such a system are those elites operating within the finance sector; the result is often upward pressure on housing prices, as noted above, and increasing socio-spatial polarization of the city (Walks, 2014).

Housing affordability is an issue of concern to North American politicians elected to address their citizens' concerns, planners seeking to guide land use and infrastructure development equitably and productively, and many other constituencies and interest groups. In the postwar period in North America, the primary response to concerns about housing affordability has been through government-aided suburbanization, by extending physical infrastructure such as roads into an expanding urban periphery and underwriting mortgages (Hayden, 2003; Solomon, 2007). While this approach continues, an increasing number of municipal and regional governments have sought to restrict expansion of new subdivisions and

finance rail transit infrastructure amid concern over the environmental impacts of automobile-dependent urban sprawl and the high recurring costs of infrastructure expansion and maintenance (Downs, 2004; Frisken, 2007).

Some economists, politicians, and industry-linked groups have warned that restricting automobile-dependent urban spatial growth means increased housing prices across metropolitan regions (Brueckner, 2000). Transportation systems theoretically allow households to live further from employment centres, and therefore access cheaper housing at the expense of greater commuting costs. In this way, transport systems alleviate housing price pressure on the central part of the metropolitan area by expanding the amount of residential and employment locations. However, prior to the mid-twentieth century, mass transit systems often achieved this objective, for example in the case of Boston's streetcar network (Warner, 1978), elevated and ground-level railroads such as in Chicago (Hoyt, 1939), the New York subway (Derrick, 2001; King, 2011) and the London Underground (Levinson, 2008). While reducing housing prices in the central area, rail transit has generally been shown to increase housing prices and land values near stations (e.g., Debrezion, Pels & Rietveld, 2007; Hess & Almeida, 2007; Mohammad, Graham, Melo & Anderson, 2013), resulting in a flattening of the rent and population density gradients away from the city centre (Clark, 1951; Wingo, 1961).

Intra-metropolitan studies of housing affordability are rare (e.g., Bogdon & Can, 1997; Bunting et al., 2004; Fisher, Pollakowski & Zabel, 2009), and have neglected to consider how housing affordability relates to the location of transit infrastructure. Affordability analyses more generally have also overlooked the relationship between transit and housing. Popular measures such as the RBC and Demographia reports consider only the affordability of owning rather than renting, reflecting a neoliberal bias toward private homeownership. Also, most research uses simplistic price-to-income ratios (Hulchanski, 1995; Stone, 2006).

This thesis will examine the relationship between the supply of affordable market rental housing and rapid transit accessibility in the Montreal (estimated 2014 population: 4,027,100) and Vancouver (estimated 2014 population: 2,470,300) metropolitan areas (Statistics Canada, 2015a).[2] Comparing and contrasting these two urban regions avoids the shortcomings of using a single case study, as phenomena observed within one particular city may be the result of local

[2] Throughout the text, unless otherwise specified, references to Montreal or Vancouver denote the entire metropolitan area.

specificities rather than broader processes. These two regions make for an interesting comparison as they represent similar but different contexts within Canada. As the second and third largest metropolitan areas in the country, they occupy similar positions in the global economy, typically ranked as lower-tier centres of predominantly regional importance (e.g., Globalization and World Cities Research Network, 2014) – in contrast Toronto, Canada's largest city, stands out as having a more important international economic presence.[3] Also, they have comparable median household incomes and non-housing costs of living, and both evince housing affordability issues. However, Montreal has relatively cheap housing and Vancouver has relatively expensive housing compared to other large metropolitan areas in Canada (CBRE, 2015; Wright & Hogue, 2015). Differences in housing costs are at least partly the result of some important contextual differences between the two case studies.

One set of differences has pertained to economic circumstances. In Montreal, the broad trends contributing to housing affordability issues in Canada discussed above have been coloured by the outward movement of capital and loss of banking headquarters to Toronto, especially from the early 1960s to late 1980s, resulting in slower growth than other major metropolitan areas in Canada and the United States over recent decades. While this process was underway by the early 20th century, some have suggested it was more recently exacerbated by political uncertainty over the Quebec separation movement and laws mandating the use of the French language, and the opening of the St. Lawrence Seaway in 1959 further eroded the city's locational advantage as a major transhipment point (Germain & Rose, 2000). In spite of resultant slow growth and the loss of population from parts of the central area, Montreal's economy and population have since stabilized and it has performed strongly as a regional center, growing at a comparable rate to other major Canadian cities (Germain & Rose, 2000; Polèse & Shearmur, 2004; Shearmur & Rantisi, 2011), though some commentators have remarked that it has "an inherited urban size beyond its role as a corporate and business centre" (Bourne, Brunelle, Polèse & Simmons, 2011, p. 62). Meanwhile, Vancouver historically had relatively little manufacturing industry, and since the mid-twentieth century has experienced growth as a post-industrial city (Hutton, 2004). At the same time, the infusion of capital in real estate, emanating largely from the Asia-Pacific region, has also been particularly evident in Vancouver (Ley, 2010; Barnes,

[3] Polèse and Simmons (2011) discuss various international rankings of Canadian cities as global centres in more detail, geographically accounting for each city's relative performances.

Hutton, Ley & Moos, 2011).[4] The importance of real estate as a key component of Vancouver's regional development is in part illustrated by the volume of dwelling units for which building permits were issued in 2014: while the population of the metropolitan area was just over 60% that of Montreal, permits were issued for roughly the same number of new dwelling units (Statistics Canada, 2015b). International investment in real estate is occurring in Montreal as well, though not to the same extent, and being outsized relative to its regional functions, it is able to absorb these flows with less impact on the overall market.

Another set of differences has been related to the character of suburban expansion. In Montreal, an expanding suburban housing supply has been facilitated by massive government investments in freeways and the relocation of manufacturing industry to outlying areas (Charbonneau, Hamel & Barcelo, 1994; Germain & Rose, 2000). By contrast, Vancouver's outward expansion – and by extension, housing supply – is constrained not only by physical geography (the North Shore Mountains, Strait of Georgia, and Fraser River), but also by an agricultural land reserve enforced by a government commission. Instead, the regional growth strategy calls for transit-oriented land development around designated transit stations, usually built as high-rise condominium or apartment towers. Together, these factors underlie the general differences in the cost of housing between the two metropolitan areas.

Both cities also feature extensive urban rail rapid transit systems (as well as bus and commuter rail service). However, these systems differ in both technology and ridership. Montreal has 68 underground stations along the 69km Metro, a rubber-tired railway utilizing nine-carriage train sets for most of its service, which carried about 980,000 passengers per day in 2014 (behind only New York City in ridership in the United States and Canada) (American Public Transit Association [APTA], 2015). Service coverage is predominantly but not exclusively within the inner city. Vancouver has 49 elevated and underground stations along the 66km SkyTrain, an automated rail mass transit system which carried approximately 323,000 passengers per day in 2014 (APTA, 2015), as well as a ferry service across Burrard Inlet and

[4] This was facilitated until recently by immigration policies favouring wealthy businesspeople who tend to locate predominantly in Vancouver and Toronto and favour investments in real estate, but is an effect distinct from immigration per se. Many immigrants have a distinctly different experience, whereby obtaining housing is a formidable challenge, particularly for those arriving in Canada on humanitarian grounds (Carter, 2005; Ley, 2010; Moos & Skaburskis, 2010; Teixeira, 2013).

semi-rapid bus service, both well-integrated with the SkyTrain network. The network extends into the suburbs to a greater extent than that of Montreal.

The geographic distribution of affordable market rental housing with respect to rapid transit service is of interest as it may have implications for social equity. There are a number of competing definitions of equity with respect to transit provision, based on moral ideas of fairness and justice; as such, they can be vague, sometimes conflicting, and usually difficult to translate into practice (Deka, 2004; Altshuler, 2010). Altshuler (2010) identifies two broad definitions: return-to-source equity and redistributive equity. Return-to-source equity is based on the principle that public benefits should be in proportion to fiscal contribution, either in such a way that the groups that use a service pay for it; or that the funding from higher levels of government should flow to lower levels in the proportion that revenues (e.g., from taxes) flow from lower to higher levels. I reject the use of the return-to-source model as it perpetuates inequalities; in fact, it can exacerbate them, since presumably the public benefits are designed to improve the quality of life of the recipients, yet the affluent will receive a greater benefit and therefore greater improvement. Repeated over time, this will have a compounding effect on inequality. Redistributive equity, on the other hand, holds that government should seek to offset private sector inequalities, either through fiscal redistribution, or through the principle of "do no harm," which maintains that public initiatives should leave no one worse off. The "do no harm" principle, however, generally does not include any form of transfer from the more- to less-affluent, it simply means reworking proposals so as to not leave either advantaged or disadvantaged parties worse off. It is redistributive only in that it prevents disproportionate harm to the already disadvantaged. A more positive statement of equity, then, would be one which seeks to reduce or eliminate existing inequalities rather than simply prevent new ones. It is this type of equity with which I am concerned.

If affordable housing exists primarily outside of rapid transit catchments, this would suggest a social equity issue as the system would be of most convenient use to those with higher incomes who can afford to live in close proximity to stations or stops. Rapid transit, meanwhile, provides metropolitan region-wide accessibility without the use of a (costly) automobile, to a much greater extent than other public (e.g., bus) or active (e.g., walking, cycling) modes of transportation (Vuchic, 1999; Newman, Kenworthy & Glazebrook, 2013). These accessibility benefits would therefore be most easily realized by those who are already relatively advantaged.

Furthermore, while it is difficult to determine how much different groups contribute to and benefit from transit services, for any given funding scheme, the less lower-income groups have access to the service, the more regressive the distribution of resources (Pucher, 1981).

The specific research questions to be addressed in this thesis are:

1. What is the geographic distribution of affordable market rental housing in the Montreal and Vancouver metropolitan areas, and how does the distribution differ for households of various income levels and compositions (e.g., single individual, lone parent, couple with children, couple without children)?
2. What is the relationship between the availability of affordable market rental housing and rapid transit accessibility?
3. Does this relationship vary by location within each metropolitan area (e.g., inner city vs. suburbs), and if so, how?

Chapter 2 provides an overview of the literature conceptualizing the measurement of housing affordability, how transport affects housing prices (one component of affordability – the other being income), and how this relationship to transport and location has been incorporated in affordability studies to date, to provide a theoretical base for this thesis research. Subsequently, Chapter 3 discusses the research methods, including collecting the rental data, developing a suitable measure of housing affordability, defining rapid transit catchments and urban/suburban zones, and employing statistical analysis. Chapter 4 presents the results, which are discussed in Chapter 5. Chapter 6 concludes. This inter- and intra-metropolitan affordability analysis offers planners case-based findings on the nuances of housing affordability and methods that could be utilized in other places.

2. Literature Review

The purpose of this chapter is to review existing research to inform the present study, and is divided into three sections. First, definitions of housing affordability are discussed, focussing in particular on the variety of ways affordability has been measured. The second section addresses the relationship between transportation – in particular, rail rapid transit – and housing prices. The final section introduces the small body of literature that has, to a limited extent, brought together an examination of transportation and location with the study of housing affordability.

2.1. Defining and Measuring Housing Affordability

Housing affordability refers to a relationship between housing price, produced by supply and demand conditions, and income. When prices are high or incomes are low, relative to the other, affordability problems arise. While a particular household could consume less housing to keep its housing costs "affordable," this may not be possible: there are substantial time and transaction costs required to change housing, households have imperfect information about prices and their own future circumstances, and constraints such as building codes or zoning requirements may limit the supply of housing, while broader economic forces may push the cost of housing out of reach for some households (Bunting et al., 2004; Skaburskis, 2004).

Housing affordability is commonly quantified as a ratio of expenditure to income. This implies a normative standard[5] whereby housing is not affordable when a household's expenditure exceeds a given percentage of income, typically 30% (Stone, 2006). Indeed, 30% is the threshold used by the Canada Mortgage and Housing Corporation (CMHC) in determining "core housing need" (CMHC, 2010). This is often accompanied by the use of a 50% threshold to indicate households with a severe burden (Bogdon & Can, 1997; Bunting et al., 2004; Moore & Skaburskis, 2004; Skaburskis, 2004).

Straightforward use of the simple ratio approach to housing affordability fails to recognize that households with a high housing expenditure to income ratio may be consuming more housing at a higher cost by choice;[6] these households should not be considered to have a

[5] As opposed to a universal law (see Hulchanski, 1995).
[6] For instance, this may be as a matter of personal preference or as an investment.

housing affordability burden (Lerman & Reeder, 1987). Similarly, households may have a low housing expenditure to income ratio because they are forced to rent poor quality or inadequate housing for their needs; these households ought to be recognized as having a housing affordability problem. Quality-based measures of housing affordability such as those developed by Lerman and Reeder (1987) and Thalmann (1999) determine the rent for a unit with a basic level of adequacy, using hedonic price methods. By this approach, households have a housing affordability problem if the rent for a minimally adequate unit exceeds a certain percentage of income; however, it is not necessarily the case that such housing is actually available (Thalmann, 1999).

A major shortcoming of the ratio approach and its quality-adjusted variants is that it does not indicate whether households can afford adequate non-housing necessities (Stone, 2006). Using a percentage of income as an affordability standard thereby understates affordability problems among larger households, such as those with children, while overstating the affordability burdens of middle- or high-income households (Stone, 1993). Also, selecting a ratio is itself arbitrary (Stone, 2006). As such, any ratio threshold used is inappropriate in determining a household's ability (or inability) to pay for housing, although it may be used validly to describe household expenditures, analyze trends over time, or in the allocation of scarce public resources for housing subsidies (Hulchanski, 1995).

Alternatively, a "shelter poverty" measure of housing affordability contends that since housing typically represents a large, inflexible share of a household's budget, a household can be deemed "shelter poor" if it is unable to pay for other basic necessities (food, basic health needs) after paying for housing (Stone, 1993). This gives rise to the residual income approach, which takes the difference between income and housing expenditures to determine if this leftover income is sufficient to cover basic non-housing necessities (Stone, 2006). In the United States, in 1991, roughly the same number of households were shelter-poor as were paying greater than 30% of their income on housing, but shelter-poor households contained 15 million more people as a result of a larger average household size (Stone, 1993). Kutty (2005) operationalizes a residual income-based measure of housing affordability using two-thirds of the official American poverty thresholds to represent the value of basic non-housing goods, though Stone (2006) suggests the use of budget standards, which account for the actual market price of these items.

While the residual income approach is conceptually far superior to the ratio approach, the question of housing quality remains. A household, having paid for housing, may have adequate leftover income to cover non-housing necessities simply because it is under-housed. The unit may, for example, have an insufficient number of rooms for the size and composition of the household, or be in need of major repairs. (It is also possible that a household may have an affordability problem because it is over-housed, although it is more difficult to define "over-housed" in an operational sense [see Stone, 2006]). Thalmann (2003) constructs another quality-based measure of housing affordability based on the residual income approach, but again, this analysis does not address the actual availability of adequate housing. Stone (2006) suggests an iterative process for studies of housing affordability, where consideration is first given to the economic standard, then the analysis is refined by attempting to account for under- and over-housing.

In the case of owner-occupied housing, monthly housing costs are not the only facet of affordability. A distinction must be made between this type of affordability and purchase affordability, the ability of households to actually buy a house in the first place. This, in turn, requires information about the household's ability to make a down payment and to borrow funds to cover the rest of the sale price, including mortgage lending standards and interest rates. Rising house prices can negatively impact purchase affordability for households looking to buy in the market, but can benefit current owners who accrue capital gains (Gan & Hill, 2009).

Regardless of how affordability is measured, housing prices or rents, and by extension affordability, also depend on location within an urban area. In market economies, this relationship is heavily influenced by transport systems, which allow access to cheaper housing away from the urban core, but also increase the value of properties made more accessible by these transport systems. The nature of this relationship is elaborated below, with specific reference to rail rapid transit systems.

2.2. The Relationship between Transportation and Housing[7]

Mobility, or the ability to move, increases the space within which people can act, and is positively correlated with the accessibility of land. In this way, transport systems, which provide mobility, increase the area within which one can live and work, and should increase income and

[7] Much of this section is adapted from Revington (2015).

reduce housing prices, which include the cost of land. It has long been acknowledged that in market economies where land is privately owned, locations that have greater accessibility (provided in part by transportation infrastructure) cost more. This relationship has been modelled in the urban context by neoclassical economists to describe how the price of residential land decreases with distance from the centre of a monocentric city.

An early such model is that of Wingo (1961). In this model, if workers earn the same gross wage, a worker living nearer the employment centre will earn a higher net wage than a worker living farther away when journey-to-work costs (including the marginal value of leisure time surrendered to commuting) are taken into account. This advantage disappears as the rent for that location is bid upwards. As a result, workers substitute directly between transportation costs and rents; the sum of these is the same everywhere. Growth in population increases rent throughout the city, leading to higher population densities in the long run as individuals reduce their consumption of space to offset these higher costs. Transportation technology factors into the model explicitly, as the time cost and the monetary cost of the method of transportation determine the spatial extent and shape of the city, and the rent structure. In this way faster, cheaper transportation technology can offset the impact of growth on rent (Wingo, 1961).

Alonso (1964) presents a model in which the influence of transportation is less direct, though no less important. Commuting costs increase with distance while the price of land decreases. The quantity of other goods that can be purchased thus varies with the quantity of land purchased, and the distance at which it is purchased, creating a three-dimensional "locus of opportunities" (Alonso, 1964, p. 21). The locus of opportunities represents all possible combinations of land, distance, and other goods an individual could consume within the constraints of its income. At the same time, individuals have preferences. In the monocentric city, all shopping and employment is at the centre, so all else equal, an individual derives satisfaction from locating closer to the centre and consuming larger quantities of land and other goods. To maintain a constant level of satisfaction, an increase in distance must be compensated with an increase in the quantity of land and other goods; a small decrease in quantity of land must be compensated with a small increase in other goods, and vice versa. The result is an indifference surface in three dimensions, indicating the various trade-offs between distance, the quantity of land, and the quantity of other goods the individual can make to maintain the same level of satisfaction. The point at which these two three-dimensional surfaces are tangent

represents the combination of distance and the quantities of land and other goods the individual consumes in equilibrium (Alonso, 1964).

Building on Alonso's basic premises, Muth (1969) presents a similar model. Households consume housing and other goods to maximize satisfaction, and therefore they will move farther away from the central business district if the savings in expenditure from an increased quantity of housing (available at a reduced price) is greater than the increased transportation costs. The model elaborates on the earlier work by accounting explicitly for the production of housing at different intensities of land use (or densities) as a result of the land rent surface, and by providing a thorough empirical analysis using census data for the Chicago metropolitan area. More recently, the Alonso-Muth framework has been extended to consider transportation mode choice and residential location (DeSalvo & Huq, 2005), while Kwon (2005) has suggested the use of a commuting cost function based on both distance and income within the basic structure of the Muth model. Ahlfeldt (2011) has gone so far as to expand Alonso's work for use in polycentric cities by accounting for land values through the use of an accessibility model that captures the urban area's transport geography and labour markets.

On the surface, these models seem to present a reasonable view of the way in which urban land markets – and in particular markets for residential space – operate. For instance, they explain long-standing observations of decreasing land value and residential density with distance from the urban centre and the development of progressively faster modes of transportation (Clark, 1951; Clark, 1958; Muth, 1969). On another level, they imply an equitable equilibrium outcome: locational advantages such as proximity to employment, services, or shopping are offset by higher rent while locational disadvantages such as increased commuting costs are compensated with cheaper and more spacious housing.[8] While some have questioned the restrictive assumptions built into these models, their purpose is to provide a starting point from which more complicated analysis can proceed by altering or elaborating on the models (Muth, 1985). For example, by relaxing the assumption of a monocentric city, a declining housing price

[8] It should be noted, however, that despite these apparently zero-sum trade-offs between accessibility and housing costs, transportation investments may provide other, broader benefits not considered here. They can contribute to overall economic development (Banister & Berechman, 2000), while specifically, transit investments can facilitate productivity improvements by enabling agglomeration economies (Chatman & Noland, 2013) and provide environmental sustainability benefits (Cervero, 1998).

gradient with distance to the CBD should still be observed as long as employment remains relatively more concentrated there than elsewhere (Muth, 1985).

More profoundly, this view of the urban system has been critiqued on the grounds that the rate at which components of the system can adapt to change is variable (Harvey, 1973). Changes to the location of transportation infrastructure, housing, or employment opportunities within a city alter the distributions of locational advantages. Those households able to adapt more rapidly – presumably those of means and education – thus have an initial advantage, which they are apt to use to further their own interests through "an attempt to organize the distribution of externality effects to gain income advantages" (Harvey, 1973, p.58). In this way, redistribution of wealth within the city tends toward inequality.

Nevertheless, much of the literature on the impacts of changes to the transportation network on housing prices draws explicitly on location theory as described by Alonso (1964) and Muth (1969), both of whom consider such changes in theoretical terms, predicting that the improved accessibility to the centre will be manifested in higher land values (e.g., Agostini & Palmucci, 2008; Bowes & Ihlanfeldt, 2001; Celik & Yankaya, 2006; Debrezion, Pels & Rietveld, 2011; Dewees, 1976; Duncan, 2008, 2011; Hess & Almeida, 2007; Lin, 2002; Martinez & Viegas, 2009). This prediction is consistent with the observation that historically, urban growth tends to be faster along transport networks and slower in interstitial spaces (Adams, 1970). Most studies of this type use hedonic price methods (Rosen, 1974) to isolate the impact of transit accessibility (or proximity) on house prices independent of other characteristics of the house or neighbourhood using multiple regression techniques. Some (such as McMillen & McDonald, 2004) use repeat-sales methods, which – as their name suggests – track the sales prices of the same houses across repeated transactions in order to control for time-invariant quality differences between units (Bailey, Muth & Nourse, 1963; Case & Shiller, 1989).

Indeed, transit access is found to have a positive effect on prices of residential properties in a number of contexts (Bowes & Ihlanfeldt, 2001; Cervero & Duncan, 2002; Dewees, 1976; Duncan, 2008, 2011; Hess & Almeida, 2007; McMillen & McDonald, 2004; Nelson, 1992) as well as on apartment rents (Benjamin & Sirmans, 1996). Widely observed in North America, these price premiums have also been reported in cities as diverse as Bangkok (Chalermpong, 2007), Izmir, Turkey (Celik & Yankaya, 2006), and Lisbon (Martinez & Viegas, 2009), among others. However, the relationship between transit access and housing prices is not necessarily

straightforward. For example, the premium on house prices may be variable over time, even appearing before the transit line is constructed, in anticipation of future benefits (Agostini & Palmucci, 2008; Knaap, Ding & Hopkins, 2001; McMillen & McDonald, 2004). Bowes and Ihlanfeldt (2001) find house values are higher near transit stations in Atlanta, but not too near, as negative externalities such as increased traffic, noise, and potential for crime[9] are dominant immediately adjacent to stations, a situation similar to that observed in Helsinki (Laakso, 1992). Bowes and Ihlanfeldt (2001) also find that the positive price effect is highest farther from the CBD, and in higher-income neighbourhoods. This echoes the findings of Hess and Almeida (2007), who find the largest positive price effects in Buffalo are in higher-income areas, while large negative effects occur in lower-income areas, although Nelson (1992), also studying Atlanta, finds the opposite relationship with neighbourhood income.

On the other hand, some studies find insignificant, weak, or outright negative effects on house prices in Rotterdam (Debrezion et al., 2011), Miami (Gatzlaff & Smith, 1993), San Jose and Sacramento (Landis et al., 1995), Sunderland, UK (Du & Mulley, 2007), and along the Batong light rail line in Beijing (Zhang & Wang, 2013). Interestingly, in a later study, positive price impacts were found in Santa Clara County, which contains San Jose, which may be attributable to improvements in the transit network, regional growth, and increased road congestion in the intervening years (Cervero & Duncan, 2002).

These variations in findings may depend on differences in methodological approaches. For instance, studies more often identify a positive price impact when accessibility is most accurately captured; that is, in terms of travel time savings provided by the transit infrastructure rather than distance to a station (Ryan, 1999). The functional form of the model used and the type of transit system under study also affect results, with commuter rail and light rail generally yielding higher increases in value than urban heavy rail (Debrezion et al., 2007; Mohammad et al., 2013).

Local factors may have an impact, too, as transit improvements may be less valuable in dispersed, automobile-oriented urban environments (Gatzlaff & Smith, 1993). Indeed, rail transit has a greater impact on land and property values in Europe and East Asia than in typically more automobile-dependent and sprawling North America (Mohammad et al., 2013). In a study of

[9] Bowes and Ihlanfeldt (2001) suggest rail transit has the potential to increase neighbourhood crime by giving criminals better access to the area and find modest evidence supporting this hypothesis.

Hong Kong and the Taiwanese cities of Kaohsiung and Taipei, Shyr, Andersson, Wang, Huang and Liu (2013) find that price premiums are inversely related to the extensiveness of the rapid transit network. Where service is ubiquitous, the relative advantage of proximity to transit, and therefore the price premium, is less; where service is uneven, a more distinct advantage and a higher price premium accompany those locations that do have transit service. Also, a "synergistic relationship" may exist between transit access and neighbourhood built form (Duncan, 2011, p. 121), the characteristics of stations themselves (Bowes & Ihlanfeldt, 2001), or local policy (Dueker & Bianco, 1999). On balance, however, proximity to transit corresponds to higher land values for residential properties in more cases than not (Debrezion et al., 2007; Hess & Almeida, 2007; Mohammad et al., 2013).[10]

This suggests at least two important considerations for research. First, there is a shortage of research addressing equity questions around the relationship between transportation and housing (see Revington [2015] for a more thorough elaboration). Second, there are two countervailing influences of transportation infrastructure on housing costs, and therefore affordability. First, by allowing residents to live farther from the centre, it can reduce housing costs; faster transport enables a "flattening" of rent gradients. Second, and conversely, by improving accessibility to the centre, land values are higher in areas with access to rapid transit. However, whether price premiums expected around stations correspond to decreased affordability in the rental market is unclear. Untangling these opposing trends requires a consideration of housing affordability that takes account of location and access to transportation within the study area, which is often referred to as "location affordability."

2.3. Location Affordability

While studies of housing affordability have tended to take an aspatial perspective, or to consider differences in affordability by broad geographic region (e.g., Kutty, 2005) or metropolitan area (e.g., Moore & Skaburskis, 2004; Skaburskis, 2004), a few studies consider housing affordability at the intra-metropolitan scale. Bogdon and Can (1997) map three different indicators of rental housing affordability in Syracuse, New York at the census block group level:

[10] Conducting a meta-analysis of published and unpublished studies, Mohammad et al. (2013) do not find a publication bias in favour of positive results (but do find evidence of bias in favour of statistically-significant results for both positive and negative findings).

the share of households spending in excess of 30% of income on housing; the stock of affordable housing, measured as the share of units renting for less than "fair market rent;" and the rental housing affordability mismatch ratio, which compares the number of units affordable to a certain income group with the number of households in that income group. Bunting et al. (2004) map the percentage of households spending greater than 50% of income on housing by census tract in 11 major Canadian metropolitan areas. Both of these papers aim in part to illustrate the spatial dimensions of housing affordability for policy purposes, yet continue to overlook the relationship between transit and housing.

As demonstrated in the previous section, rent gradients slope downward with distance from a city center as households substitute between housing and transportation costs. However, different locations within an urban area are often associated with differing transportation costs, as well (Haas, Makarewicz, Benedict & Bernstein, 2008; Haas, Morse, Becker, Young & Esling, 2013). It is therefore commonly argued that housing affordability studies should also consider transportation costs (Center for Neighborhood Technology, 2012; Fisher et al., 2009). The Center for Neighborhood Technology (2012) recommends that combined expenditure on housing and transportation be considered affordable if it accounts for less than 45% of household income and maps this relationship for nearly 900 urban regions in the United States. Fisher et al. (2009) map the quantity of housing affordable to households of a given size and income by municipality in the greater Boston area, adjusting the rents to account for accessibility to jobs, school quality, and neighbourhood safety. These adjustments are determined using a hedonic price model, which isolates the capitalization of these amenities into market rents. Towns lacking these amenities have their rent values adjusted upward by the researchers to account for the associated costs, while towns with these amenities have their rent values adjusted downward to reflect the associated benefits. This consideration of amenities is insightful, and accounts for the actual distribution of rental housing thereby addressing the supply-side issues with affordability models such as those of Lerman and Reeder (1987) and Thalmann (1999). Nonetheless, a major shortcoming – aside from the use of a ratio standard of affordability – is that adjusting rents to account for amenities and dis-amenities may obscure the fact that for certain households, housing that is affordable because it is in a neighbourhood with poor amenities may be all that it can pay for; the costs of dis-amenities may be borne in a non-monetary fashion while rent is, in the vast majority of instances, exclusively monetary.

Given the limited body of housing affordability literature dealing with both spatial patterns and the relationship between transportation and housing, there is room for this research to contribute to this area of scholarship. In particular, there appears to be no existing study that brings these elements together through the use of a more nuanced residual income measure of affordability. In the next chapter, I turn to the development of a method to achieve this task.

3. Methods

The intent of this research is to determine the geographic distribution of affordable market rental housing in the Montreal and Vancouver metropolitan areas, and how this distribution differs for households of various income levels and compositions, as well as whether or not this housing is accessible to rapid, frequent public transit. The nature of the research is quantitative, which will allow for an overview of the metropolitan area on a scale not possible through a qualitative approach.

This research concentrates solely on rental housing and does not include owner-occupied housing, for several reasons. First, a comprehensive measure of housing affordability for owners would need to account for a household's ability to acquire mortgage financing, and the conditions thereof. This would require considerably more data (or assumptions). Second, affordability problems inflicted by rising costs may be offset by capital gains in the case of owners, which presents a more complicated net impact on household well-being. Renters, meanwhile, face an unambiguously negative impact from increased housing costs. Finally, renters average half the income of owners, making them more susceptible to housing affordability problems (Hulchanski, 2005).

I situate this work within the realm of what Wyly (2009) has called strategic positivism, which seeks to use quantitative analysis for the purpose of exposing (and resolving) social and geographical injustice. Strategic positivism seeks to avoid portraying the "social world in terms of unproblematic, universal laws" and necessarily rejecting alternative understandings of reality (Wyly, 2009, p. 316), while providing numerical analysis, which tends to be viewed (rightly or wrongly, and especially by policymakers) as "rigorous." It is therefore a concept that can be used for progressive social and political ends. Wyly (2011, p. 906) later defines two "moments" of strategic positivism: "roll-back" and "roll-out."[11] The roll-back moment is concerned with challenging neoliberal ideology either by highlighting the inequalities it produces or illustrating its own failures to adhere to methodological rigour,[12] while the roll-out moment seeks to enable radical alternatives. This research fits within the frame of roll-back strategic positivism in two ways. First, it interrogates the spatial distribution of affordable market rental housing with

[11] These are, cheekily, named after Peck and Tickell's (2002) characterizations of neoliberalism.
[12] For recent examples of what could be considered roll-back strategic positivism, see Moos (2014a), Quastel, Moos and Lynch, (2012), and Walks and Tranter (2015).

respect to rapid transit accessibility from a redistributive equity perspective. Second, by taking a more geographically-specific, nuanced, and renter-focused approach to quantifying affordability, it presents a challenge to those dominant measures of affordability (and associated ideology) produced by organizations such as Demographia and RBC.

The approach was to identify the availability and precise location of affordable market rental housing, rather than to determine if the housing consumed by a given household was affordable to it. This was evaluated for a number of hypothetical household types, varying by size and income, using the residual income approach. This was comprised of four main stages. First, data was compiled from online rental listings. Second, an affordability measure was constructed to identify the supply of affordable rental housing in each metropolitan area. Third, to allow comparisons between locations served by rapid transit and without service, as well as between different portions of the metropolitan area, rapid transit catchments and urban/suburban zones were defined. Finally, statistical tests were used to examine the strength of any relationships between the supply of affordable rental housing and rapid transit access.

3.1. The Rental Housing Data Set

The first step of the research was to gather data on available market rental housing in the Montreal and Vancouver metropolitan areas. This was done by a combination of two methods: 1) scraping data from one online rental listings service (GottaRent) automatically, using a custom-coded computer script, and 2) manually collecting data from two online rental listings services (Craigslist and Kijiji). While scraping data is a promising way of gathering large amounts of data with minimal effort, there are two reasons for this combination of methods. First, some online rental listings services prohibit the use of scrapers on their sites. Second, the format of some listings services requires natural language processing to identify the required information, which is a complex problem from a programming standpoint. Therefore, to get a more complete picture of the two rental markets, data from these particular sites were collected by manually visiting the website and recording listings information rather than simply omitting them.

The scraping scripts, written in Python, were comprised of three main components. The first component defined the information, or "items," being sought from each listing (detailed below). The second, known as the "spider," sent information requests to the webpage, and navigated on the page to retrieve the specific data required, as established in the "items" routine.

Finally, the "pipeline" took the retrieved items and wrote them to a spreadsheet file. Manual data collection involved simply visiting the online rental listings sites using a web browser and entering the pertinent information in a spreadsheet.

A 20% sample of rental data was gathered from the online rental listing sites every other day between May 21 and June 3, 2014. This proved to be the largest sample size possible given time and resources available. In particular, the data gathered included the monthly rent, whether or not utilities were included, number of bedrooms, and the address or cross-street location. It should be noted that while similar hedonic pricing studies of residential properties typically feature many more attributes, I am not conducting a hedonic study, and therefore this extra data is inconsequential for my purposes. Only completely self-contained units were included; single rooms within larger units, single-room occupancy (SRO) hotels, rooming houses and the like were excluded. The data were combined into a single spreadsheet and cleaned to remove entries with missing values and duplicate listings (e.g., an apartment that is listed on more than one listings service).[13] Next, using the address, each rental unit was geocoded to geographic coordinates and mapped using GIS. Units falling outside of the study boundaries were also removed at this stage. The resulting dataset is summarized in Table 1.

***Table 1**: Summary statistics of rental units*

		Monthly Rent, Adjusted for Utilities*		
Bedrooms	**Count**	**Minimum**	**Mean**	**Maximum**
Montreal				
Studio/Bachelor	303	$400	$729	$2,500
1	808	$365	$954	$2,925
2	997	$560	$1,122	$4,700
3 or more	521	$732	$1,503	$5,157
Vancouver				
Studio/Bachelor	107	$433	$1,097	$2,878
1	788	$450	$1,265	$8,576
2	763	$650	$1,701	$7,930
3 or more	387	$771	$2,442	$7,653

* The method for adjusting for utilities is given in Section 3.2.

[13] A small number of luxury properties were also removed from the Vancouver dataset, as I consider them to represent a distinctly different market segment, and therefore should not be included in the study. Seven units, each renting above $10,000/month, were ultimately removed.

Sample selection bias can arise as the dataset is limited to only rental units that were changing occupants and not those that were currently occupied.[14] To my knowledge, no studies have attempted to measure the magnitude of this bias among rental properties, although it has been studied in the case of owner-occupied housing in the United States. Ihlanfeldt and Martinez-Vazquez (1986) found the difference in house value between households that moved within the last year and non-movers was not statistically significant. On the other hand, DiPasquale and Somerville (1995) observed statistically-significant differences in characteristics between transacting units and the entire housing stock at the national level, while at the metropolitan level, not all of these differences were statistically significant, possibly due to the small sample size of transacting units. Even so, differences were generally of a small magnitude at both the national and metropolitan levels. Nonetheless, this research does not purport to offer analysis of rental housing affordability in general, but rather of those units available on the market at the time of the study. In this case, sample selection bias of this sort is not an issue.

Another possible issue concerns the use of asking rent as opposed to transaction or market rent. It is possible, for instance, that prospective tenants may be able to negotiate lower rents or that competition for a vacant unit will force tenants to bid rents upwards. If one of these tendencies were to dominate, the dataset would be systematically biased. However, it is assumed that in practice landlords tend to be price setters and that the asking rent therefore closely approximates the market rent. Indeed, several existing transportation-land use studies have used asking rather than transaction rents or prices (e.g., Benjamin & Sirmans, 1996; Chalermpong, 2007; Du & Mulley, 2007; Martinez & Viegas, 2009).

Finally, while they are undoubtedly one of the most popular ways to advertise and locate rental housing, online listings are not the sole means of doing so, and the set of websites used is not exhaustive. Apartments may also be advertised in newspapers, signage on the building itself, or by word of mouth. Nevertheless, the sites used are well-known and among the top returns provided in search engines, and there is no reason to suspect any systematic difference in listings between these sources.[15] Furthermore, it is likely that online classifieds better capture informal legal arrangements like secondary suites in private owner-occupied housing (see Mendez, 2011)

[14] For instance, properties turning over could offer poor value in that the asking rent is too high relative to the amenities offered, or possess systematically different characteristics from the rest of the housing stock.
[15] One exception may be at the very low end of the market, in the case of rooming houses or single-room occupancy hotels, which may not be formally advertised, but these are excluded from this study.

and units owned by small landlords, and not just large purpose-built multifamily buildings. Online listings, given their relative ease of collection, are therefore the most suitable source of data for this research.

3.2. Calculating the Supply of Affordable Rental Housing

This research makes use of the residual income approach to measure housing affordability. Since the reasoning behind this approach is that housing should be considered affordable if a household can afford to pay for basic non-housing necessities after paying for housing, a minimum standard of non-housing goods and services must be specified (Stone, 1993). This is based on Statistics Canada's Market Basket Measure (MBM), one of three low income lines published by the agency.[16] It represents the estimated prices of the goods and services required for "a modest, basic standard of living" that constitutes "a compromise between subsistence and social inclusion," accounting for regional differences in cost (Statistics Canada, 2013a, p. 9; p. 5). It can be thought of as the minimal level of disposable income required to achieve this standard of living, and includes estimates of the cost of food, clothing, shelter, transportation, and other goods and services considered necessities under current social norms (Hatfield et al., 2010; Statistics Canada, 2013a). The transportation component for both Montreal and Vancouver assumes households use public transit, and a small number of taxi rides per year, and do not own or use a private vehicle (Hatfield et al., 2010). This definition of disposable income represents income after taxes, mandatory payroll deductions, child support payments, child care, and non-insured medical expenses are paid (Statistics Canada, 2013a). While the MBM is calculated for a four-person household (two adults and two children, a girl age 9 and a boy age 13), Statistics Canada provides a formula to adjust the measure for households of different sizes.

The bundle of goods and services used in my residual income measure is the MBM for Montreal and Vancouver, respectively, minus the shelter component. As the most recent MBM is

[16] The other two low income lines are the Low Income Cut-offs (LICO), the income thresholds at which a household would spend a larger share of income than average on food, shelter and clothing; and the Low Income Measure (LIM), which is 50% of median income, adjusted for household size (Statistics Canada, 2013a). The MBM follows the after-tax LICO closely over time (Hatfield, Pyper & Gustajtis, 2010). Conceptually, the MBM is the most appropriate low income line to use in conjunction with the residual income approach as it is based on the actual prices of goods and services.

for 2011, the remaining components (food, clothing, transportation, and other expenses) were adjusted using the consumer price index (CPI) to update them to 2014 prices. This data is readily available through Statistics Canada's website. This is illustrated in Table 2.

The residual income measure was used to assess the availability of affordable market rental housing rather than whether or not the housing consumed by a given household was affordable to it. Since the incomes of households seeking rental units is unknown, the availability of market rental housing was calculated separately for a number of hypothetical household sizes and income levels. These will hereafter be referred to as household types.

The household sizes included a single-person household, a single parent, a couple without children, and a couple with two children. For each household size, available units were limited to those defined as adequately sized. While what is considered adequately sized may be somewhat arbitrary, the purpose of establishing such a limit is to provide some degree of quality control – whether or not housing is appropriate for a particular household is not only a matter of cost in relation to income and other expenditures but also that it is not crowded or otherwise of poor quality. The definition of an adequately sized unit used here is based on the number of bedrooms, according to the National Occupancy Standard, which is also used by CMHC to define 'suitable' housing (CMHC, 2010) (see Table 3). Under this scheme, any unit is adequately sized for a one-person household. A couple without children requires at least one bedroom, while a couple with children or a single parent requires two. A two-parent, two-child household requires a minimum of three bedrooms (following CMHC [2010] it is assumed the children are of opposite sex and over the age of 5). Measuring other aspects of housing quality was not feasible, as it would have required inspections of each rental unit in the analysis or surveys/interviews of the occupants.

Table 2: *Value of the market basket by household type*

Household Type	**Montreal**	**Vancouver**
Single Individual	$12,886	$12,947
Lone Parent	$18,223	$18,310
Couple with Children	$25,771	$25,894
Couple without Children	$18,223	$18,310

Source: Adapted from Statistics Canada (2013b, 2015e): CANSIM Table 202-0809; CANSIM Table 326-0021.

Table 3: *Adequately-sized units by household type*

Household Size	Number of Rooms
Single Individual	Any (including Bachelor)
Couple without Child	1 or more
Single Parent	2 or more
Couple with 2 Children	3 or more

Source: Adapted from CMHC (2010).

The income thresholds used were based on the actual distribution of disposable income by household composition in the CMAs of Montreal and Vancouver, retrieved from the 2011 Survey of Labour and Income Dynamics (SLID) file at the McGill-Concordia branch of Statistics Canada's Research Data Centres Network – the most recent year for which this data is available – and converted to 2014 dollars, as was done with the MBM. The SLID measures disposable income using the same particular definition as the MBM, making it the ideal source of data to derive the income thresholds. For each household composition included in the study, the availability of affordable housing was estimated for each of the lowest three income sextiles.[17] These income thresholds therefore represented the lowest sixth and third, and the median of the income distribution. The resulting 12 household types are shown for each CMA in Table 4. Note that Very Low income single individuals in both Montreal and Vancouver are unable to afford even the non-housing bundle of goods and services (as shown in Table 2). Availability of affordable housing is not reported for households in higher sextiles as these households face a much greater range of flexibility in their housing choices; at this point, affordability begins to become subjective. Furthermore, higher-income households are more likely to occupy the ownership rather than rental market for housing (Hulchanski, 2005).

For each household type, then, the availability of affordable market rental housing was determined as the set of adequately sized units for which the disposable income level was greater

[17] These income levels are estimates in that the survey is not representative of the population, and therefore the sextiles were calculated by expanding the sample by the associated weight, which is based on the income distribution determined using income tax files. For example, an entry in the dataset with a weight of five would be counted five times. Statistics Canada confidentiality requirements mandate that estimates from restricted microdata be based on a minimum number of unweighted survey responses. Sextiles were the finest quantile possible that would meet these requirements for all household types in both study CMAs.

than the sum of the asking rent and the bundle of non-housing goods and services derived from the MBM. Equation (1) demonstrates how the affordability of a unit was determined:

$$If\ Y_H \geq R_u + B_H\ , then\ U_u = 1; else\ U_u = 0 \quad (1)$$

Where:

Y_H = the income of a household type H

R_u = the asking rent of the apartment unit u (including utilities)

B_H = the value of the bundle of non-housing goods for household type H

U_u = a binary variable which is equal to 1 if the unit u is affordable and equal to 0 otherwise.

Table 4: *Household types and income levels*

Income Sextile	Single Individual	Lone Parent	Couple with Children	Couple without Children
Montreal				
1st - Very Low	$11,500	$24,230	$43,675	$32,546
2nd - Low	$18,596	$34,094	$56,841	$42,826
3rd - Median	$24,956	$41,007	$71,722	$52,138
Vancouver				
1st - Very Low	$11,608	$22,721	$39,864	$36,460
2nd - Low	$17,026	$25,589	$56,457	$51,452
3rd - Median	$23,655	$40,701	$68,335	$67,041

Source: Statistics Canada, Survey of Labour and Income Dynamics (SLID), 2011, accessed through the Canadian Research Data Centre Network; Statistics Canada (2015e), CANSIM Table 326-0021.

If the rent for an apartment did not include utilities, an estimated amount was added. The amount differed for each of the four household compositions (single individual, lone parent, couple with children, and couple without children). If utilities were partially included – for example, in an apartment building where there is central heating but tenants are responsible for their own electricity bills – half of this amount was added. From the Survey of Household Spending (SHS), the average household expenditure on Water, Fuel and Electricity for Principal Accommodation at the second quintile of income for the years 2011-2013 (the most recent available) in the provinces of Quebec and British Columbia was taken (Statistics Canada, 2015c). The second quintile was used as it was felt to be most in keeping with the principle of

the Market Basket Measure that the amount should represent a "modest, basic standard of living" (Statistics Canada, 2013a, p. 9). These amounts were adjusted to 2014 prices and the 3-year average was taken.

This number was then scaled to adjust for household size. To do so, the ratio of expenditure across all household types and expenditure for each household type was taken (Statistics Canada, 2015d). This ratio was multiplied by the 3-year average expenditure at the second quintile of income. It was not possible to directly access the averages for the second quintile of income in each province for each household type, as some of the data is considered unreliable due to a small number of survey responses falling into each of these narrow cross-tabulations. The resulting estimates for expenditures on utilities are shown in Table 5.

Subsequently, mapping the results of this affordability analysis illustrates the variability in the availability of affordable market rental housing throughout the metropolitan area. It also allows an examination of the distribution of this housing between transit catchments and non-catchment areas, as well as across different urban and suburban strata of the two metropolitan areas. First, however, these catchments and urban/suburban zones are defined.

Table 5: *Estimated annual utility expenditures*

Household Type	Montreal	Vancouver
Single Individual	$815	$999
Lone Parent	$1,270	$1,558
Couple with Children	$1,882	$2,309
Couple without Children	$1,494	$1,833

Source: Adapted from Statistics Canada (2015c, 2015d, 2015e), CANSIM Tables 203-0022, 203-0023, 326-0021.

3.3. Transit Catchments and Metropolitan Zones

A principal objective of this research was to examine how the distribution of affordable market rental housing varies between areas with and without rapid, frequent public transit. In the case of Montreal, this included the four-line underground Metro rail transit network (68 stations), while in Vancouver, this consisted of the mainly-elevated SkyTrain rail transit network (49 stations), the two docks of the SeaBus ferry between downtown Vancouver (connecting to the SkyTrain at Waterfront Station) and Lonsdale Quay in North Vancouver, and 39 stops of the B-Line semi-rapid bus system. The SeaBus was included despite its relatively long headways (15 minutes) because of the travel time savings it imparts in crossing Burrard Inlet and its integration

with the SkyTrain network. B-Line bus routes were included as they provide faster, more frequent, and higher-capacity service than conventional bus service and serve more widely-spaced stops, but I term them "semi-rapid transit" because they operate in mixed traffic rather than dedicated lanes like true bus rapid transit.

The study is limited to these transit modes as they provide continuous, high-capacity, rapid service throughout the day on relatively short headways. They are therefore most likely to provide accessibility benefits comparable to the automobile across the metropolitan area (Vuchic, 1999; Newman et al., 2013). In contrast, commuter rail – for example – offers high capacity service but in the Montreal and Vancouver regions this is limited to peak periods and/or features long headways. Conventional bus service, while it may feature continuous service and short headway times, is typically slower with closely spaced stops and lower capacity. There is no comparable equivalent to the B-Line bus system in the Montreal region.

Walking catchments around transit stations were represented by 800m buffers, except in the case of the semi-rapid B-Line bus stops, where 600m buffers were used. While some have argued that network distance is a more accurate measurement of transit services areas (e.g., Guttierez & Garcia-Palomares, 2008), others have countered that these differences are not large enough to justify the additional effort and data needed to calculate network distances (Guerra, Cervero & Tischler, 2012). Euclidean distance was therefore deemed adequate for this purpose.

Another consideration of this research was how the distribution of rental housing varies spatially across the metropolitan areas. To facilitate this analysis, each metropolitan area was divided into four roughly concentric urban/suburban zones: the Urban Core, containing the central business district and immediately adjacent areas; the Inner City, representing the prewar urbanized area; the Inner Suburbs, comprising an earlier (pre-1971) period of postwar suburbanization; and the Outer Suburbs, including later outward development. This confers two advantages. First, it allows the analysis to consider the possibility that the relative availability of affordable rental housing within rapid transit catchments may vary with location in the metropolitan structure. For instance, preliminary work found that the particularly dense concentration of rental units with relatively high asking rents in the transit-served downtown peninsula of Vancouver produced a different picture of affordability with respect to rapid transit access across the metropolitan area than when this portion was excluded (Revington & Townsend, 2014). Second, it provides some degree of comparability between the two

metropolitan areas, despite their different trajectories and timeframes of urban development. In particular, this type of partitioning allows for more meaningful inter-metropolitan comparisons than divisions based on municipal boundaries or concentric circles of a fixed width.

The method for defining these zones was based largely on that described by Bunting et al. (2004). Using data from the 2006 census – the most recent for which appropriate data are available[18] – census tracts were identified with greater than 1.5 times the mean number of dwelling units constructed in each time period: pre-1946 (Inner City); 1946-1971 (Inner Suburbs); and post-1971 (Outer Suburbs). Tracts identified with each time period were grouped together. Those that did not clearly identify with any particular period, or which were surrounded by tracts dominated by housing from a different period, were grouped with their neighbouring tracts. In both Montreal and Vancouver, a clear block of centrally-located census tracts did not contain high levels of pre-1946 housing stock – a sign of central city redevelopment – and, in a slight modification of the Bunting et al. (2004) method, these tracts were grouped together to form the Urban Core.[19]

While others have used more sophisticated techniques for identifying urban/suburban zones (e.g., Patterson, Saddier, Rezaei & Manaugh, 2014; Gordon & Janzen, 2013), these methods are problematic in the present context as their definitions are based in part on transportation mode share – higher incidences of active transport or public transit use are indicative of more urban zones. In contrast, for my purposes, I seek to compare rapid transit catchments with non-catchment areas across otherwise similar urban/suburban strata of the city. In any case, Patterson et al. (2014) find that their Urban Core maps fairly closely onto the Inner

[18] In addition to concerns over non-response bias in the voluntary 2011 National Household Survey, which replaced the mandatory long-form census (Hulchanski, Murdie, Walks & Bourne, 2013; Vinodrai & Moos, 2015), the earliest categorization of data on dwelling age is "1960 or before," which does not capture the pre-/post-World War II divide, often seen as a key juncture in large-scale suburbanization in North America (Addie, Fiedler & Kiel, 2015). Redevelopment on the scale that would be required to significantly change the zonal divisions identified are unlikely to have taken place in the intervening years; indeed, the zones identified here using 2006 data closely match those of Bunting et al. (2004), who use 1996 data.

[19] In another slight deviation from the Bunting et al. (2004) method, exurban or quasi-rural areas within each CMA are included with the Outer Suburbs; their general paucity of rental housing (or housing in general, for that matter) and their complete lack of rapid transit service means there is little to be gained by differentiating these areas from the Outer Suburbs.

City as defined by Bunting et al. (2004).[20] The method prescribed by Bunting et al. (2004) would therefore seem adequate to my purposes.

The resulting zones are illustrated in Figure 1. As shown in Table 6, the zones account for almost identical proportions of the total metropolitan area in the two study cities. This bodes well for inter-metropolitan comparisons in the distribution of rental housing.

Table 6: *Size of zones as a percentage of total CMA area*

Zone	**Montreal**	**Vancouver**
Urban Core	0.2%	0.5%*
Inner City	2%	2%
Inner Suburbs	8%	7%
Outer Suburbs	90%	91%

Note: Columns do not sum to 100% due to rounding.
* Includes Stanley Park.

[20] A note on terminological differences: the Urban Core of Patterson et al. (2014) and the Inner City of Bunting et al. (2004) are roughly analogous; my definition of the Inner City is similar to these, while my Urban Core represents the central zone within it.

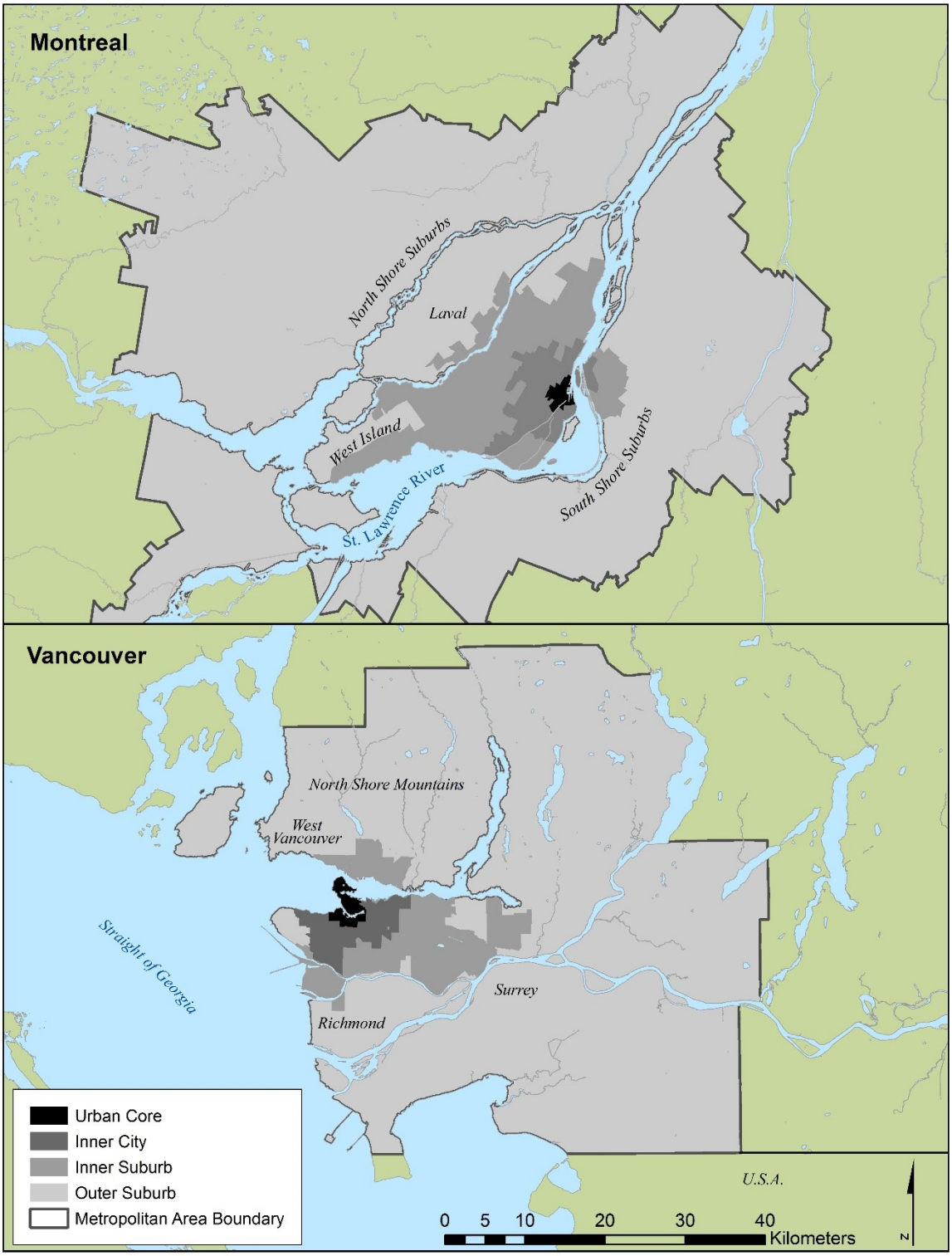

Figure 1: *Urban/suburban zones*

3.4. Statistical Analysis

A primary objective is to determine differences between rapid transit catchments and non-catchment areas in terms of the proportion of housing considered affordable within each, for each household type, at the level of metropolitan zones, as well as the level of urban/suburban zones. To approach this problem, it is helpful to consider the housing dataset as consisting of two samples: one for rapid transit catchments, and one for non-catchment areas. There are a number of statistical tests that can be used to compare two samples of binary variables.

If both samples are sufficiently large, the difference in the proportions of units considered affordable in each will approximate a normal distribution. A significance test for the difference in proportions can therefore be performed by calculating the *z*-statistic, which is simply the difference in proportions, divided by the standard error of both samples pooled together. Two-sided tests are most appropriate here, as they consider the hypotheses that affordable housing is either more *or* less prevalent in rapid transit catchments. In the two-tailed case, the null hypothesis that the proportions are equal is rejected if the absolute value of the *z*-statistic is greater than or equal to the value of the *z* distribution when the area of the upper tail of the distribution equals half the desired significance level (Moore, McCabe & Craig, 2014).

Alternatively, and perhaps more commonly, this test can be performed in the form of Pearson's chi-squared test (Hollander & Wolfe, 1999). For this test, the results are organized in a two-by-two matrix (in this case, catchment/non-catchment by affordable/not affordable). The test statistic, χ^2, is simply the sum of the squared difference between the observed and expected values of each cell in the matrix, divided by the expected value of that cell. The null hypothesis (that the proportions of affordable housing in catchments and non-catchments are the same) is rejected if χ^2 is greater than or equal to the value of the χ^2 distribution with one degree of freedom when the area of the upper tail of the distribution equals the desired significance level.

These tests produce equivalent results, but they are both considered large sample approximations of exact probabilities; the larger the sample, the closer the approximation. Typically, the sample is considered large enough if the expected value of each item in the two-by-two matrix used in the chi-squared test is at least five (Hollander & Wolfe, 1999). This was not the case for 65% of tests at the level of urban/suburban zones in Montreal and 38% of these tests in Vancouver, as well as for one household type at the metropolitan level in each city.

Therefore, the assumption that the tests approximate given probability distributions does not hold in these instances, making significance tests unreliable.

Rather, for consistency and comparability, in all cases I used Fisher's exact test, which evaluates the exact probability of a result in a two-by-two matrix such as that described for the chi-squared test.[21] It is based on the conditional distribution of the top-left item in the matrix, given that matrix's row and column sums[22] (Hollander & Wolfe, 1999). The *P*-value can be calculated simply by summing the conditional probability of the top-left item with the conditional probabilities of all possible more extreme outcomes (holding constant the row and column sums). The null hypothesis (that the proportions of affordable housing in catchments and non-catchments are equal) is rejected if this is less than the desired significance level. In other words, it is rejected if the probability of receiving this result or more extreme alternatives is relatively low, as this indicates that it is less likely that the proportions could be more different. The results of this analysis are presented in the following chapter.

[21] Results produced by the chi-squared test were similar, even though they often violated the large-sample approximation assumption.
[22] More precisely, it is a form of hypergeometric distribution (Hollander & Wolfe, 1999).

4. Results

Market rental units were available across nearly all of the built-up areas of both metropolitan regions. These spatial distributions, however, were highly uneven – with a dense concentration of rentals at the center of both metropolitan areas, and less dense clusters throughout (Figure 2) – and markedly different between the two regions (Table 7). In the case of Vancouver, roughly 15% of all rentals in the dataset were within the Urban Core, the vast majority of which were located on the downtown peninsula (Figure 3). In contrast, in Montreal, the highest densities of rental units were found immediately to either side of the Urban Core, which accounted for only 8% of units in the dataset,[23] in the Inner City neighbourhoods of the Plateau Mont-Royal and Shaughnessy Village (Figure 4).

Table 7: *Share of total rental units in each urban zone*

Zone	Montreal	Vancouver
Urban Core	8%	15%
Inner City	41%	12%
Inner Suburbs	33%	30%
Outer Suburbs	17%	43%

Note: Columns may not sum to 100% due to rounding.

Furthermore, there was a relatively high density of rental units across Montreal's entire Inner City, accounting for roughly 41% of all units, and especially in the neighbourhoods of Côte-des-Neiges and Notre-Dame-de-Grâce to the west, and to a lesser extent, Hochelaga-Maisonneuve to the east. Also noticeable were lower densities of rental units in the wealthier enclaves of Westmount and Outremont on either side of Mount Royal, which is park and cemetery land appearing as the hole in the rental density map in Figure 2. Vancouver's Inner City featured only about 12% of all units and a few small clusters, in an arc around the Urban Core, from the Grandview neighbourhood, through Mt. Pleasant and Fairview to Kitsilano. The low-density gap between Grandview and the downtown peninsula can be accounted for by railway yards and industrial lands in this sector.

[23] Note that these differences cannot be explained by differences in the relative areal extent of the urban/suburban zones; recall that they account for similar proportions of each metropolitan area.

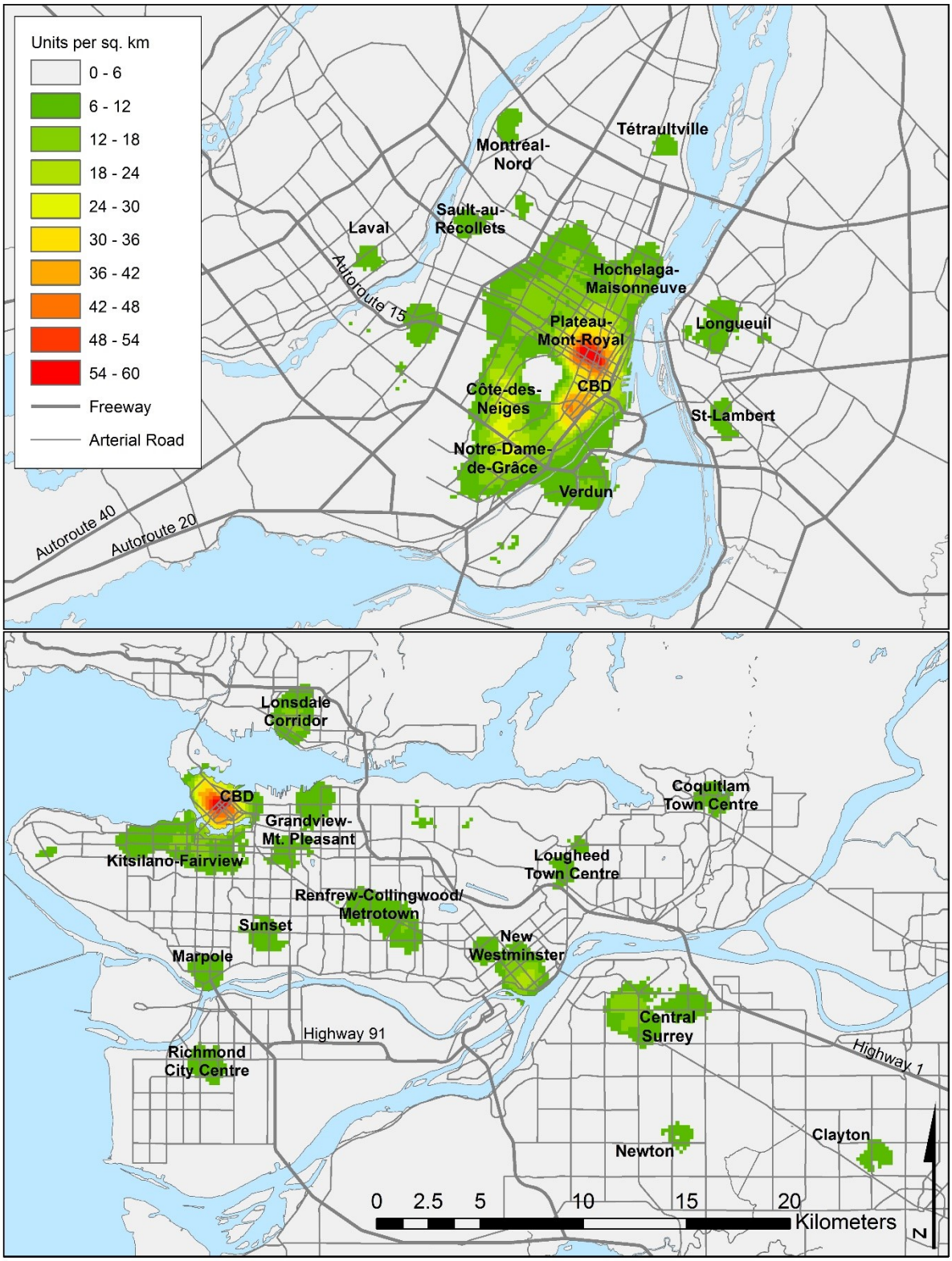

Figure 2: *Density of available rental apartments. The cell size is 175m; density calculations are based on units within 1000m radius.*

Figure 3: *The highest density of rental units in Vancouver was in the downtown peninsula. Source: Photo by the author.*

Figure 4: *The highest density of rental units in Montreal was in the Plateau Mont-Royal neighbourhood (foreground), adjacent to the CBD (background). Source: Photo by Craig Townsend.*

In both metropolitan areas, approximately a third of all rental units in the dataset were located in the Inner Suburbs. Montreal had about a half-dozen minor clusters of rental apartments, mainly to the north of the Island of Montreal, as well as in the suburban municipalities of Longueuil and St.-Lambert on the South Shore. Notably, the Longueuil cluster did not include the high-rise residential towers surrounding the Longueuil—Université-de-Sherbrooke Metro station. Vancouver, on the other hand, had a fairly dense concentration of rental units in downtown New Westminster[24] – the second-densest cluster in the CMA – and notable clusters in the Renfrew-Collingwood/Metrotown area along the SkyTrain line, and the Lonsdale Corridor in North Vancouver, with smaller concentrations in the Marpole and Sunset neighbourhoods in south Vancouver (see Figure 2). In Montreal, the Outer Suburbs accounted for only 17% of units, and there was only one notable cluster, near the De La Concorde Metro station in Laval (Figure 5). Meanwhile in Vancouver, the Outer Suburbs accounted for approximately 43% of all units and featured a number of notable clusters, including Central

Figure 5: *The only notable cluster of rental units in Montreal's Outer Suburbs was near De La Concorde Metro station. Source: Photo by the author.*

[24] New Westminster is classified as Inner Suburbs in this study, but is the oldest colonial settlement area in the Vancouver CMA and possesses some "inner city" traits such as high population density and a gridded street network.

Surrey, Richmond City Centre, and Coquitlam Town Centre. Minor clusters also appeared in the far-flung suburban neighbourhoods of Clayton and northeast Newton. However, spatial patterns were very different when results were limited to affordable housing for each household type.

4.1. The Distribution of Affordable Housing

The spatial patterns of affordable housing differed within each metropolitan area by household type, and by urban and suburban zones. This section provides an overview of these patterns for each metropolitan area in turn. These results are summarized in Table 8.

Table 8: *Share of housing affordable in each zone, percent*

Household	Income	Urban Core	Inner City	Inner Suburbs	Outer Suburbs
a) Montreal					
Single Individual	Low	0	0.6	0.8	0.7
	Median	16	52	78	67
Lone Parent	Low	14	58	82	82
	Median	54	85	96	96
Couple with Children	Very Low	7	41	72	79
	Low	53	91	95	99
	Median	80	100	100	100
Couple without Children	Very Low	19	55	83	76
	Low	74	93	98	97
	Median	94	98	99	100
b) Vancouver					
Single Individual	Median	2	9	16	23
Lone Parent	Median	10	49	70	76
Couple with Children	Very Low	0	0	3	7
	Low	0	35	74	73
	Median	30	62	90	87
Couple without Children	Very Low	23	45	65	67
	Low	70	86	94	95
	Median	90	95	98	97

4.1.1. Montreal

For households comprising single individuals, no market rental units were available at the Very Low level of income (the first sextile), as these households do not even have sufficient income to cover non-housing needs. At the Low income level (second sextile), only 16 units in

the dataset (of 2,629 units) were considered affordable. This paltry stock of affordable units was scattered across the metropolitan area but with a bias towards the portions of the Island of Montreal to the north and east of the Urban Core (Figure 6). No affordable units were identified within the Urban Core, while six were in the Inner City, seven were in the Inner Suburbs, and three were in the Outer Suburbs. Moving up to the Median income, a total of 1,585 units were considered affordable, and these were generally well-distributed throughout the metropolitan area, albeit with fewer in the predominantly residential West Island. Within the Urban Core, 16% of units were affordable, while this number increased to 52% in the remainder of the Inner City and 78% and 67% in the Inner and Outer Suburbs, respectively.

A similar pattern held for lone parent households. Once again, there were no affordable units at the Very Low income level. At the Low income level, however, 1,047 units out of 1,518 with at least two bedrooms were affordable. Spatially, this distribution was comparable to that of Median-income single-individual households, with 14% of units considered affordable in the Urban Core, 58% in the Inner City, and 82% in both the Inner and Outer Suburbs (Figure 7). At the Median income, the number of affordable units increased to 1,359, with the greatest percentage gain occurring in the Urban Core, where 54% of units were affordable. Again, the percentage of affordable units increased outward from the Urban Core, reaching 85% in the Inner City and 96% in both suburban zones.

In the case of couples with children, the picture was slightly different. Due to higher room requirements, fewer potential units were available; only 521 units in the dataset had three or more bedrooms – of which only 15 were within the Urban Core. At the Very Low income level, 311 of these were affordable, while 486 units were affordable at the Low income level and 517 were affordable at the Median income. By zones, only one unit was affordable in the Urban Core at the Very Low income level, increasing to 41% in the rest of the Inner City, 72% in the Inner Suburbs, and 79% in the Outer Suburbs (Figure 8). By contrast, at the Median income, 80% of units in the Urban Core were affordable, as were virtually all units in the other three zones. Despite having considerable affordable housing at the Very Low level on the income distribution in comparison to single individuals or lone parents (which have none), at their medians the number of affordable units was substantially lower for couples with children.

A different dynamic existed for couples without children. A combination of lower space requirements (at least one bedroom) and typically higher household incomes ensured that even at

the Very Low income level, 1,532 units (out of 2,326) were considered affordable. Not only was this comparable to the number available at the median incomes of the single individual and lone parent household types, but it also provided extensive geographic coverage across the metropolitan area (Figure 9). However, only 19% of units in the Urban Core were affordable, compared to 55% in the Inner City, and 83% and 76% in the Inner and Outer Suburbs, respectively. Moving up to the Low income level, the number of affordable units reached 2,187, including 74% of units in the Urban Core and well in excess of 90% in the remaining zones. At the Median, 2,291 units were affordable – 94% of units in the Urban Core and nearly all of those in the other zones. Together, this suggests that couples without children face much greater flexibility in the rental market in terms of both the number of options available and their geographic locale.

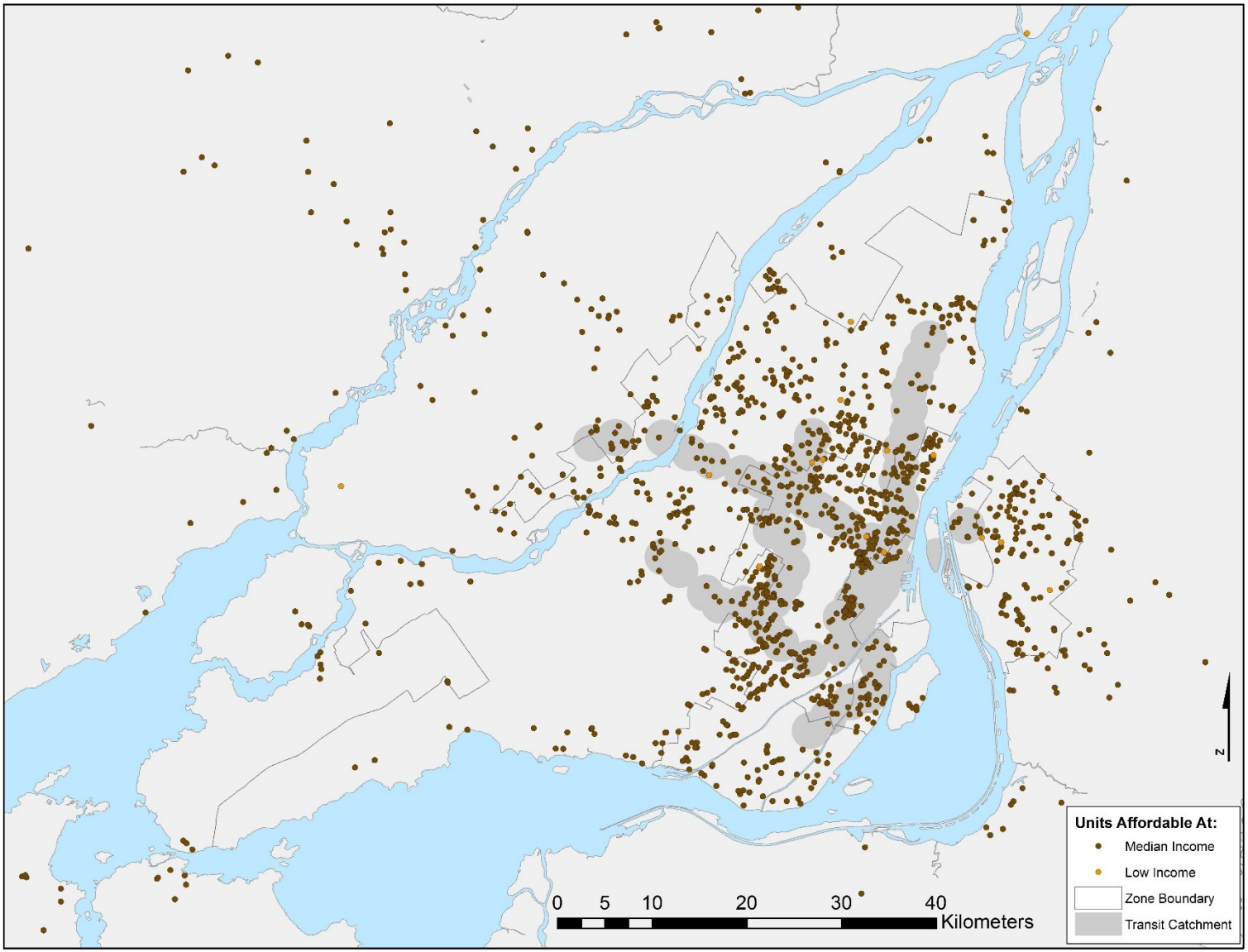

Figure 6: *Rental units affordable to single individuals, Montreal.*

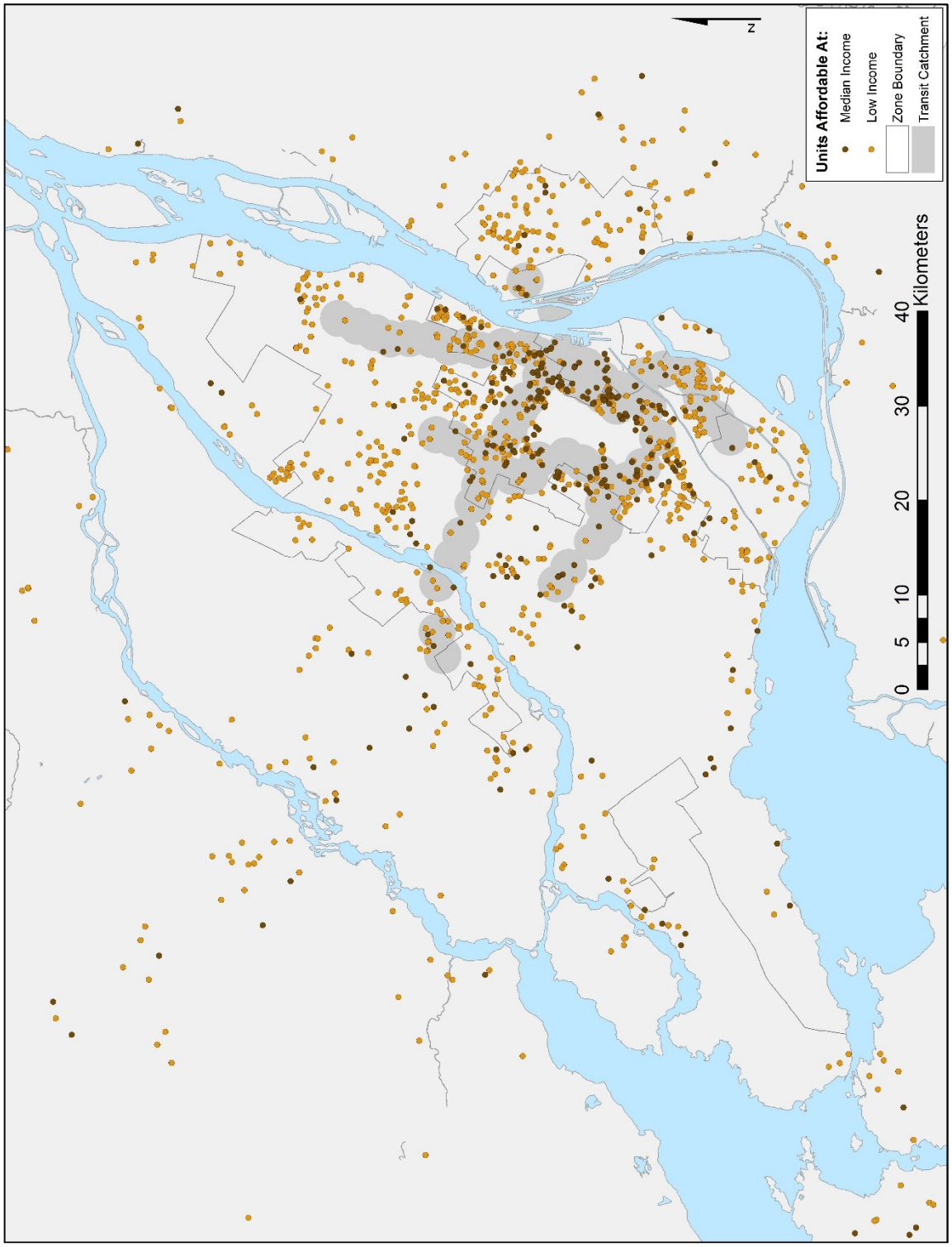

***Figure 7:** Rental units affordable to lone parents, Montreal.*

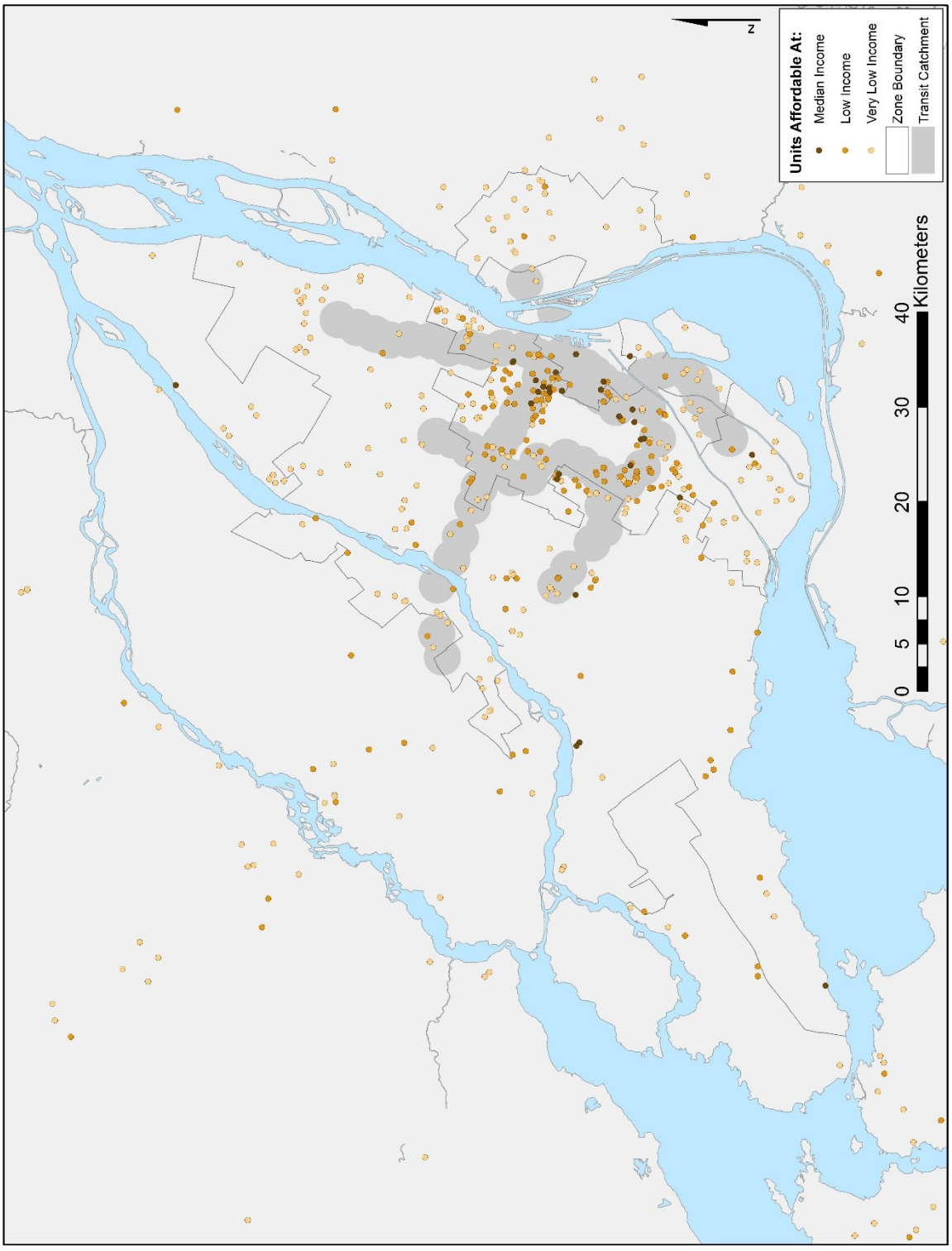

Figure 8: *Rental units affordable to couples with children, Montreal.*

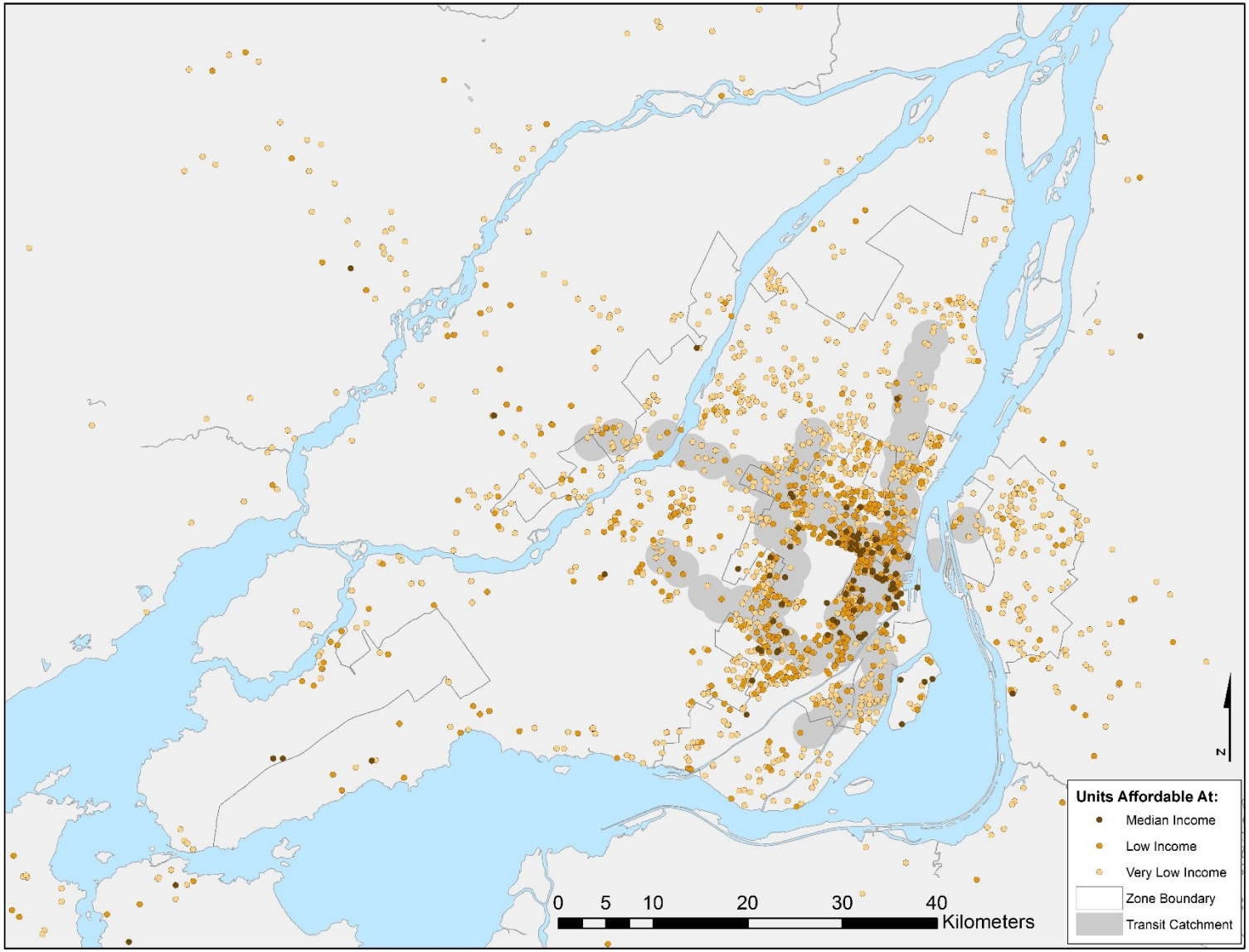

Figure 9: *Rental units affordable to couples without children, Montreal.*

4.1.2. Vancouver

In Vancouver, like Montreal, there were no rental units affordable to single individuals in the Very Low income level, where even the non-housing bundle was unaffordable; however, there were also no affordable rental units to these households at the Low income level either. At the Median income, 326 out of 2,045 units were affordable. Within the Urban Core, only 2% of units were affordable. This proportion increased to 9% for the rest of the Inner City, 16% in the Inner Suburbs, and 23% in the Outer Suburbs (Figure 10). In particular, there were few affordable units in the residential suburb of West Vancouver, which straddles the Inner and Outer Suburban zones, and Richmond, which is classified predominantly as an Outer Suburb, as well as the west side of the Inner City. Especially noteworthy is the fact that some areas identified as generally having many rental units have few affordable to single individuals: the downtown peninsula, Lonsdale Corridor, Kitsilano and Richmond City Centre.

Once again, the pattern of affordable housing for single individuals shared some similarities with that of lone parent households – there were no affordable units at either the Very Low or Low income levels, although at the Median 749 out of 1,150 units with at least two bedrooms were considered affordable. This represented not only a larger number than for single individuals, but also a greater geographical spread, although the proportion of affordable units increased in each zone moving outward from the center (Figure 11). In the Urban Core, 10% of units were affordable, whereas this figure was 49% in the Inner City and 70% across the Inner Suburbs. In the Outer Suburbs, 76% of the units were affordable.

For households with children, meanwhile, 18 units out of 387 with a minimum of three bedrooms were affordable at the Very Low income level, and none of these were located in the Urban Core or Inner City. In the Inner Suburbs, approximately 3% of units were affordable, while 7% were affordable in the Outer Suburbs (Figure 12). Moving up to the Low income level, 264 units were affordable, although there remained no affordable units in the Urban Core. In the Inner City, 35% of units were affordable, although these were predominantly toward the east, and were generally not associated with the clusters of apartments identified in Figure 2. This number rose to 74% and 73% in the Inner and Outer Suburbs, respectively. At the Median, three out of ten units in the Urban Core were affordable, as well as 62% of those in the Inner City, 90% of those in the Inner Suburbs, and 87% of those in the Outer Suburbs, for a total of 326 units across the metropolitan area.

For couples without children, on the other hand, 1,123 units out of 1,938 with at least one bedroom were affordable at the Very Low income level. This represented a far greater number of units than that affordable to the other household compositions at the Median income, as well as a considerable geographic spread (Figure 13). In the Urban Core, 23% of units were affordable, increasing to 45% in the Inner City, 65% in the Inner Suburbs, and 67% in the Outer Suburbs. Moving up to the Low income level, the total number of affordable units increased to 1,747: 70% of units in the Urban Core were affordable, as were 86% of those in the Inner City. Meanwhile, 94% and 95% of units were affordable in both the Inner and Outer Suburbs, respectively. Finally, at the Median, 1,870 units were affordable. This included 90% of those in the Urban Core, 95% of those in the Inner City, and nearly all of those in the two Suburban zones (98% and 97%, respectively).

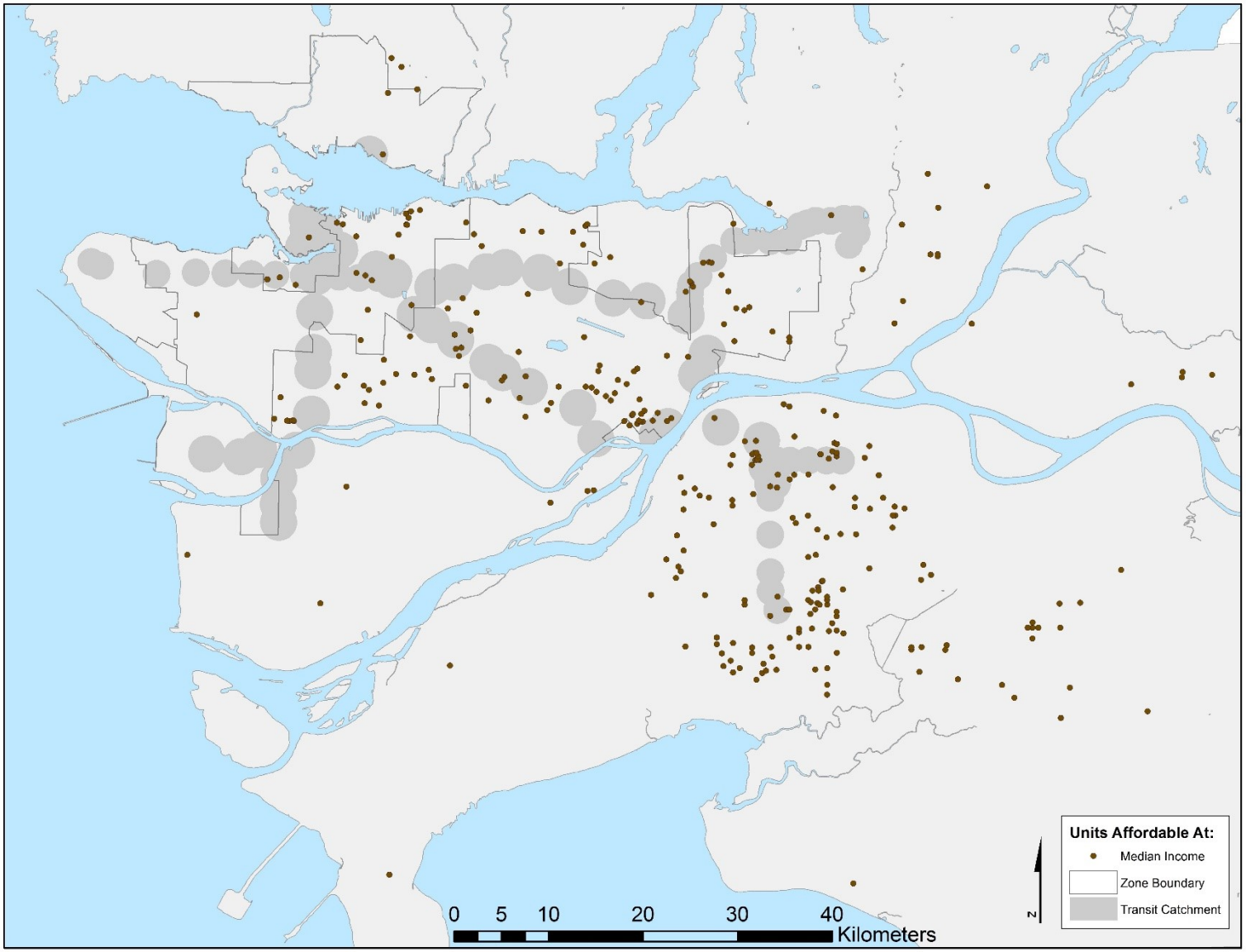

Figure 10: *Rental units affordable to single individuals, Vancouver.*

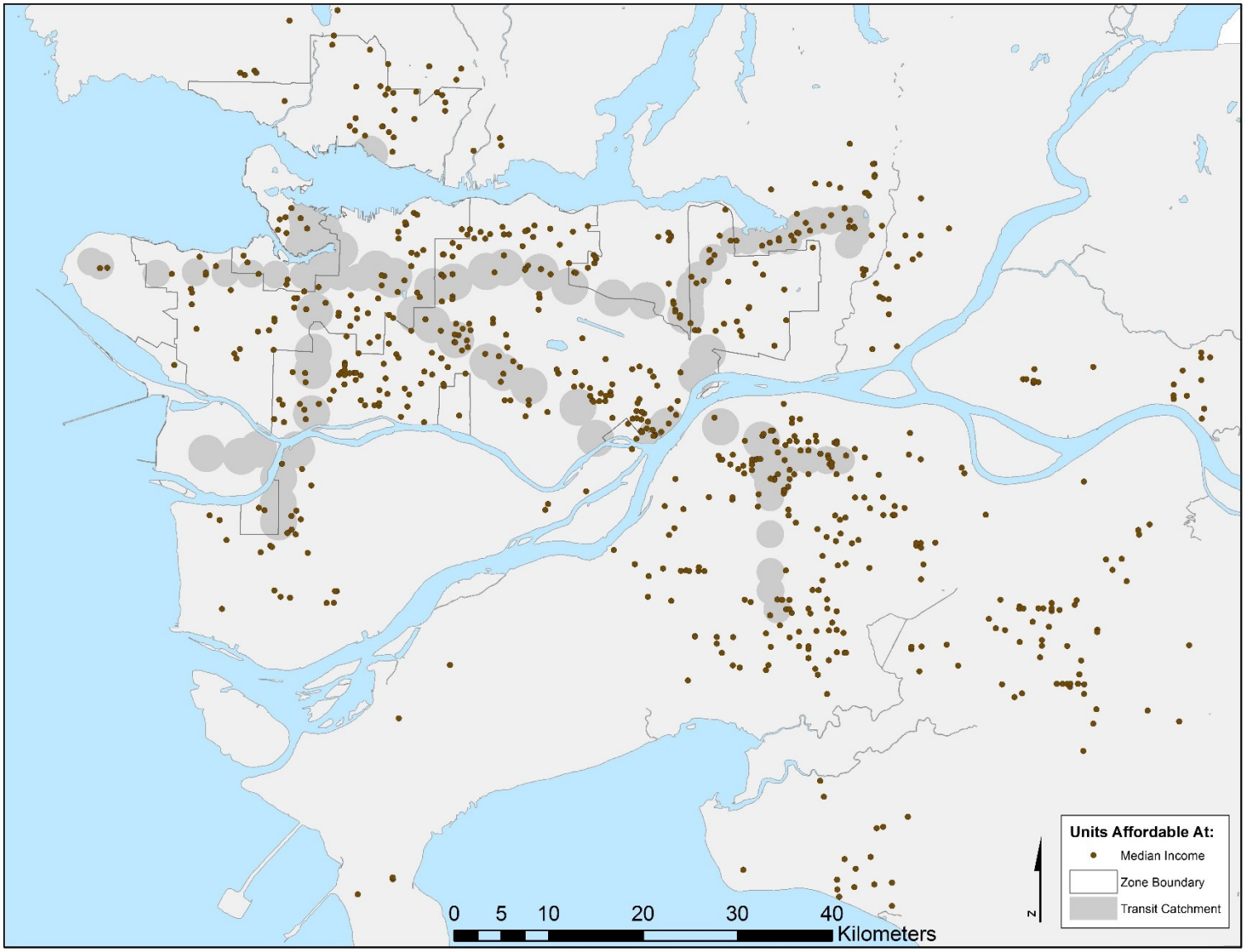

Figure 11: *Rental units affordable to lone parents, Vancouver.*

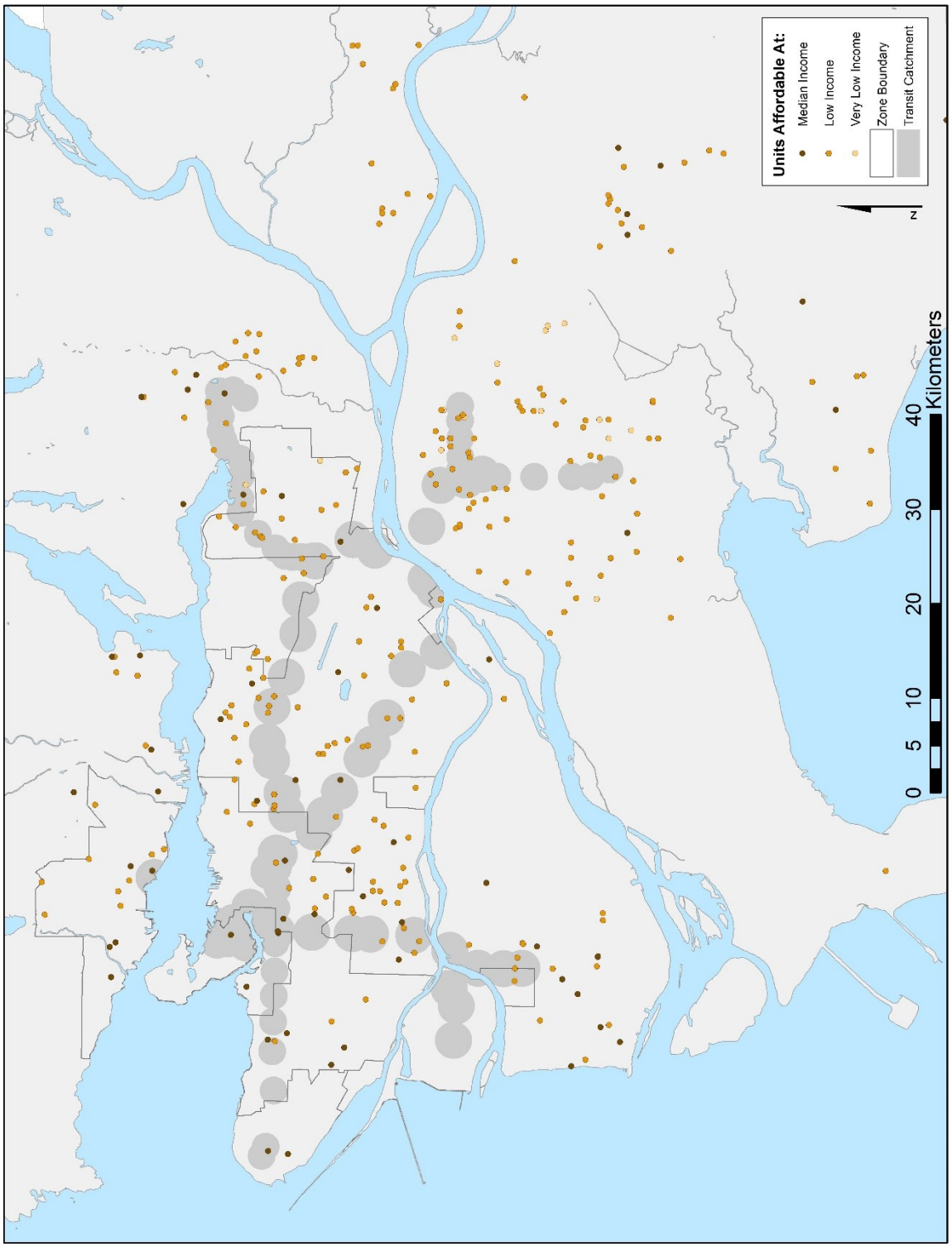

***Figure 12:** Rental units affordable to couples with children, Vancouver.*

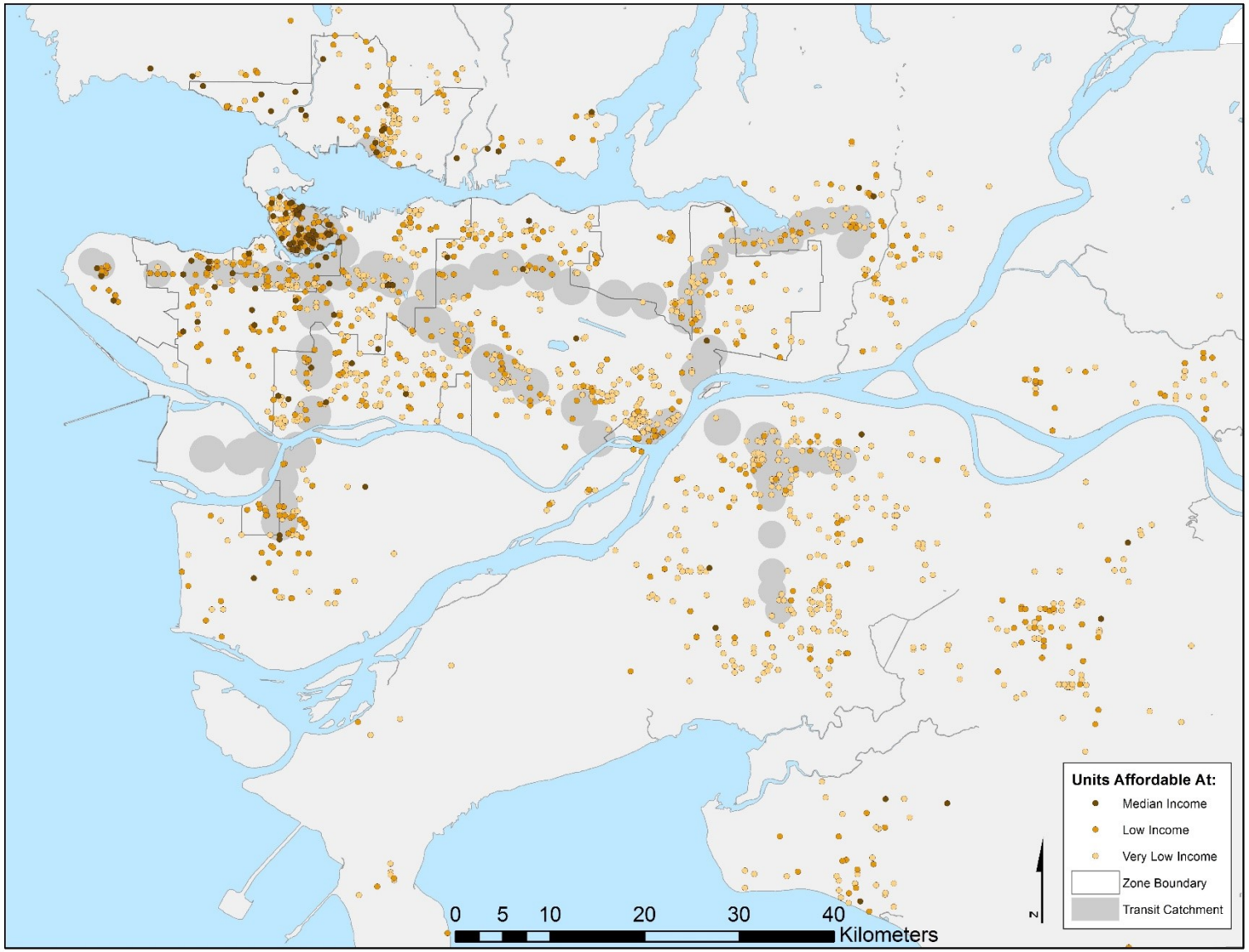

Figure 13: *Rental units affordable to couples without children, Vancouver.*

4.2. Accessibility to Rapid Transit

The spatial pattern of affordable rental housing varied between rapid transit catchments and non-catchment areas. As before, these patterns are described for each metropolitan area in turn.

4.2.1. Montreal

In Montreal, there was a strong tendency for a lower proportion of rental units to be affordable within rapid transit catchments than outside rapid transit catchments. This relationship held, and was statistically significant, for each household composition and income level, with the exception of Low-income single individuals (Table 9). Here, a small number of rental units were affordable in general, and therefore only a few affordable units were available both within and outside of rapid transit catchments.

Table 9: *Fisher's exact test by household type, Montreal.*

Household Type	Income	Location	Affordable	Not Affordable	Proportion Affordable	Fisher's Exact Test			
						p-value	Odds Ratio	95% Confidence Interval	
Single Individual	Low	Catchment	6	1103	0.5%	0.803	0.821	0.245	2.503
		Non-Catchment	10	1510	0.7%				
	Median	Catchment	519	590	47%	0.000	0.375	0.318	0.442
		Non-Catchment	1066	454	70%				
Lone Parent	Low	Catchment	271	271	50%	0.000	0.278	0.204	0.326
		Non-Catchment	776	200	80%				
	Median	Catchment	443	99	82%	0.000	0.293	0.205	0.417
		Non-Catchment	916	60	94%				
Couple with Children	Very Low	Catchment	61	107	36%	0.000	0.236	0.156	0.353
		Non-Catchment	250	103	71%				
	Low	Catchment	143	25	85%	0.000	0.167	0.070	0.372
		Non-Catchment	343	10	97%				
	Median	Catchment	164	4	98%	0.011	0.000	0.000	0.714
		Non-Catchment	353	0	100%				
Couple without Children	Very Low	Catchment	459	465	50%	0.000	0.303	0.252	0.363
		Non-Catchment	1073	329	77%				
	Low	Catchment	830	94	90%	0.000	0.293	0.198	0.427
		Non-Catchment	1357	45	97%				
	Median	Catchment	899	25	97%	0.000	0.258	0.110	0.560
		Non-Catchment	1392	10	99%				

Considering the possibility that these overall results were driven by higher-priced apartments in the central area, which is well-served by rapid transit, I also compared the difference between the number of affordable units within or outside rapid transit catchments for each urban/suburban zone. Indeed, this yielded more mixed results (Table 10a, Appendix A). For nearly all household types and income levels, and contrary to expectations, a higher proportion of housing was affordable within rapid transit catchments than outside of them in the Urban Core (the exceptions being Low income single individuals and Median income couples with children). However, in none of these cases was the result statistically significant at the 95% confidence level, likely attributable to the small number of units within the Urban Core that did not fall within a rapid transit catchment (for Low income couples with children, the result is significant if the confidence level is reduced to 90%).[25] For Median income single individuals, Low and Median income lone parents, Low income couples with children, and Very Low and Low income couples without children, there was also a higher proportion of housing considered affordable within rapid transit catchments in the Outer Suburbs. This was also the case for Low income couples with children in the Inner Suburbs. Again, these relationships were not significant, probably due to the very small number of Outer Suburban rental units that fell within a rapid transit catchment, and the fact that in many cases the difference was small.

In the majority of instances, however, the proportion of housing considered affordable remained lower in rapid transit catchments than in non-catchment areas. Indeed, at the 95% confidence level, the results were statistically significant in the Inner City for Median income single individuals, Low income lone parents, as well as Very Low and Low income couples, both with and without children. If the confidence level were relaxed to 90%, this list would include Median income couples without children, although the difference in magnitude was minor. Results were also statistically significant at the 95% confidence level in the Inner Suburbs for Median income single individuals, Low income lone parents, and Very Low income couples without children. At the 90% confidence level, this list also included Very Low income couples with children.

[25] The result is significant for Very Low income couples without children if the chi-squared test is used, but this test violated the assumptions of the large-sample approximation.

Table 10: *Summary of Fisher's exact test results by household type and zone.*

Household	Income	Urban Core	Inner City	Inner Suburbs	Outer Suburbs
c) Montreal					
Single Individual	Low	-	-	-	-
	Median	-	Lower**	Lower**	-
Lone Parent	Low	-	Lower***	Lower***	-
	Median	-	-	-	-
Couple with Children	Very Low	-	Lower**	Lower*	-
	Low	-	Lower***	-	-
	Median	-	-	-	-
Couple without Children	Very Low	-	Lower***	Lower**	-
	Low	Higher*	Lower**	-	-
	Median	-	Lower*	-	-
d) Vancouver					
Single Individual	Median	-	-	Lower**	Lower***
Lone Parent	Median	Lower**	Lower**	-	Higher*
Couple with Children	Very Low	-	-	-	-
	Low	-	Lower*	-	-
	Median	-	-	-	-
Couple without Children	Very Low	Lower***	-	-	-
	Low	Lower**	Lower*	-	Higher*
	Median	-	-	-	-

Note: * Significant at 90% confidence level; ** Significant at 95% confidence level; *** Significant at 99% confidence level. "Higher" and "Lower" refer to the proportion of housing considered affordable in rapid transit catchments relative to non-catchments. Detailed tables of the results are available in the appendices.

4.2.2. Vancouver

In Vancouver, the aggregate picture was similar to that for Montreal: a lower proportion of affordable units were found within rapid transit catchments than in non-catchment areas, for all household types (Table 11). However, the results were not statistically significant for couples with children, suggesting there is no relationship between rapid transit and the availability of larger (3 or more bedroom) affordable rental units in Vancouver. The difference between catchments and non-catchments was also not significant for Median income couples without

children, for whom nearly all rental units were affordable, regardless of whether or not it was within a rapid transit catchment.[26]

Table 11: *Fisher's exact test by household type, Vancouver.*

Household Type	Income	Location	Affordable	Not Affordable	Proportion Affordable	Fisher's Exact Test		
						p-value	Odds Ratio	95% Confidence Interval
Single Individual	Median	Catchment	63	665	9%	0.000	0.380	0.279 0.511
		Non-Catchment	263	1054	20%			
Lone Parent	Median	Catchment	187	160	54%	0.000	0.502	0.384 0.656
		Non-Catchment	562	241	70%			
Couple with Children	Very Low	Catchment	2	83	2%	0.384	0.431	0.047 1.895
		Non-Catchment	16	286	5%			
	Low	Catchment	53	32	62%	0.190	0.715	0.421 1.227
		Non-Catchment	211	91	70%			
	Median	Catchment	67	18	79%	0.131	0.619	0.324 1.216
		Non-Catchment	259	43	86%			
Couple without Children	Very Low	Catchment	319	352	48%	0.000	0.522	0.430 0.634
		Non-Catchment	804	463	63%			
	Low	Catchment	575	96	86%	0.000	0.486	0.355 0.664
		Non-Catchment	1172	95	93%			
	Median	Catchment	641	30	96%	0.119	0.661	0.395 1.116
		Non-Catchment	1229	38	97%			

When disaggregated by urban/suburban zone, the results were once again mixed (Table 10b, Appendix B). A higher proportion of rental housing was affordable within rapid transit catchments in the Outer Suburbs in the case of Median income Lone Parents, Low and Median income couples with children, as well as couples without children at all income levels. In none of these cases, however, were the results significant at the 95% confidence level; in most cases the differences in magnitude are small. If the confidence level was relaxed to 90%, significance was attained in the cases of Median income lone parents and Low income couples without children. A higher proportion of units were also affordable in the Inner Suburbs, for Low and Median

[26] When the chi-squared test was used, the difference was statistically significant at the 90% confidence level for Median income couples without children. In practical terms, this remains a trivial result, since nearly all units are considered affordable in this scenario.

income couples, both with and without children. Again, none of these results were statistically significant.

As in Montreal, in the majority of cases, the proportion of housing considered affordable was lower within rapid transit catchments. These differences were statistically significant at the 95% confidence level for single individuals at the Median income in the Inner and Outer Suburbs, but for Median income lone parents as well as Very Low and Low income couples without children, statistical significance was attained in the Urban Core. Results were also significant for lone parents at the Median income in the Inner City; at the 90% confidence level this is also the case for Low income couples with and without children. The implications of these uneven geographies are the subject of the next chapter.

5. Discussion

This chapter begins by recapping the most salient results uncovered in the previous chapter to sketch out some major similarities and differences in the availability and spatial distribution of affordable rentals between the two metropolitan areas. This is to provide a clearer foreground for the discussion in the subsequent three sections. Section 5.2 focuses on equity issues that emerge from these results, while section 5.3 considers briefly some policy implications of the research. Finally, section 5.4 discusses the limitations of this work, and in doing so, outlines some directions for future work to expand on this research.

5.1. Montreal and Vancouver Compared

Both metropolitan areas featured rental units across the residential parts of each region, but these distributions were highly uneven, with several areas of greater concentrations of apartments. However, in Montreal, there was a tendency for apartments to be centralized, with a high density across the Urban Core and Inner City, a few lesser clusters in the Inner Suburbs, and a single minor cluster in the Outer Suburbs. In contrast, in Vancouver, while the greatest concentration was likewise centrally located in the metropolitan area, this was predominantly confined to the Urban Core and immediately adjacent areas. The Inner City did not feature a high density of rental housing everywhere; instead, the pattern was one of dispersed clusters, especially in the Inner and Outer Suburbs. This difference is confirmed when the distribution of rental units across the urban/suburban zones is considered. Montreal had a much smaller share of its rental housing in the Outer Suburbs than Vancouver; this is consistent with reports that find a shortage (in terms of very low vacancy rates) of rental housing in the outer areas of the Montreal metropolitan region (*Communauté métropolitaine de Montréal*, 2014) and the widespread proliferation of secondary suites in formerly single-family homes across the Vancouver metropolitan area (Mendez, 2011). That rental housing followed a more monocentric pattern in Montreal and a more polycentric pattern in Vancouver is also interesting, given that employment clusters also display greater monocentricity in Montreal and greater polycentricity in Vancouver (Shearmur & Coffey, 2002). These employment and rental housing clusters are not, however, necessarily coincident.

Despite different intra-metropolitan distributions of rental apartments, in both cities, the affordability of housing tended to increase outward from the centre: the percentage of the rental stock considered affordable was lowest in the Urban Core and highest in the Inner and Outer Suburbs regardless of household type or income level. This tendency aside, in Montreal, the distribution of affordable rentals tended to follow the major patterns of rental units in general. In Vancouver, there were some areas with notable absences of affordable rentals for certain household types. For single individuals and couples with children, the downtown peninsula, west side, and West Vancouver all lacked affordable rentals, while Richmond also lacked affordable rentals for singles. Another major difference between the two metropolitan areas was that – for nearly all household types and in nearly all urban/suburban zones – a smaller proportion of rental units were affordable in Vancouver. This is not surprising, but it is reassuring that the data reflects popular perceptions in this regard (e.g., CBRE, 2015; Wright & Hogue, 2015).

The results also evince affordability issues as being particularly acute for lower income single individuals and lone parents. This is particularly the case in Vancouver, however, where no units were affordable to either household type at sextiles below the Median. This is no doubt driven largely by the fact that these households do not have the potential for dual incomes that couples with or without children do. In Vancouver, couples with children also have limited options for affordable rental housing in the Inner City, relative to Montreal. On the other hand, in both cities, couples without children face much greater flexibility in the rental market in terms of both the number of affordable options available, and their geographic locale.

In terms of access to rapid transit, a lower proportion of housing was considered affordable within rapid transit catchments at the metropolitan scale in both cities. This held, and was statistically significant, for nearly all household types and income levels, with the notable exception of couples with children in Vancouver. This relationship also did not hold for Low income singles in Montreal or Median income couples without children in Vancouver, where hardly any and nearly all units were affordable, respectively. At the zonal level, results are more mixed, but referring back to Table 9, there is a tendency for location affordability to be lower in the Inner City and Inner Suburbs in Montreal, but in the Urban Core and Inner City in Vancouver. That the pattern is less clear in Vancouver is consistent with the findings of Grube-Cavers and Patterson (2014), who found that rapid transit was associated with gentrification in Montreal, though not in Vancouver.

5.2. Equity Concerns

The lack of affordable market rental housing for particular household types of low income presents a problem in that the study design explicitly means that these households would have to give up other essentials to obtain adequate housing in the market (Kutty, 2005; Stone, 2006), a situation which is potentially detrimental to long- and short-term health (Kirkpatrick & Tarasuk, 2007; Pollack et al., 2010) unless households have access to subsidies or social housing. By most accounts, these types of housing assistance are scarce relative to need in Vancouver (e.g., Bula, 2014; Howell, 2014), with over 10,000 households in the region on the waiting list (K. St. Denis, BC Housing, personal communication, June 12, 2015). Meanwhile, over 53,000 Montrealers are on the social housing waiting list, with average wait times of about four years, yet the province of Quebec has cut funding for new social housing in the name of the *Parti liberal du Québec*'s regressive neoliberal austerity agenda (Bernstien, 2015). Of course, they could also choose less-than-adequate housing, or might choose to share a larger rental unit with others, thereby diffusing the cost of housing, but a household's inability to afford adequate housing presents an equity issue worth addressing (Hartman, 2006). At the extreme, it indicates a greater risk of either homelessness (O'Flaherty, 1995; Park, 2000; Quigley et al., 2001) or a need to rely on single-room occupancy (SRO) hotels (and/or quasi-legal support recovery housing), which may expose their users to drug use, disease, and violence (disproportionately affecting women) (Knight et al., 2014; Linden, Mar, Werker, Jang & Krausz, 2012; Shannon, Ishida, Lai & Tyndall, 2006).

Looking through the lens of location affordability, a lower proportion of housing within rapid transit catchments is affordable than outside rapid transit catchments at the metropolitan level, with few exceptions. At the level of urban/suburban zones, while results are less consistent, the trend is generally the same, as more zones more commonly feature a statistically-significantly lower proportion of affordable housing in catchments than in non-catchment areas. Overall, this suggests an equity issue in that households at low income levels have less opportunity to locate in areas with high-quality transit. While transportation and land use research has typically framed property price premiums associated with rail transit access as a benefit (e.g., Cervero & Duncan, 2002; see Chapter 2), it has generally neglected equity concerns

associated with gentrification or decreasing rental affordability (Revington, 2015; see Grube-Cavers and Patterson [2014] for a notable exception). The results therefore contest this one-dimensional view of rail transit benefits to housing markets, at least in the absence of interventions aimed at maintaining (or increasing) affordability in proximity to these services, despite the obvious mobility benefits they may provide. It would seem that either rapid transit service has increased rents within station walking catchments, with negative implications for affordability, or it has been provided in areas where the existing rent structure limits access by lower-income households. While the research design cannot distinguish which of these scenarios is the case, both can be considered inequitable outcomes relative to an alternative situation in which a greater amount of affordable housing is available close to rapid transit.

The MBM bundle of non-housing goods used to calculate housing affordability assumed that households did not own or use an automobile. Adding the often-substantial costs of vehicle ownership, insurance, operation and maintenance is bound to reduce the number of affordable rental units outside of transit catchments.[27] In other words, based on the study design, adding costs associated with a vehicle to access housing outside of rapid transit catchments will often entail giving up other basic necessities. This may compound – and be compounded by – the issue that at lower income levels, the majority of affordable housing is in automobile-oriented, spatially peripheral areas that require greater automobile use (Walks, 2015). This is particularly acute in Vancouver, where approximately 73% of rental units in the dataset fall within the Inner and Outer Suburbs, but is also the case in Montreal, where the two Suburban zones account for about 50% of rental units.

In fact, at the intra-metropolitan scale, greater spending on motor vehicles is associated with higher household debt, leading to greater financial vulnerability, and impeding household wealth creation (Walks, 2015). At the neighbourhood scale, after controlling for other variables, a 10% increase in the proportion of census tract residents who drive to work increases average

[27] The Canadian Automobile Association (CAA, 2013a, 2013b) estimates that in 2013, based on a modest 12,000km driven per year in a fuel efficient compact car, the total cost of automobile ownership and use came to nearly $8,000/year, while citing Statistics Canada data that puts the average household figure at about $9,500/year. The transportation component of the MBMs for rural areas and small cities is based on private automobile use rather than public transit, and estimated that automobile ownership and operating costs representing a minimum consumption standard for subsistence and social inclusion (and hence minimal use of an economical vehicle) approached a more modest $5,000/year in 2011 (in Quebec and British Columbia), but this remains nearly twice that of the public transit scenario encapsulated in the MBMs for Montreal and Vancouver that same year (Statistics Canada, 2013b). Specifically, in this research, the transportation component of the non-housing basket for 2014 is valued at $2,616/year for Montreal and $2,905 for Vancouver for a four-person household.

tract household debt as a proportion of disposable income by 1.8% (Walks, 2013). It also makes households more vulnerable to the adverse effects of fuel price increases. While bordering on fear-mongering, Dodson and Sipe (2007, 2008)[28] are surely correct that lower-income suburban households are most liable to face unpalatable trade-offs in their consumption patterns should fuel prices rise. In particular, among all 57 metropolitan areas of over one million residents in the United States and Canada, Montreal had the highest average gasoline prices in 2014 ($1.38/litre) and Vancouver had the second-highest ($1.36/litre) – in comparison, the highest price in the US was only $1.12/litre in San Francisco, while the lowest prices were in Houston and St. Louis, averaging $0.90/litre and $0.91/litre, respectively.[29] Already facing relatively high fuel costs, the ability of households in the two case study cities to absorb further increases may therefore be less robust than elsewhere. These trends are highly spatialized, with suburban areas being the most negatively impacted (Dodson & Sipe, 2007, 2008; Walks, 2015).

The concentration of affordable rental housing to the metropolitan fringe is consistent with trends towards the increasing suburbanization of poverty in Canada, since the households inhabiting these cheaper units will tend to have lower incomes (Ades, Apparicio & Séguin, 2012; Bunting et al., 2004; Pavlic & Qian, 2014). While this suggests a greater inability for residents of these areas to afford a private automobile, less-compact areas such as these are also difficult and expensive to serve by public transit systems (Power, 2012). For example, public transit offers poor connections to suburban employment locations for low income industrial workers in Montreal and Vancouver (Mendez, Moos & Osolen, 2015). These environments are also typically not walkable (El-Geneidy, Patterson & St.-Louis, 2015). By limiting accessibility to employment, services, shopping, recreation, and health care, this transport disadvantage can contribute to social exclusion, or the degree to which individuals are unable to participate in society to the extent required for a reasonable quality of life (Deka, 2004; Hine, 2008; Lucas, 2004; Schwanen et al., 2015). This, in turn, may further exacerbate social inequalities (Lucas, 2012) and reduce self-reported personal well-being (Stanley, Henscher, Stanley & Vella-Brodrick, 2011). Social exclusion should be thought of not as a binary state, but as a dynamic

[28] Dodson and Sipe evocatively call their analytical measures the "VIPER" (Vulnerability Index for Petrol Expense Rises) (2007) and the "VAMPIRE" (Vulnerability Assessment for Mortgage, Petrol and Inflation Risks and Expenditure) (2008).

[29] These prices are all in Canadian dollars and were compiled by Craig Townsend from average retail gas prices downloaded at regular intervals from the GasBuddy website (www.gasbuddy.com).

process produced by both local and non-local factors (including structural conditions), and as being a relative phenomenon (Schwanen et al., 2015).[30] Therefore, in the context of this research, social exclusion should not be interpreted to mean that areas without rapid transit access are excluded, but rather that they offer relatively less potential for social inclusion.[31]

Conversely, the paucity of affordable rental housing in central areas with high concentrations of employment and services easily accessible without the use of automobiles disadvantages low-income households, especially those who work and/or take children to school in different locations, or who do not have a fixed workplace address. In Montreal, for example, the number of jobs accessible within 45 minutes by transit is highest in those locations which correspond roughly to the Urban Core and Inner City as defined in this research (and to a lesser extent, the Inner Suburbs) and these areas are also the most walkable (El-Geneidy et al., 2015). The possibility for low-income households to "appropriate different forms of mobility" (Mendez et al., 2015, p. 111) is therefore reduced, as these neighbourhoods are more amenable to active modes and transit without necessarily foreclosing on the option of car use. Indeed, Glaeser, Kahn and Rappaport (2008) argue that this is why the poor tend to locate in urban centres. If rents are prohibitively expensive to low-income households, they will be deprived of this opportunity. If indeed rapid (and semi-rapid) transit flattens rent gradients in Montreal and Vancouver, it has not done so to the extent that would permit many households, particularly of lower income, the choice to live centrally.

Caution should be taken not to overstate the degree of segregation implied by this or other research on the Canadian urban context. Canadian cities remain relatively integrated (Stanger-Ross & Ross, 2012) and this is largely borne out in the data presented here for Montreal: for most household types, there were few parts of the metropolitan area completely lacking affordable rental housing (with the exception in some instances of parts of the Urban

[30] The concept of social exclusion, while useful, is not entirely unproblematic; see Schwanen et al. (2015, pp. 124-125) for discussion.

[31] It also bears mention that transport disadvantage does not directly equate to social exclusion; it is possible to be socially excluded but have good transport access, or vice versa – the importance is in their interaction (Lucas, 2012). Likewise, geographic proximity to rapid transit is only one factor in transport disadvantage: physical barriers (e.g., stairs that are difficult for the elderly to manage), distances from facilities, monetary or time costs, other time demands, fear (e.g., of crime), and surveillance and management techniques that disproportionately target certain groups (e.g., youth) may contribute to an inability or unwillingness to access transportation (Church, Frost & Sullivan, 2000).

Core).[32] In Vancouver, for some household types, certain areas had a distinct lack of affordable housing (see Section 5.1), but in most instances this was not the case. Nevertheless, there has been persistence and growth of pockets of concentrated poverty, and neighbourhood inequality and polarization have increased over the past half-century, while housing tenure and price are determinants of income segregation (Stanger-Ross & Ross, 2012; Walks, 2011; Walks & Bourne, 2006). These tendencies should remain sources of concern. After all, there is a "need [for] spaces in which to encounter otherness and sameness, where we are at once confirmed and challenged" (Borden, 2003, p. 114). These pluralistic spaces of encounter are necessary for a progressive and inclusive urban democracy that benefits the "many not the few" (Amin, Massey & Thrift, 2000).

There is, however, at least one somewhat encouraging result. When the results were disaggregated by urban/suburban zone, there was no significant difference between catchment and non-catchment areas in the proportion of housing considered affordable in the Outer Suburbs for nearly all household types in both cities, as well as the Inner Suburbs in the case of Vancouver. While the lack of statistical significance may be a result of the small number of Outer Suburban rental units within rapid transit catchments in Montreal, this is unlikely to be the case in Vancouver. This finding, particularly in Vancouver, suggests that these places allow a comparatively greater opportunity for lower-income households to live affordably in proximity to rapid transit, relative to the inner portion of the metropolitan area. A more pessimistic interpretation, however, may be that access to rapid transit is not capitalized into apartment rents in these more automobile-oriented environments as it provides less benefit in a dispersed urban form (Gatzlaff & Smith, 1993). This would contradict the findings of Bowes and Ihlanfeldt (2001), who find that, in fact, price premiums associated with rapid transit access are higher at greater distances from the CBD in Atlanta. It should be noted, however, that a far greater absolute number of affordable units remain outside of catchment areas. Either way, this issue merits further investigation.

[32] Households for which very little affordable housing (or none at all) was available in general notwithstanding (e.g., Low income single individuals).

5.3. Policy Implications

Caution should be taken with respect to the policy implications of this research; it does not discern cause and effect with regards to any relationships between transit service and housing affordability. It does, however, point to the fact that certain groups face greater challenges in accessing affordable market rental housing in the Montreal and Vancouver metropolitan areas generally, and within the most transit-accessible locations specifically. Policymakers seeking to address these equity concerns should therefore focus efforts to ensure adequate affordable housing exists for single individual and lone parent households, especially at lower levels of income where no affordable market rental housing was identified in the dataset. Geographically speaking, policy interventions that are able to establish affordable housing in the downtown core and surrounding neighbourhoods may offer substantial benefits, especially in Vancouver where it is particularly lacking, as these areas are well-served by rapid transit. This is especially the case for families with children in Vancouver. Improving the opportunity for lower-income households to find affordable housing within rapid transit catchments more generally would also represent a more equitable outcome. Interventions targeting couples without children would seem misplaced, as these households were found to enjoy much greater flexibility in the rental market at all income levels and in both cities.

Given the high shares of affordable rental housing in the suburbs of both cities, another considerable challenge for policymakers is to provide quality transit service to these locations so that affordability is not eroded by the costs of automobile ownership and operation. This is difficult given the low-density and automobile-oriented nature of these places (Power, 2012). One strategy might be to encourage affordable housing in proximity to existing transit infrastructure. This would need to go beyond mere "sustainability-as-density," which has not succeeded in increasing affordability near transit in Vancouver (Quastel et al., 2012), to more fully incorporate social justice objectives. Such a strategy may encounter opposition over fears that neighbourhood character and community will be disrupted.[33] Paradoxically, new

[33] The pace of new development and its impacts on neighbourhood character and the social realm within the city (e.g., Davison, 2011; Quastel et al., 2012) can give the impression that *everything* is slated for redevelopment, and is satirized in an article titled "Vancouver mayor Gregor Robertson to be torn down, replaced with condos" in online humour magazine *The Syrup Trap* (2014).

developments of affordable housing may be opposed if they are misperceived as gentrification,[34] or due to misconceptions around perceived social ills associated with affordable housing (Davison, 2011; Litman, 2011; Quastel et al., 2012).

Another strategy may involve expanding rapid transit networks into underserved, affordable areas. There is uncertainty around this approach, however. In addition to not being able to identify causality in the relationship between affordable housing and rapid transit (and hence whether or not extending the rapid transit network will simply make new catchment areas less affordable), the portion of Montreal's Outer Suburbs with rapid transit is small, casting doubt on the ability to extrapolate from the results for this zone. Some research suggests that transit is of limited benefit and/or effectiveness in automobile-oriented environments such as these (Power, 2012; Gatzlaff & Smith, 1993; Mohammad et al., 2013), while others have found greater residential price premiums farther from the CBD (Bowes & Ihlanfeldt, 2001), which could result in rents being bid upward, reducing affordability. From another angle, increased ubiquity of transit appears to reduce the price premium on housing; this might mean negative impacts on affordability are mitigated (Shyr et al., 2013). However, these transport improvements must be made with the needs of low-income households in mind, and ahead of the neoliberal imperatives of "efficiency"[35] and the interests of capital (Grengs, 2004; Farmer, 2011). Indeed, it is possible that discourses around the desirability of increasing mobility in the suburbs can be mobilized by the state to actively encourage gentrification of transit-accessible nodes (Enright, 2013). Clearly, this is at cross-purposes to the goal of providing affordable housing with access to rapid transit. In this regard, the disaggregate results are hopeful since, for the most part, I did not find less affordability within rapid transit catchments in the Outer Suburbs, although more in-depth research is required.

Ultimately, coordination of effective rapid transit with affordable housing may require engagement with progressive community-based planning (Angotti, 2008) which recognizes a collective right to the city (Marcuse, 2009) and by extension a right to housing (Hartman, 2006) and mobility (Blomley, 1994; Cresswell, 2006). At stake is a recognition of the fact that shelter

[34] Concerning affordability, it is always important to ask "affordable to whom?" Developers may market their projects as "affordable," meaning to middle-class rather than low-income households, or relative to more expensive single-family homeownership. These alternate definitions of affordability may go a long way in explaining this paradox.

[35] Garrett and Taylor (1999) argue that shifting the focus of transit provision away from those who most depend on it, in addition to being unjust, is often actually *inefficient*.

and mobility are essential to urban life. This would require going beyond tokenistic public participation in top-down transportation planning (Booth & Richardson, 2001; Bickerstaff, Tolley & Walker, 2002; Bickerstaff & Walker, 2005) to give marginalized communities collective agency in shaping the city to their needs for social justice (Marcuse, 2009). This is not to suggest that the role of planners be eliminated, but rather that it shift from authority to facilitation (Angotti, 2008), and is largely a redistributive claim – that the allocation of surplus produced through capitalist urbanization be determined by more than political and economic elites (Harvey, 2008). In the North American context, examples of social justice movements expressing such a principle – and relating to transportation planning – would include the Los Angeles Bus Riders Union, a social movement which fought to preserve and improve bus service for minority riders slated for cuts, imposed to redirect funding to suburban rail serving predominantly white and wealthier patrons (Cresswell, 2006; Grengs, 2002; Wexler, 2000). More recently, community organizers in Minneapolis-St. Paul won three stations in disadvantaged neighbourhoods along the new Central Corridor light rail line, while advocating for zoning policies to protect affordable housing (Blackwell et al., 2012). Whether or not these policies are effective remains to be seen – rents have gone up in the area, but so have a number of non-profit housing developments (PolicyLink, 2014). A successful movement for housing and mobility would undoubtedly need to engage with a broad variety of tenure arrangements, not just market rentals (Stone, 1993).

5.4. Limitations and Areas for Future Research

This research has been exploratory in the sense that few studies have considered intra-metropolitan patterns of housing affordability, while none have used a residual income technique or considered the relationship between rapid transit and affordability, particularly in Canada. As a result, there remain a number of limitations to this study, perhaps best thought of as opportunities for future inquiry. In the interests of transparency, they are reviewed here.

One limitation of this research is that it is a cross-sectional study. While expanding the research to include a temporal dimension was not feasible due to limitations on time and resources, and the difficulty of obtaining online rental listings from a past period, this presents some interesting avenues for further research. Rental data could be collected using the same

method at some point in the future. This may be more manageable if the study is extended over time in one of the case study cities rather than both. Considering trends over time would allow an investigation of changes in the overall geography of rental housing within a metropolitan area, an examination of the robustness of the relationship between affordable housing and transit access over time, and possibly even establish the causal nature of any such relationship – for instance by comparing rental housing affordability before and after construction of a new rapid transit line.

Another limitation pertains to the measurement of transit access. This research considers access to rapid transit as a binary variable, and excludes other modes of public transit, such as conventional buses and commuter rail. It also assumes that access to any station or stop on the network is equally valuable (and that other areas are not). In reality, a better reflection of transit accessibility would be a measure that captures a rental unit's accessibility to important destinations like employment opportunities on the basis of travel time, weighted by their relative importance (number of jobs), regardless of whether this journey uses rapid transit, another transit mode, or both. Alam, Thompson and Brown (2010), Chen et al. (2011), and Dodson, Burke, Evans and Sipe (2011) present recent examples of what such a model might look like. To some degree, this would represent a maximum potential accessibility level, as other factors may impede transit access, such as physical barriers, monetary and time costs, competing demands on time, fear, and space exclusion (such as targeted surveillance of certain groups) (Church et al., 2000). Again, incorporating such an advanced accessibility model would be incredibly data- and labour-intensive, and was therefore not included in this research.

A related issue is that this research does not compute housing affordability using a bundle of non-housing goods that includes the costs associated with automobile ownership and use, to compare how this differs from when the bundle accounts for public transit use only. Undoubtedly, this would reduce the number of affordable units, since these costs are substantial when licensing and registration, insurance, fuel, maintenance, and loan payments are included, but by how much remains unclear. This is made complicated by the fact that these amounts can vary considerably depending on the age and type of car, how much it is used, and – particularly in the case of insurance – characteristics of the driver. By contrast, a monthly transit pass allows an unlimited amount of travel over a given region for a fixed price, eliminating much of this variation. The transportation component of the MBM in smaller centres and rural areas is based on private transportation, but Hatfield et al. (2010) describe in detail the extensive pricing data

and assumptions required to do so; transferring the amount from rural areas to major metropolitan areas may not be feasible due to variations in price and degree of use between rural and urban regions. While these issues could not be addressed within this study, they remain a possibility for future research.

Similar methodological challenges also exist around including owner-occupied housing. Data would be required to estimate households' abilities to acquire mortgage financing, as well as for interest rates, down payments, and amortization periods. Owner-occupied housing also raises the conceptual issue of capital gains: high housing costs are an obstacle for entrants to the ownership market, yet if they represent an appreciation in value of existing homeowners' assets, they stand to benefit. The net impact of high prices on household well-being is therefore ambiguous in the case of the ownership market. Tenants, meanwhile, have nothing to gain from high rents. For these reasons, the ownership market was omitted from this study, but if future research can overcome these issues, it will give a more complete picture of intra-metropolitan affordability patterns. Similarly, assessing whether public or other non-market housing tends to be situated in areas with rapid transit access or not was beyond the scope of this research, but remains an interesting question.

This research also ignores how patterns in the affordability of housing and its accessibility to rapid transit intersect with categories of difference beyond income, including but not limited to race, ethnicity, immigrant status, gender, and sexual orientation. However, this is an important consideration for further research, for at least three reasons. First, certain groups may have particular residential ecologies within a city. Second, immigrants may face barriers to housing due to their unfamiliarity with the local language, laws, or rental market. Finally, particular groups may face discrimination in the housing market.

Although racialized ghettos do not exist in Canadian cities to the extent of their American counterparts (Walks & Bourne, 2006),[36] certain groups have particular distributions within urban space and therefore may face corresponding challenges accessing both transportation and housing (Hess, Huang & Vasic, 2015). For instance, different immigrant groups may have different settlement patterns within metropolitan areas, and these increasingly coincide with automobile-oriented inner-suburban areas; this has gendered implications for transportation as it

[36] According to Walks and Bourne (2006), tenure, housing form, and the price of housing appear more important in determining residential segregation in Canadian metropolitan areas than "visible minority" status.

is women who most often do not have access to a car (Hess et al., 2015; Teixeira, 2013; Walks & Bourne, 2006). Similarly, LGBTQ populations may be over-represented in certain neighbourhoods, such as the Gay Village east of downtown in Montreal or Davie Village in Vancouver's West End (Ray & Rose, 2000; Lauster & Easterbrook, 2011). Likewise, changing demography and household characteristics among young adults have led to their residential concentration in dense neighbourhoods – along transit lines in Vancouver and in central areas of Montreal (Moos, 2014b). The distribution of affordable rental housing relative to transit may therefore have unique implications for each of these groups.

Meanwhile, certain groups, particularly immigrants, may face specific barriers to finding suitable housing. They may have insufficient language skills; a reluctance to complain about landlord abuses; ignorance of legal rights and responsibilities of both tenants and landlords, and how to get assistance with these questions; and a lack of knowledge of their new city's housing markets (Teixeira, 2013). Realistically, these considerations probably constrict the perceived availability of housing relative to the amount of affordable housing identified here.

Finally, discrimination may mean that certain households may be prevented from accessing housing for reasons other than simply affordability, and has been observed across Canadian metropolitan areas (Novac, Darden, Hulchanski & Seguin, 2002). Recently, Lauster and Easterbrook (2011) found discrimination against same-sex male couples as well as single mothers and single fathers in the metropolitan Vancouver rental market using an auditing technique. Meanwhile, using a similar method, Hogan and Berry (2011) found significant discrimination against Muslim/Arabic racialized men, and to a lesser – but no less troubling – extent, east and south-east Asian men, Black men and women, and Muslim/Arabic women in the Toronto rental market. Opportunity-denying treatment by landlords was most common for those seeking small, inexpensive units; in other words, those who are already most marginalized economically (Hogan & Berry, 2011). In interviews with three groups of immigrants in Toronto, Somali, Jamaican, and Polish immigrants all reported residential discrimination, and discrimination was most common among Somalis and Jamaicans, groups that generally constitute "visible" minorities (Dion, 2001). This is by no means an exhaustive account of the aspects of difference upon which discrimination may be based (or the literature thereon), but rather is meant to highlight the considerable potential for future work to explore their interactions with housing affordability and rapid transit access.

Finally, while the research identified households for which very little or no housing was affordable, these households must reside somewhere. Most likely, this will involve giving up other necessities, but may also include subletting portions of apartment units or renting a room rather than a self-contained dwelling, or renting a less-than-optimally sized unit for the number of members in the household (Teixeira, 2013). For example, a couple with two children might inhabit a two-bedroom apartment rather than a three-bedroom apartment as is assumed here. Others may have access to subsidized housing, while at the extreme, some might experience homelessness. Considering how (and how many) households negotiate each of these coping strategies was not possible with this study, but is an important (and understudied) aspect of housing affordability issues to understand. Together, these issues present promising opportunities for future research.

6. Conclusion

This thesis answers three empirical questions: First, what is the geographic distribution of affordable market rental housing in Canada's second and third largest metropolitan areas – Montreal and Vancouver – and how does this distribution look through different "lenses" of household composition and income? Second, what is the relationship between the availability of affordable market rental housing and rapid transit accessibility? And finally, how does this relationship vary between urban and suburban zones within these two cities? While these cities are similar in many respects, they differ in several important ways, including economic history, patterns of suburban expansion, and the cost of housing.

These are important questions insofar as housing affordability is an issue in Canada, with consequences for household health, well-being, and financial vulnerability (Kutty, 2005; Stone, 2006; Kirkpatrick & Tarasuk, 2007; Pollack et al., 2010; Walks, 2013) – and at the extreme, homelessness (O'Flaherty, 1995; Park, 2000; Quigley et al., 2001) – yet it is seldom considered at an intra-metropolitan level. Likewise, despite established relationships between transportation networks on the one hand, and residential land values and housing prices on the other, the implications of these relationships for housing affordability have not been given sufficient attention. Answering these questions therefore contributes to a more nuanced understanding of intra-metropolitan housing affordability as well as an alternative perspective on the link between housing and transportation.

These are also important questions from the perspective of social equity. Within a framework of redistributive social equity, conceptualized as a situation in which inequalities are reduced or eliminated, a lack of affordable market rental housing with access to rapid transit presents an equity issue. As affordable units would most likely be occupied by lower-income households, if these units are less common within rapid transit catchments, it would mean that higher-income households can more readily make use of the transit service. However, rapid transit is the only mode of urban transportation that is capable of providing metropolitan area-wide mobility on a level comparable to that of a costly private automobile (Vuchic, 1999; Newman et al., 2013). Furthermore, given that rapid transit is largely publicly funded, if lower income households are less able to access the service, this would represent a more regressive distribution of resources within society. That is, left unchecked, it would tend toward greater inequality and exclusion.

To answer these questions, I constructed a residual income measure of housing affordability, based on the principle that housing should be considered affordable if after paying for it, a household has enough income left over to obtain basic non-housing necessities (Stone, 2006). This was applied to a database compiled from online rental listings in Montreal and Vancouver, to determine affordability for four household configurations at three income levels. The income levels represented the lowest sixth and third, and the median of the actual income distribution of each household configuration, within each metropolitan area. After geocoding and mapping these rental listings, Fisher's exact test was used to compare the availability of affordable housing within rapid transit walking catchments to non-catchment areas, at the level of each entire metropolitan area, and within four roughly concentric urban/suburban zones.

As a preface to the answers to the specific questions posed in this research, it is useful to consider the pattern of available rental housing in general. This was highly uneven in both cities. In Montreal, there was a relatively high density of units across the Inner City, peaking on either side of the central business district, and a small number of less-dense clusters in the suburbs, while in Vancouver, there was a very high density of rental apartments on the downtown peninsula, and also a number of prominent although less-dense clusters scattered across the metropolitan area. In other words, the distribution of available rental housing was more monocentric in Montreal and more polycentric in Vancouver. A larger share of the metropolitan area's rental stock was in the suburbs in the case of Vancouver (about 73%) compared to Montreal (about 50%).

In response to the first research question, housing affordability increased at greater distances from the city centre in both metropolitan areas, with a lower percentage of housing considered affordable in the Urban Core, and a higher percentage in the suburban zones. This was the case across household types and income levels. Despite this trend, the distribution of affordable rental housing generally followed that of rental housing in general, although in Vancouver there were some notable exceptions: the downtown peninsula and west side of the City of Vancouver, and the municipality of West Vancouver all lacked affordable rentals for single individuals and couples with children. Affordability issues were, intuitively, more pronounced at lower income levels, but particularly in the case of single individuals and lone parents. Conversely, couples without children had a far greater selection and geographic spread of affordable housing, suggesting affordability is less of an issue for these household types

relative to the others. Overall, Vancouver was less affordable than Montreal, with a lower proportion of affordable rentals in nearly all urban/suburban zones for nearly all household types.

The second and third questions were concerned with location affordability; that is, affordability with respect to transportation accessibility. This research found that rapid transit catchments were less affordable than the rest of the metropolitan area in both Montreal and Vancouver. This result was statistically significant for nearly all household types, with the exceptions of those for whom affordability was either very limited or scarcely an issue, and couples with children in Vancouver. Within each metropolitan area, however, results were more mixed. In many cases, there was no significant difference between rapid transit catchments and non-catchment areas in terms of affordability. However, in Montreal, rental units within catchments tended to be less affordable in the Inner City for nearly all household types, and in some cases, in the Inner Suburbs. In Vancouver, there was significantly less affordable housing in the Urban Core and Inner City for several household types, yet affordability within catchments was actually *higher* (at the 90% confidence level) in two instances in the Outer Suburbs – Median income lone parents and Low income couples without children.

That some household types could not afford any rental housing is an issue in that they would need to give up other necessities in order to access housing. But the fact that in many instances rental housing was more affordable outside of rapid transit catchments is also an equity concern. This is especially the case given that so much affordable housing was in suburban areas. This means that lower income households are not only less likely to find housing with access to rapid transit catchments, but that they are also more likely to find housing in less walkable, less transit-serviceable parts of each metropolitan area. Without access to a car, this can contribute to social exclusion; however, a private automobile comes with substantial fixed and variable expenses, which are not taken into account in this study. Adding these costs will not only decrease the pool of affordable rental housing, but will also increase financial vulnerability (Walks, 2015). It is possible that suburban areas offer potential to combine both affordable housing and rapid transit access, although more research is needed to make this claim confidently. To redress these inequities, therefore, policy should seek to provide rapid transit in areas with affordable housing, and increase affordable housing in areas with rapid transit.

This research presents a challenge to more widely-publicized measures of affordability, such as those of Demographia or RBC, which present a single metric for each entire city. On the

contrary, market rental housing affordability is quite varied within as well as between metropolitan areas. Differences exist spatially, but also by household configuration and income. In particular, by looking at rental housing, and using a residual income approach, it is clear that housing affordability is a serious issue for certain types of households, who must make material sacrifices in order to access market rental housing at all, and not simply an impediment to the middle-class ideal of homeownership. Spatial patterns of affordable housing matter as well, as they are indicative of equity issues, including – as this research has shown – in terms of access to rapid transit.

The methods used here are innovative in their use of web data to study housing affordability. They may therefore provide a valuable tool for social science research, particularly in Canada since the demise of the long-form census (Hulchanski et al., 2013; Vinodrai & Moos, 2015) and the consequent need for alternative approaches to quantitative research – for example, the technique used by Bunting et al. (2004) to examine intra-metropolitan patterns in housing affordability stress relied on this census data. The methods are also easily adaptable to other contexts. Given an income threshold, whether representing the actual income of a particular household or simply a point on the income distribution, the household composition, and the value of the non-housing bundle, the affordability of any rental unit or set of units could be evaluated. MBMs exist for most regions in Canada and so transfer of these methods would be simplest within the country, but in principle, as long as a non-housing basket can be priced, the residual income approach could be used anywhere.

There are also a number of possibilities for further research to expand on the work presented here. Future inquiry could extend the study over time, to consider trends in market rental housing affordability over time, and possibly to examine causality between rapid transit provision and affordability. Particular attention could also be given to Outer Suburban areas to build evidence as to whether or not these areas really do offer promise for providing affordable housing that is accessible to rapid transit, as my results tentatively suggest. New research could also consider how housing affordability varies with respect to a more nuanced measure of transit accessibility, between public transit use and automobile ownership scenarios, and including a wider range of housing tenures such as owner-occupation and public housing. Another particularly promising direction for future research is to consider how housing affordability and accessibility to rapid transit intersect with difference beyond income, for example race, ethnicity,

immigrant status, gender, and sexual orientation. Patterns of affordability and accessibility may have unique implications for certain groups as they cut across their particular geographies within the city and since other barriers to housing (e.g., discrimination) may compound affordability issues. Furthermore, an account of how households cope with affordability issues would be a valuable contribution perhaps suited for qualitative study.

Some entirely new directions for research also emerge. Interactions between the housing stock and demographic structure of metropolitan areas could be explored. For instance, there were few affordable rentals available to couples with children, especially in Vancouver, where these were generally located to the east of the metropolitan area. This could have demographic effects: as a result, this type of household might be more likely to move out of the metropolitan area to more affordable regions, or choose not to locate there in the first place, while those without children may choose to delay or forgo starting a family. Causality may also run in the other direction: affordable rentals may not be available for larger households in the western part of the Vancouver CMA due to a relative lack of market demand. It is possible that these and other trends are ongoing simultaneously. Determining their importance thus requires careful research attention.

Another new direction for research could consider the differences in the distribution of rental housing between the two cities (and perhaps others) in more detail. Rental housing, as shown here, and employment (Shearmur & Coffey, 2002) both exhibit a seemingly more monocentric pattern in Montreal and a more polycentric pattern in Vancouver. While the clusters of each do not necessarily overlap, an examination of whether or not the same economic, social, or political forces are behind the intra-metropolitan structure of both employment and rental housing locations may be warranted.

Overall, this thesis can serve as a fruitful starting point for subsequent research. This is true as a result of both the questions it raises, and the methods it describes, which are amenable to modification or refinement in other contexts. As long as housing affordability continues to be an issue in Canada and elsewhere, it remains an important topic of study.

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Appendix A

Table A1: *Fisher's exact test by household type and zone, Montreal*

Household Type	Income	Zone	Location	Affordable	Not Affordable	Proportion	Fisher's Exact Test		
							p-value	Odds Ratio	95% Confidence Interval
Single Individual	Low	Urban Core	Catchment	0	201	0%	1.000	0.000	0 Inf
			Non-Catchment	0	15	0%			
		Inner City	Catchment	4	741	0.5%	1.000	0.926	0.132 10.284
			Non-Catchment	2	343	0.6%			
		Inner Suburbs	Catchment	2	138	1.4%	0.315	2.093	0.197 12.946
			Non-Catchment	5	723	0.7%			
		Outer Suburbs	Catchment	0	23	0%	1.000	0.000	0.000 46.820
			Non-Catchment	3	429	0.7%			
	Median	Urban Core	Catchment	33	168	16%	0.475	2.741	0.390 119.702
			Non-Catchment	1	14	7%			
		Inner City	Catchment	369	376	50%	0.027	0.746	0.572 0.972
			Non-Catchment	196	149	57%			
		Inner Suburbs	Catchment	100	40	71%	0.044	0.644	0.421 0.996
			Non-Catchment	579	149	80%			
		Outer Suburbs	Catchment	17	6	74%	0.649	1.386	0.508 4.390
			Non-Catchment	290	142	67%			
Lone Parent	Low	Urban Core	Catchment	12	68	15%	1.000	Inf	0.143 Inf
			Non-Catchment	0	5	0%			
		Inner City	Catchment	210	180	54%	0.007	0.615	0.425 0.885
			Non-Catchment	133	70	66%			
		Inner Suburbs	Catchment	37	21	64%	0.000	0.315	0.167 0.604
			Non-Catchment	370	66	85%			
		Outer Suburbs	Catchment	12	2	86%	1.000	1.296	0.277 12.226
			Non-Catchment	273	59	82%			
	Median	Urban Core	Catchment	45	35	56%	0.175	5.053	0.473 258.416
			Non-Catchment	1	4	20%			
		Inner City	Catchment	329	61	84%	0.393	0.793	0.463 1.326
			Non-Catchment	177	26	87%			
		Inner Suburbs	Catchment	55	3	95%	0.457	0.654	0.177 3.634
			Non-Catchment	421	15	97%			
		Outer Suburbs	Catchment	14	0	100%	1.000	Inf	0.140 Inf
			Non-Catchment	317	15	95%			
Couple with Children	Very Low	Urban Core	Catchment	1	13	7%	1.000	Inf	0.002 Inf
			Non-Catchment	0	1	0%			
		Inner City	Catchment	42	82	34%	0.018	0.488	0.260 0.908
			Non-Catchment	39	37	51%			
		Inner Suburbs	Catchment	15	11	58%	0.099	0.474	0.184 1.254
			Non-Catchment	104	36	74%			
		Outer Suburbs	Catchment	3	1	75%	1.000	0.814	0.063 44.139
			Non-Catchment	107	29	79%			
	Low	Urban Core	Catchment	8	6	57%	0.467	Inf	0.029 Inf
			Non-Catchment	0	1	0%			
		Inner City	Catchment	106	18	85%	0.002	0.079	0.002 0.523
			Non-Catchment	75	1	99%			
		Inner Suburbs	Catchment	25	1	96%	1.000	1.314	0.157 61.628
			Non-Catchment	133	7	95%			
		Outer Suburbs	Catchment	4	0	100%	1.000	Inf	0.001 Inf
			Non-Catchment	135	1	99%			
	Median	Urban Core	Catchment	11	3	79%	1.000	0.000	0.000 155.623
			Non-Catchment	1	0	100%			
		Inner City	Catchment	123	1	99%	1.000	0.000	0.000 63.569
			Non-Catchment	76	0	100%			
		Inner Suburbs	Catchment	26	0	100%	1.000	0.000	0 Inf
			Non-Catchment	140	0	100%			
		Outer Suburbs	Catchment	4	0	100%	1.000	0.000	0 Inf
			Non-Catchment	136	0	100%			
Couple without Children	Very Low	Urban Core	Catchment	35	133	21%	0.127	Inf	0.687 Inf
			Non-Catchment	0	12	0%			
		Inner City	Catchment	316	298	51%	0.002	0.635	0.475 0.848
			Non-Catchment	192	115	63%			
		Inner Suburbs	Catchment	91	29	76%	0.025	0.580	0.357 0.962
			Non-Catchment	563	104	84%			
		Outer Suburbs	Catchment	17	5	77%	1.000	1.048	0.359 3.727
			Non-Catchment	318	98	76%			
	Low	Urban Core	Catchment	128	40	76%	0.079	3.175	0.801 12.607
			Non-Catchment	6	6	50%			
		Inner City	Catchment	563	51	92%	0.040	0.528	0.265 0.988
			Non-Catchment	293	14	95%			
		Inner Suburbs	Catchment	117	3	98%	0.459	0.654	0.169 3.708
			Non-Catchment	656	11	98%			
		Outer Suburbs	Catchment	22	0	100%	1.000	Inf	0.168 Inf
			Non-Catchment	402	14	97%			
	Median	Urban Core	Catchment	159	9	95%	0.508	1.601	0.034 13.609
			Non-Catchment	11	1	92%			
		Inner City	Catchment	599	15	98%	0.069	0.262	0.029 1.139
			Non-Catchment	305	2	99%			
		Inner Suburbs	Catchment	119	1	99%	1.000	1.080	0.129 50.098
			Non-Catchment	661	6	99%			
		Outer Suburbs	Catchment	22	0	100%	1.000	Inf	0.001 Inf
			Non-Catchment	415	1	100%			

Appendix B

Table B1: *Fisher's exact test by household type and zone, Vancouver*

Household Type	Income	Zone	Location	Affordable	Not Affordable	Proportion	Fisher's Exact Test		
							p-value	Odds Ratio	95% Confidence Interval
Single Individual	Median	Urban Core	Catchment	5	225	2%	0.329	Inf	0.339 Inf
			Non-Catchment	0	85	0%			
		Inner City	Catchment	6	85	7%	0.358	0.575	0.177 1.624
			Non-Catchment	16	130	11%			
		Inner Suburbs	Catchment	23	176	12%	0.045	0.599	0.346 1.007
			Non-Catchment	74	339	18%			
		Outer Suburbs	Catchment	29	179	14%	0.000	0.469	0.294 0.727
			Non-Catchment	173	500	26%			
Lone Parent	Median	Urban Core	Catchment	5	78	6%	0.021	0.218	0.047 0.951
			Non-Catchment	6	20	23%			
		Inner City	Catchment	14	27	34%	0.033	0.404	0.168 0.938
			Non-Catchment	44	34	56%			
		Inner Suburbs	Catchment	69	33	68%	0.606	0.859	0.507 1.470
			Non-Catchment	168	69	71%			
		Outer Suburbs	Catchment	99	22	82%	0.096	1.542	0.914 2.694
			Non-Catchment	344	118	74%			
Couple with Children	Very Low	Urban Core	Catchment	0	8	0%	1.000	0.000	0 Inf
			Non-Catchment	0	2	0%			
		Inner City	Catchment	0	16	0%	1.000	0.000	0 Inf
			Non-Catchment	0	18	0%			
		Inner Suburbs	Catchment	0	30	0%	0.564	0.000	0.000 6.751
			Non-Catchment	3	80	4%			
		Outer Suburbs	Catchment	2	29	6%	1.000	0.987	0.103 4.717
			Non-Catchment	13	186	7%			
	Low	Urban Core	Catchment	0	8	0%	1.000	0.000	0 Inf
			Non-Catchment	0	2	0%			
		Inner City	Catchment	3	13	19%	0.080	0.241	0.033 1.328
			Non-Catchment	9	9	50%			
		Inner Suburbs	Catchment	24	6	80%	0.473	1.528	0.518 5.167
			Non-Catchment	60	23	72%			
		Outer Suburbs	Catchment	26	5	84%	0.192	2.082	0.737 7.286
			Non-Catchment	142	57	71%			
	Median	Urban Core	Catchment	2	6	25%	1.000	0.378	0.004 39.143
			Non-Catchment	1	1	50%			
		Inner City	Catchment	8	8	50%	0.291	0.396	0.072 1.956
			Non-Catchment	13	5	72%			
		Inner Suburbs	Catchment	28	2	93%	0.725	1.696	0.322 17.089
			Non-Catchment	74	9	89%			
		Outer Suburbs	Catchment	29	2	94%	0.389	2.367	0.545 21.592
			Non-Catchment	171	28	86%			
Couple without Children	Very Low	Urban Core	Catchment	22	169	12%	0.000	0.122	0.061 0.237
			Non-Catchment	40	37	52%			
		Inner City	Catchment	35	50	41%	0.403	0.780	0.432 1.401
			Non-Catchment	62	69	47%			
		Inner Suburbs	Catchment	117	74	61%	0.198	0.788	0.543 1.147
			Non-Catchment	267	133	67%			
		Outer Suburbs	Catchment	145	59	71%	0.201	1.265	0.888 1.817
			Non-Catchment	435	224	66%			
	Low	Urban Core	Catchment	126	65	66%	0.019	0.470	0.230 0.916
			Non-Catchment	62	15	81%			
		Inner City	Catchment	68	17	80%	0.073	0.480	0.205 1.108
			Non-Catchment	117	14	89%			
		Inner Suburbs	Catchment	183	8	96%	0.345	1.524	0.650 3.988
			Non-Catchment	375	25	94%			
		Outer Suburbs	Catchment	198	6	97%	0.078	2.188	0.905 6.400
			Non-Catchment	618	41	94%			
	Median	Urban Core	Catchment	170	21	89%	0.507	0.685	0.217 1.851
			Non-Catchment	71	6	92%			
		Inner City	Catchment	80	5	94%	0.520	0.636	0.142 2.859
			Non-Catchment	126	5	96%			
		Inner Suburbs	Catchment	189	2	99%	0.725	1.682	0.316 16.748
			Non-Catchment	393	7	98%			
		Outer Suburbs	Catchment	202	2	99%	0.129	3.158	0.757 28.102
			Non-Catchment	639	20	97%			