“The Effects of Urban Rail Rapid Transit Station Types on Housing Prices in Toronto and Vancouver, Canada”

Jasmine (Yasaman) Eftekhari

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By: Jasmine (Yasaman) Eftekhari

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Signed by the final Examining Committee:

____ Chair

Dr. Norma Rantisi

____ Examiner

Dr. Tingyu Zhou

____ Examiner

Dr. Zachary Patterson

____ Supervisor

Dr. Craig Townsend

Approved by ____

Dr. Pascale Biron

Chair of Department

____

Dr. André Roy

Dean of Faculty of Arts and Science

Date ____

Abstract

The Effects of Urban Rail Rapid Transit Station Types on Housing Prices in Toronto and Vancouver, Canada

Jasmine Eftekhari

Previous research has shown that proximity to transit stations correlates positively with housing values. However, it is also possible that negative impacts on housing prices could result from negative externalities associated with stations and their surrounding tracks. The overall goal of this study is to distinguish effects of urban rail rapid transit which raise housing prices from those which lower housing prices while isolating the impact of station type.

This thesis examines the impact of urban rail rapid transit station types (underground, ground-level, or elevated), on values of adjacent residential properties in Toronto and Vancouver Metropolitan Areas. This is done through applying a hedonic price modelling methodology to analyze housing values in those two cities. Results indicated that on average, proximity to urban rail rapid transit stations led to higher residential property values and that the type of the closest urban rail rapid station was among the factors determining the amount of this capitalization. This relationship varied based on the city, characteristic of the neighbourhood, those of the transit infrastructure and the property itself.

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Table of Contents

List of Tables

List of Figures

1. Introduction

Starting in the 1960s, with concerns about the environmental impacts of automobile use rising sharply, Canada's government began to invest more heavily in public transit infrastructure. This was also to address traffic congestion due to higher number of commuters in urban areas, and the demand for less polluting modes of transportation. Public transportation is defined as a system with a large passenger capacity that is open and available to the majority of the population and includes modes such as bus, trolleybus, rail and monorail (Vuchic, 2005). If people switch from using cars to transit, per capita emissions and land requirements for automobiles (in the form of highways, roads, parking lots, and so on) decrease. If levels of car use remain constant while increasing mobility and accessibility,[1] then higher productivity without additional emissions could result.

Researchers have shown that the general impacts of public transit can be classified temporally as short term (i.e., related to savings in cost and travel time), and long term (i.e., stemming from slow but persistent changes in the natural and built environment) (Debrezion, Pels, & Rietveld, 2007). This distinction could also be geographical. Although transit infrastructure greatly impacts areas surrounding it, the effects tend to spill over to areas further away from the vicinity of the infrastructure (Mejia, Paez, and Vassallo, 2011). Improvements in public transit could cause more clustered and higher-density employment, in turn enabling urban growth, giving rise to agglomeration economies by improving labor market accessibility, increasing information

[1] In this work I will assume the following distinction between mobility and accessibility: I define accessibility as "the potential of opportunities for interaction" (Hansen, 1959, p. 79) or the "ease of reaching places" (Cervero, 1996, p. 1) while defining mobility as a measure for "vehicle-km or person-km travelled" (Vuchic, 2005, p. 51). This definition is different from the concept of "universal accessibility" or "accessible design" which refers to providing equal opportunity of access to mobility, facilities, devices, and services for people with disabilities (Audriac, 2008).

exchange and facilitating industrial specialization (Chatman & Noland, 2014). It also provides the "transportation disadvantaged" (Gendreau, Laporte & Mesa, 1995), such as low-wage populations, access to jobs and opportunities that would not have been possible otherwise (Blumenberg & Ong, 2001).

Public transit infrastructure is provided to the public by governments which set user charges (fares) below cost recovery in most if not all high income countries such as Canada. As a result, the infrastructure and operations of that infrastructure is paid for by the population through taxes and the fares are maintained at levels considered highly affordable. In Canada's five largest metropolitan areas, transit infrastructure includes both bus and railway systems.[2] These projects have been expanded over a period of decades and many additional projects are underway or in the planning stages (Figure 1). Three cities, Montreal, Toronto, and Vancouver have at least two types of railway systems in operation. These include an underground metro system and at-level commuter rail (RMT) in Montreal, an underground and surface subway and elevated Light Rail Transit (LRT), streetcars, commuter bus and heavy commuter railway (GO Transit) networks in Toronto, and elevated and underground LRT system (SkyTrain) and West Coast Express heavy commuter railway in Vancouver.[3]

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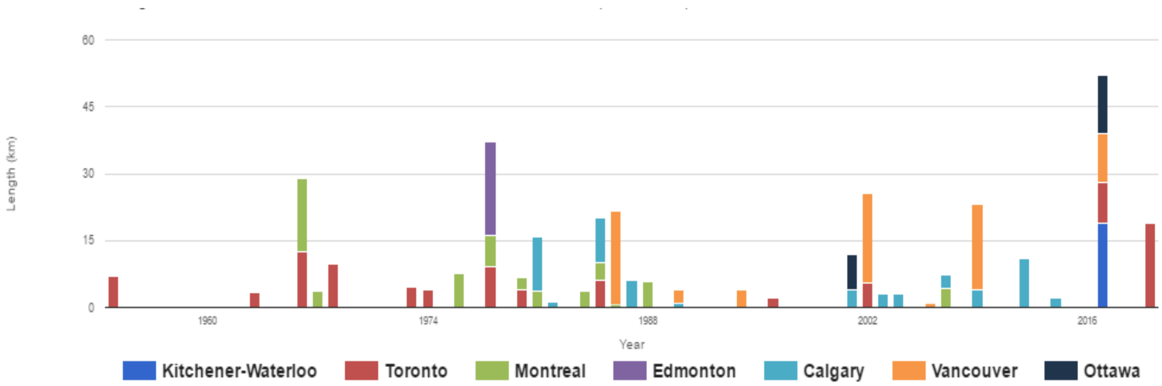
[2] As defined by Vuchic (2007), the "family of rail transit modes" comprises four basic modes: streetcars and tramways, light rail transit (LRT), rail rapid transit (metro, subway), and regional rail. All rail modes have the characteristics resulting from guidance and rail technology, and most have those caused by electric propulsion. LRT consist of electrically powered, high-capacity, quiet vehicles with high riding quality operating in one-to four-car trains on predominantly separated ROW. Rail Rapid Transit has a fully controlled ROW without any external interferences. Simple guidance, electric traction, and fail-safe signal control allow the maximum speed possible with given station spacings. RRT requires the greatest investment of all modes primarily because of its entirely grade-separation ROW and large stations. Regional Rail represents local services of long-distance railroads with a service characterized by long average trip lengths, long station spacings, high speed, and reliability (Vuchic, 2007). These three rail modes that have partial or full Right-of-Way (ROW) separation represent transit modes with the highest overall performance of all modes but that are limited in their network extensiveness because of high investment costs.

[3] In addition to the LRT systems that are under construction in Ottawa and Kitchener Waterloo, projects such as Eglinton Crosstown and Sheppard East LRT in Toronto and Millennium Line Broadway Extension and Surrey Light Rail in Vancouver are underway.

Figure 1: Inauguration of Urban Rail Mass Transit Projects in Canada (1954-2020)



If a real estate market is open and competitive, the benefits provided by a localized service or amenity would be capitalized into the values of adjacent properties (Duncan, 2008). Accordingly, if transportation infrastructure (roads, highways, railways and public transit) provides accessibility and mobility benefits to the population living in its proximity, values of the properties in close proximity to the infrastructure should be higher. However, undesirable externalities such as noise, air pollution, visual intrusions and automobile traffic associated with transportation infrastructure may affect property values negatively.

The importance of measuring the effects of public transportation projects on housing values is twofold: first, due to the long-term nature of housing selection,[4] housing values[5] have always been among the most efficient indexes of the effects of various planning interventions on the well-being of communities. This concept was examined by Knaap (1998), who argued that if planning serves primarily to preserve and enhance neighbourhood amenities (including providing

[4] In examining land and property markets, economists distinguish between the value of *using* the property from the value of *owning* the property, hence creating two markets in the land: one for its use and another for its ownership. The main focus of this work will be one the ownership of property, however, use and ownership are interconnected phenomena because the ownership price is usually determined by the expected value of the use of the property in the future (Skaburskis & Moos, 2010).

[5] As emphasized by Davis and Heathcote (2007), Davis and Palumbo (2008), and Davis, Oliner, Pinto and Bokka, (2017) housing can be viewed as a bundle consisting of a structure that provides shelter and land that provides utility because of its particular location and the price of property is a reflection of the value of both land and structure. In this work, unless specified otherwise, value of housing refers to the value of land and structure considered together.

better accessibility through transit infrastructure), then planning will increase housing prices; Second, as argued by Dubé et al. (2013), part of the process of financing public transit may include studying the connection between accessibility to public transit infrastructure and real estate markets since the former may generate externalities that are in turn reflected in building values and property taxes. As seen in transit value capture models such as Hong Kong's 'Rail + Property' development model, a potential increase in property values due to transit infrastructure could be captured using development charges and this could in turn be used to finance the transit project (Cervero & Murakami, 2009).[6] In Canada, property taxation is based on assessed market value and does capture some of that gain goes into general municipal revenue and is used to fund services such as education, road repair, recreational programs and public transit.

One basic question when planning for urban rail rapid transit infrastructure is whether the track should be at ground-level, elevated or underground.[7] All other things equal, tunnelling is more expensive than constructing elevated railways, which is in turn, more expensive than laying tracks at ground-level (Flyvbjerg, Bruzelius, & van Wee, 2008).[8] Considering that all three types[9] can provide the same amount of increase in accessibility, the benefits and costs of each type of station should be carefully considered.

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[6] While the actual policy practice varies in different cases, Land Value Tax (LVT) has been increasingly justified as a viable method for financing the construction and maintenance of public transport infrastructures (Wang, Potoglou, Orford & Gong, 2015). The argument that publicly invested transport network can promote the values of nearby land can be traced back to Smith (1937) and George (1879) who believed that the value of land comes from the adjacent infrastructures and amenities invested by the whole community. For a more detailed argument regarding Land Value Tax refer to Wang et al, 2015.

[7] Traditional underground rail rapid transit systems are generally associated with higher construction costs than surface rail rapid transit and they usually offer a higher carrying capacity (Vuchic, 2007). On the other hand, surface (or elevated) rail rapid transit infrastructure is usually associated with higher degrees of negative environmental externalities.

[8] This cost varies depending on factors such as location of the infrastructure, environmental and safety constraints, labour costs, and the characteristics of the infrastructure such as station spacing and type of rolling stock (Flyvbjerg et al., 2008). A detailed comparison of capital costs per route-kilometre in urban rail transit infrastructure can be found in Flyvbjerg, Bruzelius, and van Wee (2008).

[9] In this work, station type, attributes, and characteristic are used interchangeably and refer to the physical placement of and type of the station and its surrounding tracks.

In order to examine the interaction of value of transit-related accessibility and value of transit-related local environmental nuisances at urban rail rapid transit stations and in their proximity, it is necessary to study places where nuisance level is higher while holding accessibility and other variables constant. One way of measuring this would be to model housing prices, simultaneously taking into account the externality costs and accessibility benefits. Effectively, if there are multiple stations offering similar accessibility benefits, housing prices should decrease when exposure to externality (e.g. noise, vibration, unsightliness, etc.) increases. In other words, negative externalities associated with operations of the railway should counteract accessibility because some stations offer the same accessibility but different levels of externality.

This thesis will assess the impact of different urban rail rapid transit station types on housing prices in Canada's first and third largest Census Metropolitan Areas: Toronto (2016 population: 5,928,040) and Vancouver (2016 population: 2,463,431).[10] The study will be carried out in Toronto and Vancouver for three reasons: first, in each of these metropolitan areas there has been discussion and debate concerning which types of urban railways and stations to build. For example, in Vancouver, recent debate and planning has centered on the Broadway Avenue corridor[11] while in Toronto there has been discussion on whether to build an underground subway or an LRT line in Scarborough;[12] Second, because of similar patterns in the residential property markets of Toronto and Vancouver, findings from these two cities can be correctly compared (Bank of Canada, 2016; Hiebert, 2011); and third, both cities feature an extensive

[10] Throughout the text, unless otherwise specified, references to Toronto and Vancouver indicate the entire metropolitan area.
[11] The Millennium Line Broadway Extension will be an approximately 6 kilometre continuation of the existing Millennium Line. It will continue west from VCC-Clark on an elevated guideway, and will transition to an underground type near Great Northern Way. The Project will have six new stations (TransLink, 2017).
[12] The Scarborough Subway Extension project is a 6.2 km extension of Line 2 from Kennedy Station to Scarborough Centre. The extension is required to replace the aging Line 3 Scarborough and will eliminate the transfer at Kennedy Station. In March 2017, City Council confirmed support for the one-stop underground subway from Kennedy Station to Scarborough Centre. The future of the project is currently unknown (Pagliaro, 2016).

urban rail rapid transit system (as well as bus and commuter rail service) which includes a variety of different station types. Toronto's subway system (TTC subway) carried about 915,000 passengers per weekday in 2017 (APTA, 2017). 46 of the 69 TTC subway stations are located underground, 13 are located at ground-level, 4 are partially underground and partially at ground-level, 3 are elevated and 3 are located in a trench (are underground but uncovered). Service coverage is predominantly within the City of Toronto, with the exception of the recent Toronto-York-Spadina Subway Extension (TYSSE) which crosses the border of Toronto and travels into York Region.[13] Vancouver's SkyTrain, an automated rail mass transit system which carried approximately 376,000 passengers per day in 2016 (Translink, 2017), consists of 58 stations. The majority of the stations (40) are elevated. 9 are located underground, 6 are located at ground-level, 2 are partially underground, partially elevated and 1 station is elevated and covered.

To examine the relationship between type of the urban rail rapid transit station and property values, this study will address three specific research questions:

1. To what extent and how strongly does proximity to urban rail rapid transit stations affect housing prices in Toronto and Vancouver?

2. To what extent is that effect (positive or negative) related to whether urban rail rapid transit stations and their surrounding tracks are underground, elevated, or at ground-level?

3. How transferrable are the methods? Does the same method work in two different cities? Are similar results found in two different cities? What are the prospects for using the same method in a more different context?

This thesis will contribute to research on the relationship between public transportation and

[13] TYSEE stations are not included in this study as they were completed after the data gathering stage.

property values and more broadly about the interplay between accessibility provided by transit infrastructure and local environmental externalities caused by that infrastructure. Chapter 2 provides an overview of the literature conceptualizing transportation's effect on housing prices. Subsequently, Chapter 3 discusses the research methods, including collecting the real-estate, location, and neighbourhood data, and developing a suitable statistical model for measuring the relationship between residential property values and public transportation infrastructure. Chapter 4 presents the results, which are then discussed in Chapter 5. Chapter 6 offers a conclusion of the findings and arguments.

2. Literature Review

This chapter begins by laying out theories on location, property values[14] and transportation. It then discusses the existing literature on the relationship between residential property values and urban rail transit. Lastly, it offers an overview of previous findings with regards to the environmental impacts of transportation projects.

2.1 Location, Land Value, and Transportation

Although historically the concern of economists with land values and rent dates at least to the Physiocrats in the 18th century,[15] the conceptual frameworks of land markets have been derived from the classical economic theories of Adam Smith (1937) who observed that regardless of what is grown, land rents near the market are higher than rents further from the market on the account of the added cost of transportation. He viewed rent for agricultural land as the residual value or the difference between the cost of growing produce and the price paid for the produce at the market (Smith, 1937). Adam Smith's land-value theory was also examined by David Ricardo who presented a theory of agricultural rent at the beginning of the 19th century (Alonso, 1960). Ricardo recognized that land which was in closer proximity to the market bore lower transportation costs and that this advantage benefited the landlords in the form of rent as a result of competition among the farmers (Alonso, 1960).

J.H. von Thunen (1826) developed the theory of location differential rent to a fuller extent by arguing that the various agricultural land uses in proximity to a market place bid for the use of

[14] In the context of this section, whenever a distinction is not made, property refers to an estate ranging from a vacant piece of land to a developed area occupied by residential and/or commercial buildings.

[15] The physiocrats, a group of 18th Century French economists who were led by Quesnay, believed that the wealth of nations was derived solely from the value of agriculture. By "rent", Physiocrats meant the price of using agricultural land (Alonso, 1960) and believed that the real profit in capitalist production was the rent obtained by the owner of the agricultural land on which the production was taking place (Alonso, 1960; Ware, 1931).

land, and land was acquired by the highest bidder in each case. Using this theory, the rent at any location would be equal to the value of its product minus production and transportation costs. As a result, when compared to the land with the highest proximity to the market, the most distant land yields no savings in transportation, and consequently the amount of rent at that location would be zero (von Thunen, 1826).

The concept of proximity was also explored by Richard M. Hurd who was among the first economists to examine urban land value in the 20th century. In *Principles of City Land Values,* Hurd (1903) argued that "the value of urban land depends on economic rent and rent on location and location on convenience and convenience on nearness" (p. 11-12). He then suggested that the intermediate steps can be eliminated and that the final value of land within a city depended on proximity or "nearness" as he referred to it (Hurd, 1903).[16]

While economists such as Ricardo and von Thunen focused primarily on agricultural land, Alfred Marshall was among the first economists to specifically focus on urban land values. In *Principles of Economics*, Marshall (1890) emphasized the importance of location within the city and defined "situation value" as the sum of the money values of the situation advantages of a site. Also offering a theory on urban land values, Clark (1958) argued that during the 19th century, the annual value of urban site rents, relative to national income as a whole, was rising and this in turn, created an increasing urgency in the demand for urban space.

Economists such as Alonso (1960) accepted that advantages of one site over another arise from the differences in their location and applied it to the problem of intra-urban patterns of land use. Focusing on the relation of land values to land uses within the city, Alonso (1960) explained the

[16] In addition to proximity, by "nearness" Hurd was referring to the "land requirements of different utilities, their distribution over the city's area and the consequent creation and distribution of values." (p. 13)

effect of location on changes in land values through a bid-rent analysis. He argued that every agent (classified by Alonso into three groups of agricultural producers, manufacturing or service entrepreneurs, and private households) is willing to pay a certain amount of money to use a certain parcel of land and that amount is highly dependent upon the location of the land (Alonso, 1960). Fundamental to Alonso's argument is the proposition that all travel is radial to the center of the city (monocentric city model), where all services and employment facilities are concentrated. This in turn led to a rent gradient that declined with distance from the Central Business District (CBD). Thus, in the basic theory on real estate prices, the dominant factor explaining the difference between land values was accessibility as measured by the distance to the CBD (Alonso, 1960).

The relationship between housing prices and urban transportation was also explored by Robert M. Haig (1926) who argued that the cost of rent and transportation are two connected phenomena: "Rent appears as a charge which the owner of a relatively accessible site can impose because of the saving in transportation costs which the use of the site makes possible" (Haig, 1926, p. 421). Haig viewed transportation as a device to overcome the "friction of space." Furthermore, he argued that "the cost of friction" is not constant and varies with the site (Haig, 1926). The ideal location for the activity, according to Haig, would have a "desired degree of accessibility at the lowest costs of friction" (Haig, 1926, p. 423). Following Haig's concept, Mitchell and Rapkin (1954) argued that central sites afford maximum accessibility –which they defined as "contact with relatively low friction" (Mitchell & Rapkin, 1954, p. 108) – but since the supply of land in central parts of the city is limited, establishments and activities that can make the greatest savings in transportation costs will bid up rents for these sites and others less able to pay will be compelled to utilize less advantageous locations (Mitchell & Rapkin, 1954).

Meyer, Kain and Wohl (1965) argued that households choose housing locations and transportation modes so as to maximize their income. Workers employed at high-density workplaces (such as the CBD) have to choose higher transportation costs or higher housing expenditure and many choose to make longer and costlier work-trips from the suburbs in order to minimize cost of housing or maximize housing space (Meyer et al., 1965). It also seems probable, they argued, that the cost of other residential attributes, such as the quality of the structure and the level of community services, may vary significantly from one area to another and these will influence location and transportation choices (Meyer et al., 1965). Effectively, from the viewpoint of city governments, Capozza argued, migration of population into suburban jurisdictions tends to reduce land values in the city relative to outlying areas, thus decreasing the tax base of the city, and exacerbating fiscal problems if the demand for city services does not decrease proportionately (Capozza, 1973).

While Meyer et al. (1965) studied the relationship between land use, housing and transportation choice, until the early 1970s only a relatively small number of governments had invested in rail rapid transit (most investments before then had been by private railway firms) as a means of increasing accessibility to the CBD. However, beginning in the 1970s and as concerns with environmental impacts of mass automobile use grew, governments began investing more in rail rapid transit. The resulting accessibility created by public transit reduced the demand to live closer to the CBD by attracting households to settle around the stations and commute to downtown instead, creating suburban subcenters clustered around stations and causing a shift to a city model in which accessibility (as provided by different modes of transportation especially public transit) remained an important feature for determining values of properties (Debrezion et al., 2007). Contemporary examples of cities with planned suburban centres along railway lines include Stockholm, Copenhagen, Tokyo, and Singapore.

Although early studies found that property values generally declined with distance from the CBD (Brigham, 1965) some other studies (Waddell et al, 1993; McDonald and McMillen, 1990; Heikkila et al, 1989) showed that property values reflect accessibility to several urban centres in addition to the CBD. A study by Heikkila et al (1989), found that not only does accessibility to subcenters in Los Angeles influence residential land values, but their inclusion totally swamps any impact that CBD accessibility might appear to have in a less comprehensively specified model. A key idea behind the monocentric model, and one which rests on several restrictive assumptions such as that workplaces are spatially centralized is that accessibility to the CBD is the major determinant of location-specific land values and site rents. As argued by Heikkila et al. (1998), most studies of spatially differentiated site values have shown that they are influenced by distance (or time cost) to the CBD and that the land-value gradient is strongly negative if there is appropriate standardization for other variables (for example, characteristics of dwellings or non-residential buildings). However, research of this type, although prolific in the inclusion of other variables (including neighborhood variables), have given little attention to the possibility that accessibility to nodes other than the CBD might be important (Heikkila et al, 1989).

Given a high degree of residential mobility, sites offering accessibility to many employment nodes are more valuable because it is not very likely that successive owners will work at the same workplace; and, particularly important, accessibility may be important to nodes other than the workplace (for example shopping malls, and recreational facilities) (Skaburskis & Moos, 2015). Increases in business-related travel have made airport locations more important to many firms than downtown locations, and sub-centres have developed around the major airports that partially explain the secondary peaks in land values. Land values also increase around “suburban downtowns” and emerging employment nodes in suburban locations, where firms move for lower rents as well as proximity to an increasingly suburban labour force as cities continue to spread outward (Skaburskis & Moos, 2015).

In general, there is a consensus in the literature that accessibility resulting from location and transportation infrastructure (including transit stops) reduces travel time and costs and correlates positively with land values. Saved time and money is expected to increase the desirability of living closer to transportation infrastructure, hence causing the value of the land to increase.

2.2 The Relationship between Type of Rail Transit and Property Values

At the beginning of the 20th century, the electric tram and other transportation technologies created new site values in the suburbs but at the same time negatively impacted values of old sites at a rate that made the aggregate site rent rise less rapidly than national income as a whole (Clark, 1958).

The majority of the contemporary studies on rail transit and property values reported a significant positive relationship between proximity to rail transit and values of properties while some reported a depreciation of property values in close proximity (within a 400 m buffer) of rail transit stations (e.g. Pan et al., 2014). Although all three kinds of rail transit scheme studied (commuter rail, subway, and LRT) had positive impacts on property values, the gains for properties in the vicinity of commuter rail stations were generally reported to be larger (Dube et al, 2013, Duncan, 2008; Celik & Yankaya, 2005; Armstrong, 1994). One explanation for this difference could be that commuter rail provides a more beneficial access to commuters travelling longer distances (due to higher travel speeds of commuter rail and the resulting accessibility premium attached to locations within close distance of a station) and hence are valued more than subway and LRT which are more suitable for shorter distances (Mohammad et al, 2013). Debrezion et al. (2007) suggested that in addition to the type of real estate considered (vacant land, commercial, or residential), the effect of transportation infrastructure on property values also varies according to the characteristics of the stations and their strength may considerably vary depending on ridership, type of clientele and, service quality.

Bowes and Ihlanfeldt (2001) argued that Metropolitan Atlanta Rapid Transit Authority (MARTA) stations had a positive impact on the value of nearby properties by reducing commuting costs or increasing accessibility for residents while their negative externalities included emitting sound and pollutants and providing higher access to criminals. On the positive side, MARTA stations increased accessibility to public transportation for the people that live nearby and reduce their travel time and cost to other destinations in urban areas, which produces a network externality (Bowes & Ihlanfeldt, 2001). Similarly, business activities close to the stations benefited from the increase in passersby to and from the stations. They concluded that the effects described above depended on the type of transport infrastructure, its location, and its specific characteristics (Bowes & Ihlanfeldt, 2001).

Among the studies which focused on the effects of LRT projects on property values, most examined changes in property prices after a light rail system was in service. A few also studied the preservice impacts of light rail plans. Using data on vacant land sales in Washington County, Oregon, Knaap, Ding and Hopkins (2001) found that plans for light rail investments had positive effects on land values in proposed station areas. Yan, Delmelle and Duncan (2012) estimated the effect of proximity to light rail, housing characteristics and spatial components on single family house values in Charlotte, North Carolina. Applying the same model to each time period that coincided with the pre-planning, planning, construction and operation phase of the light rail system, these authors observed a greater desirability to live closer to a light rail station as the transit system became operational (Yan et al., 2012).

In another study, Ferguson, Goldberg, and Mark (1988) examined the impact of Vancouver's initial automated light-to-mid metro (the SkyTrain Expo Line) during the planning and construction phases. Trying to determine whether the announcement of plans to build the transit system had any effect on residential property values, the authors found that while house values were influenced in the expected direction by structure age (values declined) and by the area of the house and lot (values increased), there was no evidence that the announcement of plans to build the SkyTrain in 1980 had any effect on house values (Ferguson et al., 1988). However, in 1983 and about two and half years before the SkyTrain line was expected to become operational, proximity to a transit station (then under construction) was associated with a statistically significant increase in house values (Ferguson et al., 1988).

Another indication of the effect of proximity to rail rapid transit is neighborhood change. This could be in the form of change in zoning which specifies the density and type of future development to encourage landscapes conducive to transit use (Atkinson-Palombo, 2010) or through changes in demographic factors such as race, income, or car ownership (Pollack, Bluestone, & Billingham, 2010). While employing a conventional definition of gentrification and using the survival analysis technique in order to approach the onset of gentrification as an event, Grube-Cavers and Patterson (2014) analyzed the likelihood that areas surrounding stations in Montreal, Toronto and Vancouver would experience gentrification. They argued that in Vancouver, despite many different models being tested, only distance from water proved to be statistically significant in and negatively related to the likelihood of gentrification in a neighborhood (Grube-Cavers & Patterson, 2014). The lack of correlation between transit and gentrification in Vancouver, Grube-Cavers and Patterson (2014) argued, was consistent with research findings that demonstrated that poverty is actually spreading along the SkyTrain lines rather than gentrification as seems to be the case in other cities such as Toronto and Montreal. Similarly, Bowes and Ihlanfeldt (2001) observed a significant relationship between proximity to Atlanta's MARTA stations and crime rates in neighborhoods immediately surrounding the station. Additionally, the most immediate properties (within 400 meters from the station) were found to have an 18.7% lower value than those located outside of the stations' vicinity (Bowes & Ihlanfeldt, 2001).

A Madrid Region case study by Mejia, Paez, and Vassallo (2011) focused on its five most important southern municipalities which previously lacked interconnection through urban mass transportation. The results of the study indicated that better accessibility to the newly built subway line's stations had a positive impact on real estate values and that the effect was particularly marked in cases in which the house was for sale (Mejia et al., 2011).

A study by Bajic (1988) identified the effects of Toronto's subway line on residential property values. The author's argument was based upon the idea that the benefits from an improvement in transportation were reflected in premiums paid for housing. Results were obtained by estimating direct benefits from the improvement in transportation per owner-occupant household as well as through identifying direct subway effects on housing prices. The findings indicated that the direct savings in commuting costs had been capitalized into housing values (Bajic, 1998).

A study by Haider and Miller (2000) on the effect of Toronto's TTC subway on property values found different results. Using the hypothesis that proximity to transportation infrastructure influences residential real estate values, Haider and Miller (2000) estimated the impact of locational elements on residential property values. Price of residential properties sold in 1995 in the Greater Toronto Area was analyzed. The study's models used a combination of location influences, neighborhood characteristics, and structural attributes to explain variance in housing values. The results indicate that compared to other variables such as number of bedrooms and bathrooms, and distance to CBD, proximity to a subway line had a smaller impact on housing values (Haider & Miller, 2000).

2.3 Localized Negative Environmental Impacts of Transportation Infrastructure on Property Values

Findings from previous studies suggest that effects of rail transit infrastructure on property values vary according to the characteristics of the stations in addition to the effects relating to larger operating and neighbourhood characteristics (Debrezion et al., 2007). The externalities of rail transit infrastructure may include disruption and noise associated with the construction and operation of the line and stations, increased automobile traffic near the station, and visual unsightliness (Chalermpong, 2007).

Although it is useful to study the environmental impacts of one transportation project on its surrounding neighborhood, these effects are not isolated and therefore, multiple transportation projects should be taken into account simultaneously. In a study on the combined impacts of highways and light rail transit stations on residential property values for Phoenix, Arizona, Seo, Golub and Kuby (2014) found that dis-amenities such as noise, represented by distance from both highway and light rail track, appear to have no significant effect on residential property values. For highway exits, benefits were moderate at close distances, highest for residences about 1.2 kilometers from a highway exit, and decreased steadily for houses further away. These results indicated that the accessibility benefits adjacent to the station or highway exit were somewhat offset by the dis-amenity from proximity to railway lines (Seo et al., 2014). Various other studies identified negative environmental impacts from railways proximity to the line to a variety of reasons noise and vibration resulting from construction of a new line, the upgrade of an existing line, from everyday operations or new switches and crossings (Connolly, Marecki, Kouroussis, Thalassinakis & Woodward, 2015; Carpenter, 1994).

The Surrey Rapid Transit Alternatives Analysis, a multi-phase study that evaluated alternatives for rapid transit in Surrey, British Columbia considered a range of criteria including regional vehicle emissions, noise and emissions, and potential for impact on biodiversity, fish bearing watercourses, parks and open space, and agricultural resources and concluded that all rapid transit alternatives (Bus Rapid Transit, Light Rail Transit, and Rapid Rail Transit) produce noise and vibration, with the Rapid Rail Transit having the most potential impact (IBI Group, 2012).

In a study that analyzed the effect of LRT stations on sale prices of single-family homes in metropolitan Portland, Oregon, Al-Mosaind et al. (1993) found that although the housing market viewed proximity to an LRT station as a benefit, the short and long-term nuisance effects due to construction and operation of stations may have reduced that benefit. They concluded that in this case, the positive effects of accessibility were stronger than the nuisance effect. This might have been due, in part, to the design of LRT stations and as a result, design treatment should be sensitive to potential impacts on nearby neighborhoods and failure to do so may lead to an adverse price effect on homes (Al-Mosaind et al., 1993).

After studying the impact of the commuter rail system operated by Amtrak on the values of single family properties located in the Boston, Massachusetts Metropolitan Area, Armstrong (1994) reported that at a regional level, access to the CBD provided by commuter rail service had an appreciative impact on values of single family properties. In a more recent study, Dubé, Thériault, and Des Rosiers (2013) argued that due to the externalities created by commuter rail projects, transit investments are highly capable of influencing the real estate market. This was proven through estimating the actual effect of proximity to commuter train stations along the Mont-Saint Hilaire route occurring in 2000-2003 using a hedonic price model with a difference-in-differences (DID) estimator. The authors found a location premium for houses located in proximity to the stations (Dubé et al., 2013).

In order to identify the impact of land prices of replacing at-grade or elevated railways with underground subways in Seoul Metropolitan Area, Lee and Sohn (2013) found a significant difference in several variables according to whether a station area belongs to at-grade (or elevated) or underground subway, confirming that property prices of areas along at-grade or elevated railway are much less than those along underground railways. The authors argued that in the past few decades, Seoul's at-grade or elevated railways have led to economic deterioration by severing neighborhoods and also have given rise to serious environmental problems such as noise, vibration and unattractive landscapes (Lee & Sohn, 2013). In particular, Lee and Sohn (2013) believed that the segregation caused by at-grade or elevated railways has done more harm to nearby neighborhoods than any other form of at-level transport facilities. Moreover, according to the statistics provided by the Korean Railway Corporation (KRC) railway crossings have caused serious safety problems (Lee & Sohn, 2013). Aside from property values, the statistical test conducted in this study also verified the significant differences in several variables (including employment level, station locations, office and other-use floor areas, number of pedestrian friendly nodes, highway closeness and station intermodal characteristics) which varied greatly between at-grade station areas and underground subway stations (Lee & Sohn, 2013).

The Final Environmental Impact Statement/Environmental Impact Report (EIS/EIR) for Los

Angeles’ Westside Subway Extension Locally Preferred Alternative concluded that characteristics important in creating real estate value premiums near station sites include proximity to stations, relatively high-density zoning, a safe pedestrian-friendly environment, and a balanced origin-destination mix within the fixed guideway system (Los Angeles County, 2012). Negative impacts on property values from transit (which the report called nuisance effects) could also occur according to the report's findings (Los Angeles County, 2012). Measurable noise impacts from vehicles, increased pedestrian traffic, transit structures, transit-associated parking, and increased bus traffic can reduce the desirability of properties near a transit station and such externalities will most likely have a more pronounced negative effect on values of properties in areas where value is not attributed to the accessibility improvements that transit provides (Los Angeles County, 2012).

Connolly et al (2015) analyzed a collection of technical ground-borne noise and vibration reports produced for rail projects including light rail, tram lines, underground/tunneled lines, freight, conventional rail and high speed rail. They found that railway vibration is a growing global concern, and as such, assessments have become more prevalent and that vibration and re-radiated noise are undesirable environmental impacts which can result in human distress and real-estate losses (Connolly et al., 2015), therefore concluding that in densely populated urban areas the economic risk associated with excessive levels of ground-borne noise and vibration is high (Connolly et al., 2015).

In *The Environmental Impact of Railways*, Carpenter (1994) identified noise, structural vibrations and atmospheric pollution, and visual intrusion as “extended disturbances” caused by railways. These factors exist both during construction and operation of the railway and might cause a decrease in property values. He argued that noise is the most measurable nuisance caused by railways and can be generated from engines and ancillary equipment escaping through exhausts or openings in the casing; wheels running on rails; aerodynamic effects; or vibrating structures (Carpenter, 1994).

The types of externalities associated with rail transit infrastructure are to a certain degree similar to externalities created by other transportation infrastructure such as highways. Assessing the qualitative benefits created by the spatial alterations of transportation projects, Tajima (2003) argued that the demolition of the existing elevated Central Artery (Interstate 93) in Boston and placing it underground will remove two prodigious effects on the city's appearance: "1) a source of noise, air pollution, and an eyesore; and 2) a physical and symbolic barrier that has separated harbor-front parcels from the rest of the city" (Tajima, 2003, p. 643) (both of these qualities are similar to those of exposed rail transit infrastructure). In order to estimate the effects of two newly developed highways in Netherlands on housing values located in their surrounding municipalities, Levkovich, Rouwendal and van Marwijk (2015) used several repeat sales model specifications and controlled for neighborhood effects. They reported that improvements in accessibility provided by the highways resulted in a significant positive effect on the price of housing but increased noise pollution and traffic intensity levels resulted in a decrease in prices. Combining the positive and negative effects of all externalities, the effect of highway development on the price of housing was confirmed to be generally positive (Levkovich et al., 2015). Similarly, in a study on the impact of the Superstition Freeway Corridor in Mesa and Gilbert, Arizona on property values, Carey and Semmens (2003) found long-term added traffic noise and pollution and reduced transportation time and cost of freeways affected property values depending on the property type (Carey & Semmens, 2003). Proximity to the freeway had a negative effect on the value of detached single-family homes but a positive effect on multifamily residential developments (such as townhouses and apartment buildings) (Carey & Semmens, 2003).

While defining a negative externality as “a by-product of production or consumption activities that adversely affects third parties not directly involved in the associated market transactions” , Nelson (2008, p. 2) argued that environmental noises above ambient noise levels can disturb daily activities and in severe cases can have adverse effects on health. In another study that focused on the negative externalities of highways, Nelson (1982) searched for a noise pollution externality consensus among nine empirical studies and found negative impacts reported by the studies to be ‘‘fairly consistent’’(p. 129) and in the range of an 8–10% lower price for houses located adjacent to highways (Nelson, 1982).

Carpenter (1994) argued that visual impacts are related both to close intrusion and to wider views of scenic resources and could also include an obstruction of views by railway structures, and the negative effect of railway infrastructure and trains on the wider landscape. Although the analysis of views (or unsightliness) should be placed in the wider context of the analysis of externalities on property values (Bourassa, Hoesli & Sun, 2004), only a relatively small number of studies have examined the value of the view as an amenity (or dis-amenity) (Benson, Hansen, Schwartz & Smersh, 1996). Most of the studies that examined the impact of views on property values found that view has a statistically significant effect on the value of homes (Bond, Seiler & Seiler, 2001; Benson et al., 1996; Bourassa et al., 2004). In a study that examined the effect that a view of Lake Erie has on the value of a home, Bond et al. (2001) found that in addition to square footage and lot size, having a lake view was the most significant determinant of home value- it added an 89.9% premium to the value of the home. Another study by Benson et al. (1996) provided estimates of the value of the view amenity in single family residential houses.

Findings of this study suggested that depending on the particular view including ocean, lake, and mountain, willingness to pay for the amenity view is quite high (Benson et al.,1996). In a study which examined nearly 5000 sales in Auckland, New Zealand, Bourassa et al. (2004) found that wide views of water added an average of 59% to the value of the waterfront property but that this effect diminished rapidly as the distance from the coast increased. In addition, they found that attractive improvements in the immediate surroundings of a property added another 27% to the value on average and in contrast, properties in neighborhoods with poor-quality landscaping experienced a 51% decrease in price on average (Bourassa et al., 2004).

In summary, there is a consensus in the literature that transportation infrastructure reduces travel time and costs and this correlates positively with property values. Although the literature on the relationship between accessibility (and proximity) to transportation infrastructure and property values is quite extensive, the impact of urban rail rapid transit station attributes (types) on housing values seems to be mainly absent from this area of scholarship.

3. Methods

This research assesses the effect of urban rail rapid transit station types on housing values. In particular, the concern is with whether a monetary benefit is associated with different station types: underground, elevated, and ground-level (or any combination of these types). As explained in Chapter 1, this study will be carried out in Toronto and Vancouver because of three reasons: first, in each of these metropolitan areas there has been discussion and debate concerning which types of urban railways and stations to build (City of Toronto, 2016; Pagliaro, 2016); Second, similarities between residential real-estate markets in Toronto and Vancouver make it possible to compare findings from these two cities (Bank of Canada, 2016; Hiebert, 2011); and third, both cities feature an extensive urban rail rapid transit system which include a variety of station types.

This research focuses on owner-occupied residential property values and does not include other property types such as commercial, office, or industrial, nor does it look at rental housing. The decision to use owner-occupied residential properties was made due to several reasons: first, as argued in Chapter 1, housing values have always been among the most efficient indexes of the effects of various planning interventions (such as development of new transit infrastructure) on the urban environment and well-being of communities; Second, according to Epple, Quintero and Sieg (2015) housing values and rents are usually closely linked in equilibrium (when rent control is absent) because the value of the house is given by the expected net present value of the discounted stream of rental income. Similarly, Skaburskis and Moos (2011) argue that rent and ownership price of a property are interconnected because the ownership price is usually determined by the expected value of the use of the property; and third, as argued by Dubé et al. (2013), part of the process of financing public transit may include studying the connection between accessibility to public transit infrastructure and real estate markets since the former may generate externalities that are in turn reflected in building values and property taxes.

A quantitative research method allows for the examination of the real estate data in such detail and on a scale that would not be possible through a qualitative approach. Linear regression with Ordinary Least Squares (OLS) and spatial econometric models are employed statistical methods widely for measuring the impact of transportation infrastructure on housing values. In general, researchers use three OLS methods to assess real estate prices and the factors that influence them: median price, repeated sales approach and hedonic price analysis (Dorsey, Mayer & Wang, 2010). As Mejia, Paez, and Vassallo (2011) argued, due to difficulties in gathering the data and other limitations such as the assumption that quality is constant between sales dates (Dorsey, Mayer & Wang, 2010), median price and repeat sales implementations are less commonly used compared to hedonic price analysis. Accordingly, hedonic price analysis was considered an appropriate methodology for this study.

Additionally, the hedonic price approach fits well with this study's objective of isolating the impact of urban rail rapid transit station characteristics (types) on housing prices. Using hedonic price modelling, property prices can be decomposed to evaluate the price of various structural, locational and neighborhood characteristics on the value of the property. To estimate the implicit price for each attribute, price of the property is modeled as a function of various attributes and multiple regression analysis is used in order to isolate the size of each variable's effect (Mejia et al, 2013).

According to Yan et al. (2012), because accessibility is capitalized into land and has no influence on the value of the physical structure of a property, ideally one would use land values when conducting a hedonic price analysis. However, because urban rail rapid transit is rarely built in undeveloped areas, there are usually not enough vacant parcels to estimate a model with any degree of statistical significance (Yan et al, 2012). Because land value data is not easily available in all regions, several studies such as those by Hess and Almeida (20017), Al-Mosaind et al. (1993) and Celik and Yankaya (2005) have used value of buildings instead (assessed value, sales price and listing price respectively). In the case of Toronto and Vancouver, data for land values was not available to the public (at least in Toronto)[17] and there was not enough vacant land parcels in the vicinity of all urban rail rapid station types to allow building an accurate model. As a result, values of properties were used in the hedonic price analysis.

This chapter is organized to correspond with three main stages: first, the real-estate listing data used in this study will be discussed; Second, a summary of property, neighbourhood and location variables will be offered; and third, the hedonic price modelling methodology will be discussed.

3.1 Data

The first step of the data collection process was to gather data on property values and housing characteristics. The data used in my study was cross-sectional and in the form of residential real-estate listing prices in Toronto and Vancouver Metropolitan Areas obtained from an online real estate platform (realtor.ca).[18]

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[17] In 2005, MPAC, the Ontario Government and Teranet Enterprises Inc. completed the Ontario Parcel™ – an ambitious project that brings assessment, ownership and land parcel data for almost 4.6 million properties into a standardized digital database. The Ontario Parcel™ is available to Ontario municipalities, public organizations and private businesses but not to individuals.

[18] Realtor.ca is an advertising website created by The Canadian Real Estate Association (CREA) and as of the data-collection stage of this study, was the only publicly available platform for accessing real estate listings in Canada. The listing content comes from the various MLS® Systems operated by Real Estate Boards and Associations across Canada (CREA, 2017). It should be mentioned that a recent ruling by the federal Competition Tribunal required the Toronto Real Estate Board to allow broader public access to the past selling prices of properties in its Multiple Listing Service (MLS) data (Competition Bureau, 2016). In order to gather the listing information, the data corresponding to each property listing was exported as a CSV file using a script written in JavaScript. Each listing was manually converted into HTML and using the script, the listing information was converted into JSON. The

Ideally, final sales price or assessed value of the property would have been a more accurate representation for the value of properties included in this study as the listing price decision is not necessarily final. The seller has the option to set an initial listing price, observe market reaction to that price, and then adjust the listing price in response the observed demand for the home (Knight, 2002). In this study, the use of listing prices was dictated by a lack of access to official databases containing property sale prices. Several studies such as those by Celik and Yankaya (2005) and Pan et al. (2014) also used listing prices instead of sales prices due to lack of access to final sales price data.

When using listing prices, risk of including under or over-valued properties in the sample increases. Knight (2002) observed that the two most important determinants of price revision are the total length of time the home is marketed and the amount by which the home is mis-priced initially. Data regarding changes in listing price during the listings' marketing period are available to general public in Toronto and Vancouver. As a result and in order to measure the variance of listing prices of properties used in this study from actual sales prices, a comparison between average listing prices and average reported sales prices is offered later in this chapter.

Listing information was collected from the website during two seven-day periods (one for each city) between August and October, 2016. In total, 8614 listings were included in the initial stage. In addition to the asking price, property listings on realtor.ca usually include geographical information of the property (address and postal code), and characteristics of the property.

In order to create a more coherent database, leasehold properties were excluded from this

JSON file was then converted into CSV. The final step was to manually merge these CSV files into one single database.

study.[19]According to Wang et al. (2015), a freehold property is likely to show a higher price compared with a property under leasehold tenure. [20] A study by Lazrak et al. (2013) which focused on the real estate transactions in Zaanstad, Netherlands, also confirmed that houses on leasehold plots of land sell at a 4.7 % discount rate, a premium homeowners were willing to pay to reduce uncertainty. Retirement, rental, cooperative and unusual properties (such as boat houses) were also excluded from the database. This decision was made because these properties represent a unique type of homeownership and are part of a different segment of the real-estate market. Listings for which critical information (such as number of bedrooms and bathrooms) was missing were also omitted.

To minimize problems that could arise from extreme values, outlier properties with unusual prices were also identified and excluded from the database using the interquartile range. In this study, outliers were defined as observations that fell below Q1 − 1.5 IQR or above Q3 + 1.5 IQR. In total, 84 properties in Toronto and 121 properties in Vancouver were excluded from the database.

The remaining property listings were categorized into three property types: apartment (condominium), single family and townhouse. In Vancouver, after removing leasehold properties and outliers, the number of remaining townhouse properties (48) was not enough for building an accurate model. As a result, these properties were omitted from the sample. In the end, the remaining properties were entered in 5 databases according to their type and city: apartment

[19] Among single-family property listings in Vancouver, 98 properties have the ownership type "Strata." According to the Government of British Columbia, "Strata housing is often referred to as condos or condominiums but there are many different kinds of strata housing and strata corporations. Single family homes in bare land strata corporations ("strata subdivisions"). These properties were not omitted from the database but because "strata developments can also be either freehold or leasehold," the two categories of freehold and strata were kept for the single family homes.

[20] According to the Province of British Columbia, the following differences exist between leasehold and freehold properties: right to occupy a premise; fees and taxes; buying and selling (British Columbia, 2017).

properties (Toronto, Vancouver), single family properties (Toronto, Vancouver), and Townhouse properties (Toronto). Table 1 provides a summary of the final number of property listings in each city.

Table 1: Count of property listings by type and city

Property Type	Toronto	Vancouver
Single Family	1040	1767
Apartment	2888	2118
Townhouse	347	N/A

Using the address and postal code provided in the listings, each property was geocoded and mapped using GIS. Figures 2 and 3 show the spatial distribution of listings based on dwelling

Figure 2: Distribution of property listings, Toronto

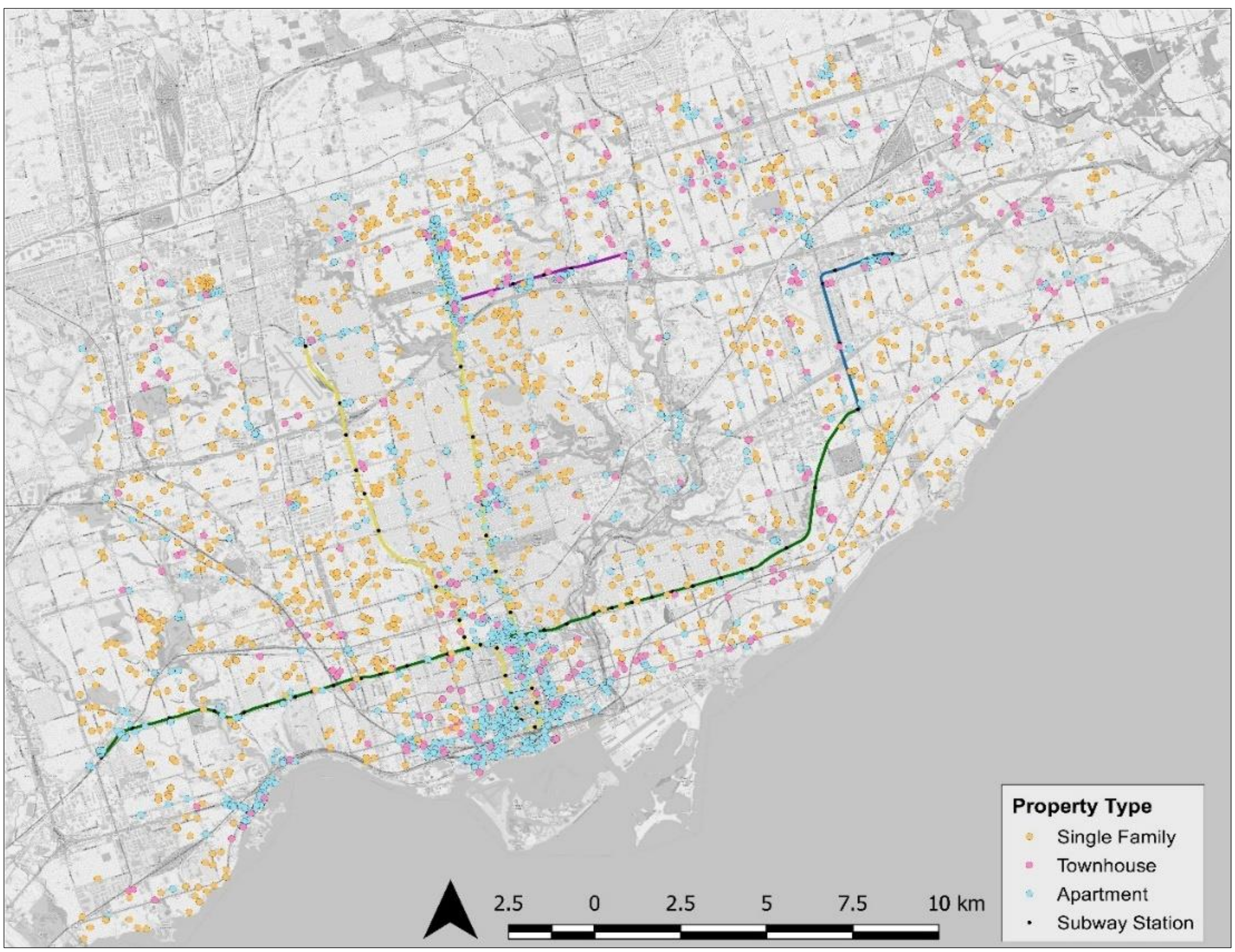
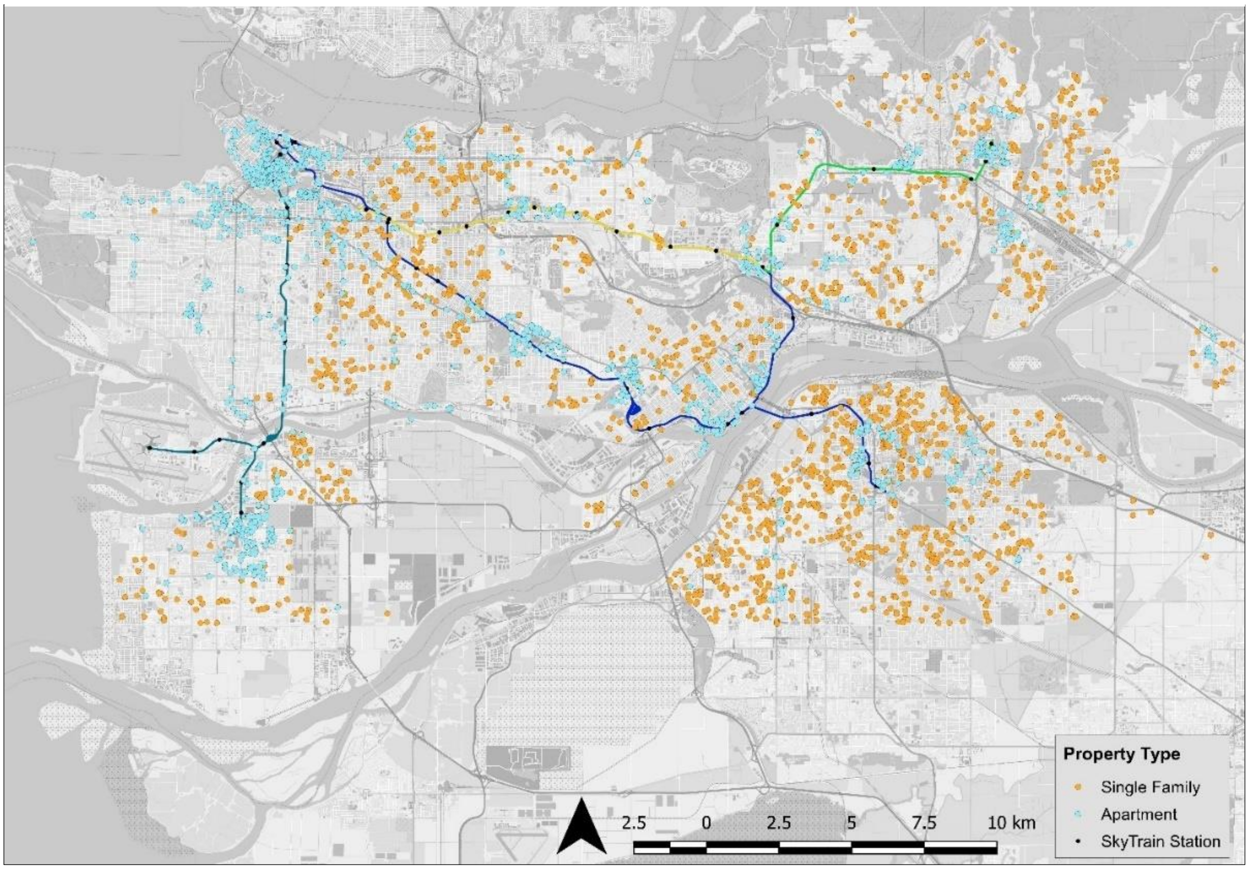


Figure 3: Distribution of property listings, Vancouver



type in Toronto and Vancouver. The locations of property listings are shown as dots. Housing units within the same complex have identical geographical coordinates and are displayed with one indicator (dot). TTC subway and SkyTrain lines and stations are also shown on the maps.

Figure 4 shows the density of apartment and single family listings in Toronto. Clusters of apartment properties appear along Line 1 between Finch and York Mills subway stations and in the downtown area south of Bloor-Yonge station. There is a small concentration of apartments along Lake Ontario in Mimico neighborhood in Etobicoke. While single family property listings are more evenly spatially distributed, a higher number of single family properties are located north of Eglinton Avenue, along Line 1 and in North York. As shown in Figure 5, townhouse properties are more spread out with some concentration around Finch station and in

Scarborough.

According to Figure 6, Vancouver apartment listings are highly concentrated in the downtown area with some clusters around the end of each SkyTrain corridor. Most of these clusters match the location of "Urban Centres" in Vancouver.[21] In contrast, single family properties are more evenly distributed than apartments across Metro Vancouver, with some concentration in the suburbs of Surrey and Coquitlam.

[21] Urban Centres are transit-oriented communities with diverse populations, a range of employment opportunities, public spaces, and lively cultural and entertainment amenities. Metro Vancouver has a network of 26 connected Urban Centres ranging in size and character. The Metro Core, Surrey Metro Centre and 7 other Regional City Centres are regional-scaled activity hubs. The smaller, Municipal Town Centres are more local-serving Centres. All Urban Centres share common elements of transportation accessibility and planned residential and employment growth. For a detailed map of Urban Centres, refer to: http://www.metrovancouver.org/services/regional-planning/livable-urban-centres/about-urban-centres/Pages/default.aspx

Figure 4:Density of apartment and single family property listings, Toronto. Density calculations are based on units within 750m radius.

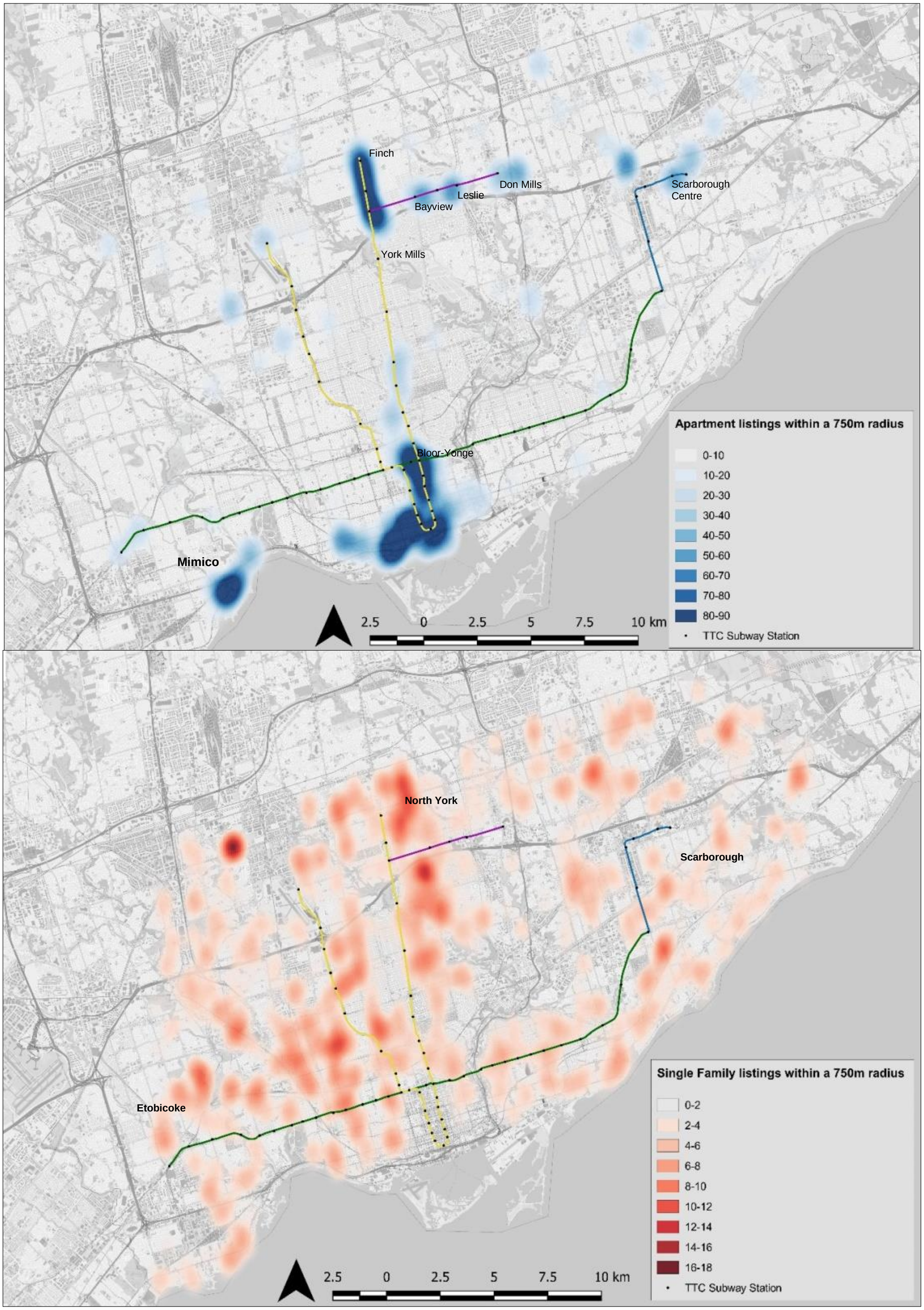


Figure 5: Density of townhouse properties, Toronto. Density calculations are based on units within 750m radius

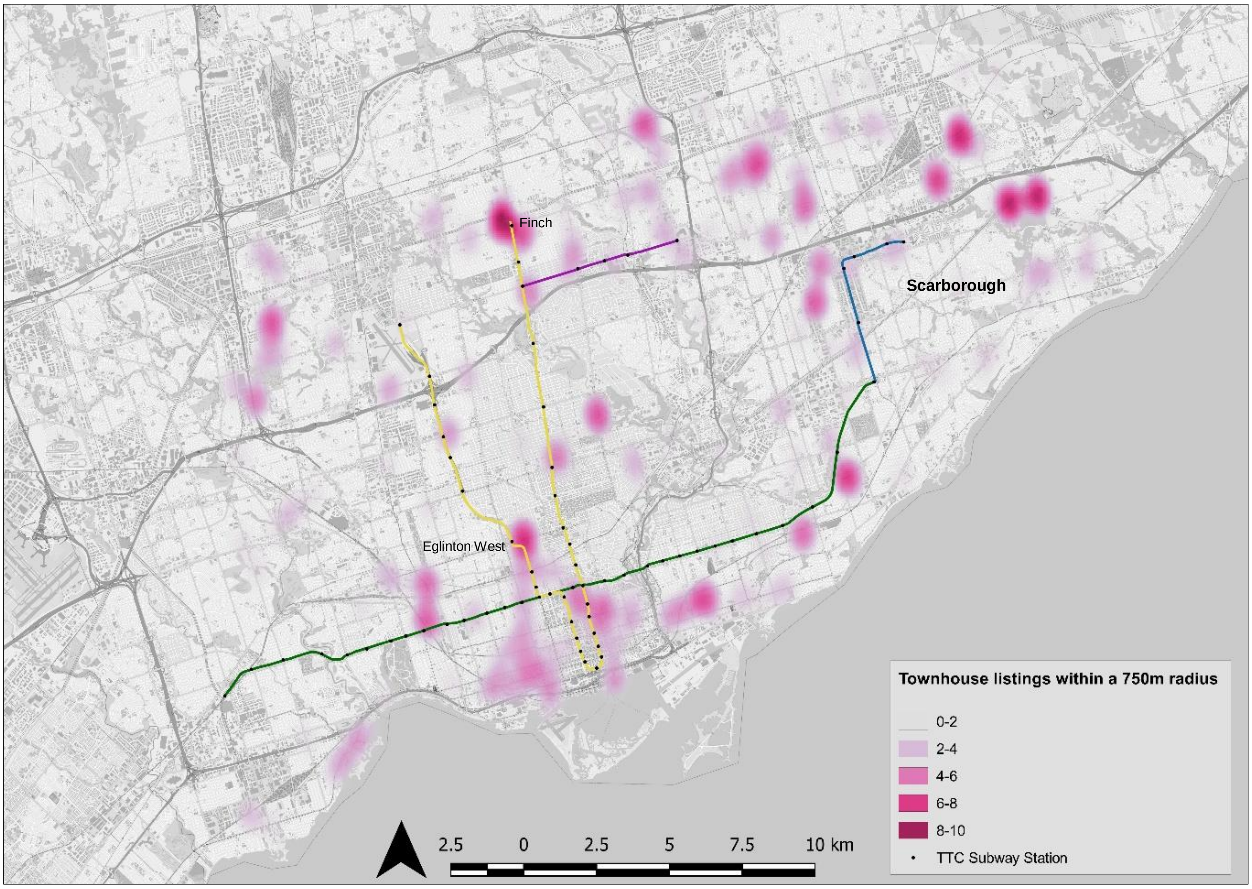
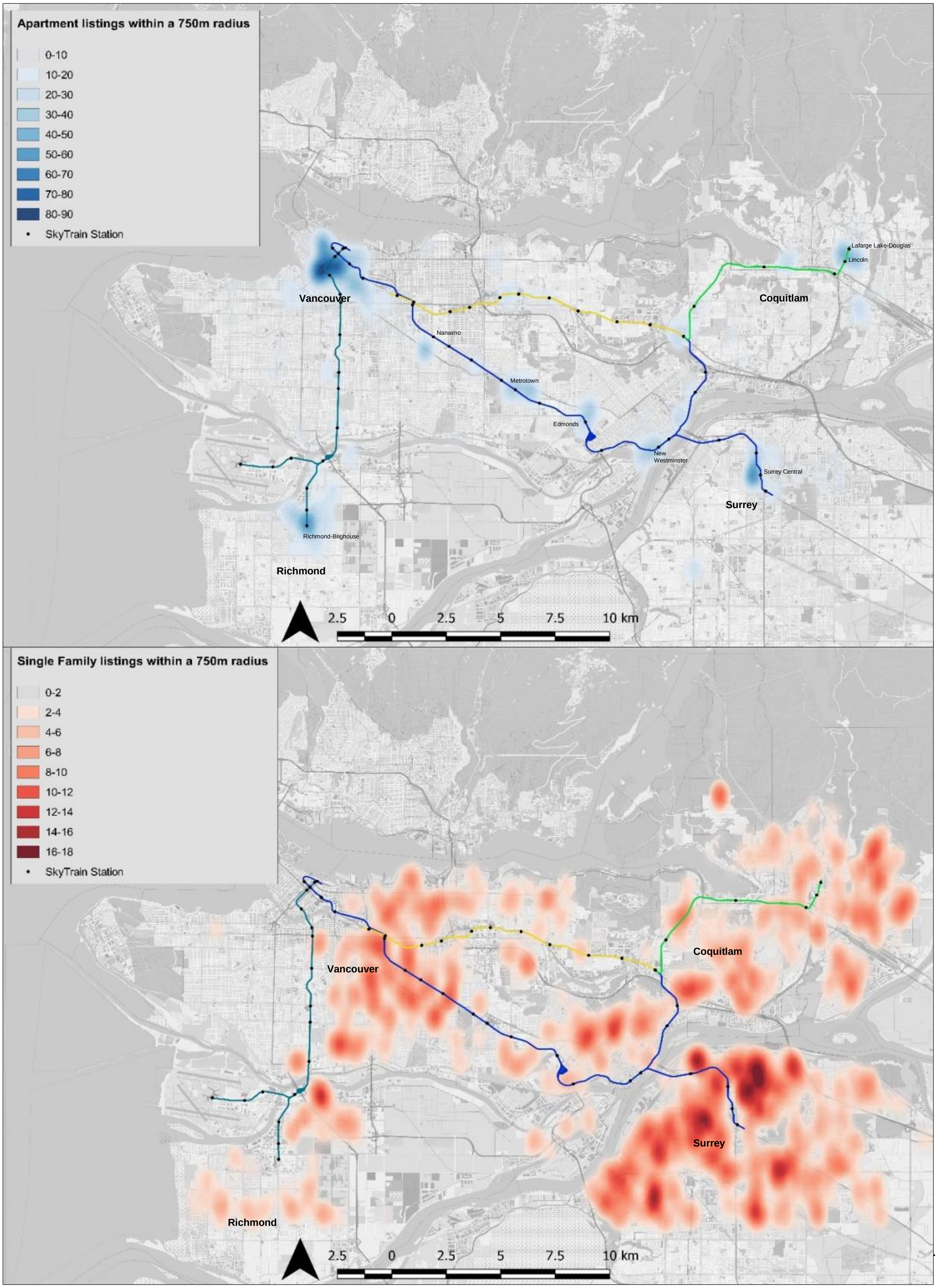


Figure 6: Density of apartment and single family property listings, Vancouver. Density calculations are based on units within 750m radius



3.2 Building, Neighbourhood, and Location Variables

After finalizing the number of property listings to be included in the database, property information such as asking price, type of building, total living space or land area, number of bedrooms and bathrooms, number or presence of parking spaces, number of floors, and type of ownership was extracted from each property listing and entered into the database.

Several studies have shown that differences in socio-economic characteristics of the neighbourhood impact property values (Yinger, 1979; King and Mieszkowski, 1973; Downing, 1970). According to Bowes and Ihlanfeldt (2001), proximity to a rail station is of higher value to low-income residential neighborhoods than to high-income residential neighborhoods. The reason is that because lower-income residents tend to rely on public transit, they attach higher value to living close to the station (Bowes & Ihlanfeldt, 2001). Among various socio-economic factors, income usually captures social divisions most effectively. Accordingly, each property listing was located in a census tract and the median income level of all households in 2016 in that census tract was recorded and entered in the database (Statistics Canada, 2017).

The next step was to construct a separate database for all urban rail rapid transit stations in Toronto and Vancouver metropolitan areas. This included 69 TTC subway stations in Toronto and 53 SkyTrain stations in Vancouver.

To examine the relationship between station characteristics and property values, details on the type of each TTC subway and SkyTrain station were identified through conducting fieldwork (by visiting the stations and their surrounding area in person) and analysis on Google Earth. Each TTC subway station was assigned one of the following types: underground, ground-level, partly underground partly ground-level (Figure 7), underground and uncovered (Figure 8) and elevated while each SkyTrain station was categorized as elevated, underground, ground-level, partly underground and partly elevated (Figure 9), or elevated but covered (Figure 10).

Figure 7: Example of a partly underground, partly ground-level station, aerial and street view, Keele subway station, Toronto. Source: Google Maps

Figure 8: Example of an underground and uncovered station, aerial and street view, Davisville subway station, Toronto. Source: Google Maps and Google Images

Figure 9: Example of a partly underground, partly elevated station, aerial and street view, Columbia SkyTrain Station, Vancouver. Source: Google Maps

Figure 10: Example of an elevated and covered station, aerial and street view, New Westminster SkyTrain Station, Vancouver. Source: Google Maps and Google Images

In addition to station types, other variables such as presence of parking were calculated for assigned to each station. It is becoming increasingly understood that various stations serve different but complementary functions within a given transit system (Atkinson-Palombo, 2010). Some stations—for example, those in downtowns with a high concentration of entertainment and employment— are considered destinations while stations with a parking lot are essential to service commuters (Atkinson-Palombo, 2010). In order to account for those differences and to also capture differences in ease of accessing the station using other transit modes and automobile, information on number of bus routes with arrivals or departures from the station, as well as presence of parking was calculated for each station.

The next step was to identify the closest urban rail rapid transit station (TTC subway or SkyTrain) to each property. Using Euclidean distance,[22] the closest urban rail rapid transit station was identified for each property in GIS. Corresponding characteristics of the station (type, presence of parking and number of bus route arrivals and departures) were then assigned to each property listing and entered in the properties database.

Figures A1 to A15 in the Appendix section show the spatial distribution of property listings in relation with station types. As shown in Figures A1 to A3, Toronto single family properties closest to a ground-level station were mostly located around the University branch of Line 1, between Saint Clair West and Sheppard West stations as well as around the eastern end of Line 2 and also south of Line 3. The clusters of Toronto apartment listings in the downtown area as well as around the first 4 stations on the Yonge branch of Line 1 (Finch to York Mills subway stations) in North York were closest to underground subway stations. In assigning all of the Toronto apartment listings to the closest TTC subway station, it was found that 76% of listings were closest to an underground subway station. 10% were closest to a ground- level station, 8% to an elevated station, 3% to a underground and uncovered subway station, and 2% were closest to a partially underground, partially ground-level station. Properties that were closest to partially

[22] How to measure access or distance is a major methodological issue when modelling the effects of transportation infrastructure on the urban environment. The type of distance measurement would relate to the type of impacts that are being researched. Network distance is more accurate in measuring the accessibility effects while Euclidean (straight-line) distance may be more accurate in measuring impacts of noise or air pollution, although those could also be affected by things like the built form (whether there is a "canyon effect") or prevailing winds. While some authors such as Guttierez and Garcia-Palomares (2008) have argued that network distance is a more accurate measurement of transit services areas, 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). In the interest of resources, Euclidean distance was used in this study.

underground, partially ground-level stations were located close to the western end of Line 2. Similar to apartment listings, the pattern of dots representing single family houses showed a concentration of listings that were closest to an underground but uncovered station between Eglinton and Bloor-Yonge subway stations (Figures A4 to A6). After assigning all of the Toronto single family property listings to the closest TTC subway station, it was found that 40% of listings were closest to an underground subway station, 37% of them were closest to a street-level station, 12% to an elevated station, 9% to a partially underground and partially ground-level station, and 2% were closest to an underground but uncovered station.

As shown in Figures A7 to A9, although a smaller number townhouse properties with the same station type appear on the map, distribution of properties sharing a similar station type for listed townhouses in Toronto was similar to those of apartments. The majority (53%) of Toronto townhouses were closest to an underground subway station, 24% were closest to a street-level station, 18% were closest to an elevated station, 2% to an underground but uncovered station and 2% were closest to a partially underground and partially ground-level station.

As demonstrated in Figures A10 to A12, apartment units located in downtown Vancouver were closest to an underground SkyTrain station. Properties located along the stretch between downtown and New Westminster, across the southern part of Millennium Line, were closest to an elevated SkyTrain station. Similarly, around the end of the Expo Line in Surrey, Canada Line in Richmond, and Evergreen line in Coquitlam were areas where apartments were closest to an elevated station. In addition, there were small clusters of apartments that were closest to an elevated but covered as well as a partially underground, partially elevated stations in downtown (around Stadium-Chinatown SkyTrain station) and on the border of New Westminster and Surrey (New Westminster and Columbia SkyTrain stations). Of all the Vancouver apartment listings included in the database, 64% were closest to an elevated SkyTrain station, 26% were closest to an underground station, 5% were closest to a partially underground and partially elevated station, 4% were closest to an elevated but covered station and only 1% were closest to a street-level SkyTrain station.

Figures A13 to A15 shows the spatial distribution of single family properties in Vancouver in relation to station types. 86% of single family property listings were closest to an elevated SkyTrain station, 6% were closest to an underground station, 5% to an elevated but covered station, 2% to a street-level and only 1% to a partially underground partially elevated station.

Several approaches have been proposed for measuring and representing distance to transportation infrastructure in spatial models. One of the methods is to include a variable for distance between the property and the transportation infrastructure (stations in the case of this study). In this method, the distance between the property and the station is measured and entered in the database as a continuous variable (Diao & Ferreira, 2010). Another method is to use buffer zones or catchment areas around the transit station. In this method, concentric geometrical shapes (usually circles) with decreasing attraction factors (or increasing attraction factors where negative externalities exist) are built around each station (Pagliara & Papa, 2011). Each property is then assigned a dummy code according to the buffer it is located in and the dummy variable is entered in the database. Because there is no consensus in the literature about which method is more accurate or efficient, in this study, both variables (distance and buffer) were calculated and included in the database. These variables were included in separate models.

To calculate the distance variable, Euclidean distance from each property listing to the closest TTC subway or SkyTrain station was measured in GIS and added to the database. To calculate the buffer zones variable, three concentric circles were created around each TTC subway and SkyTrain station: the first buffer included properties which were located within a catchment of 800 meters of the station. The second buffer contained properties that were within 800 and 1600 meters of the station and third buffer included properties that were beyond 1600 meters of the station. Each property listing was then assigned a dummy code (first, second, or third) according to the buffer it was located in.

To account for other location (and accessibility) characteristics that could impact property values, the following spatial information was also calculated for each property and included in the database: Euclidean distance to the closest TTC and SkyTrain track (to account for properties that are close to the tracks but far from a station), Euclidean distance to freight (major) railway,[23] Euclidean distance to the closest regional transit station (GO Transit in Toronto and West Coast Express in Vancouver[24]) (to capture accessibility) and exposed regional transit track (to capture nuisance), Euclidean distance to closest expressway ramp (to account for the accessibility provided by the expressway), and closest expressway section (to account for negative externalities created by automobile traffic), and Euclidean distance from the property to a central point in the Central Business District (identified as the tallest building in each metropolitan area which are currently the First Canadian Place in Toronto and Shangri-La Hotel in Vancouver).[25]

[23] Major Railway is designated for the fast, long distance, inter-provincial movement of cargo or passenger trains (City of Toronto, 2017). Euclidean distance to exposed railway track was assumed to correspond with negative externalities such as vibration, air and noise pollution. In this study, I will use the terms major railway and freight rail interchangeably.

[24] Owned by Metrolinx, GO Transit is the regional public transit network of the Greater Toronto and Hamilton Area and is a network of commuter train and bus lines. These routes provide service in the area stretching from Hamilton and Kitchener-Waterloo in the west to Newcastle and Peterborough in the east, and from Orangeville, Barrie and Beaverton in the north to Niagara Falls in the south (Metrolinx, 2018).West Coast Express is the regional rail service for the Lower Mainland in British Columbia and is owned by TransLink. It operates between Vancouver and Mission and has eight stations (TransLink, 2018).

[25] The decision to assume a monocentric city model was made for the sake of simplicity and because identifying centers other than CBD was beyond the resources available for this study.

For properties located in Toronto, Euclidean distance to the shoreline of Lake Ontario was also calculated and included in the database.[26]

Using ratings from walkscore.com, each property was assigned a Walk Score and Bike Score in order to evaluate the walkability and bicycle-friendliness of the area surrounding the property. Walk Score is a number between 0 and 100 and measures the walkability of any address. For each address, points are awarded based on the distance to amenities in each category. Amenities within a 5 minute walk (400 meters) are given maximum points. A decay function is used to give points to more distant amenities, with no points given after a 30 minute walk. Walk Score also measures pedestrian friendliness by analyzing population density and road metrics such as block length and intersection density. Data sources include Google, Education.com, Open Street Map, and places added by the Walk Score user community (Walk Score, 2017). Similarly, Bike Score measures whether a location is good for biking on a scale from 0 – 100. This measure is based on the following components: presence of bike lanes and hills, destinations and road connectivity, and bike commuting mode share (Walk Score, 2018).

The following tables provide a summary of the information that was discussed in this section. Table 2 provides a detailed description of all the variables included in the study for each property type in each city as well as the source of the data or the calculation method used. Tables 3 to 7 summarize the descriptive statistics of quantitative variables that were included in the database for each property type in each city.

[26] In the case of Vancouver, due to the special geography of the region and presence of different shorelines, this variable was not included in the model

Table 2: Summary of variables included in the database

Variable	Description	Type	Property Type and City	Source of Data
Number of bedrooms	Number of bedrooms in the property	Quantitative	All	Property listing
Number of bathrooms	Number of bathrooms in the property	Quantitative	All	Property listing
Land area (sqm)	Land area of the property	Quantitative	Single family-Toronto Townhouse-Toronto	Cacluated in GIS using City of Toronto Property Boundaries File
Living area (sqm)	Interior size of property	Quantitative	Apartment-Vancouver Single family-Vancouver	Property listing
Number of floors	Number of floors	Quantitative	Single family-Toronto Townhouse-Toronto	Property listing
Parking space	Number or availbility of parking space for each property	Quantitative (Toronto properties) and Categorical (Vancouver properties)	All	Property listing
Ownership	Ownership of property	Categorical: Freehold or Condominium	Townhouse-Toronto	Property listing
Listing price ($)	Listing price of the property	Quantitative	All	Property listing
Natural log of listing price	Natural log of listing price	Quantitative	All	Calculated in Excel using listing price
Distance to CBD (m)	Euclidean distance from property listing to First Canadian Place in Toronto (Toronto properties) and Shangri La Hotel in Vancouver (Vancouver properties)	Quantitative	All	Calculated in GIS
Closest TTC Subway Station	Name of closest TTC Subway Station	Categorical	Apartment-Toronto Single family-Toronto Townhouse-Toronto	Calculated in GIS using TTC Subway Shapefiles
Alignment of closest TTC Subway Station	Alignment of the closest TTC Subway Station	Categorical: Ground-level, Underground, Elevated, Underground but uncovered, Partly ground level-partly underground	Apartment-Toronto Single family-Toronto Townhouse-Toronto	Measured using Google Earth, Google Maps, and fieldwork analysis
Distance to closest TTC Subway Station (m)	Euclidean distance from property to closest TTC Subway Station	Quantitative	Apartment-Toronto Single family-Toronto Townhouse-Toronto	Calculated in GIS using TTC Subway Shapefiles
Distance to TTC Line (m)	Euclidean distance from property to closest TTC subway line	Quantitative		Calculated in GIS using TTC Subway Shapefiles
Closest SkyTrain Station	Name of closest SkyTrain Station	Categorical	Apartment-Vancouver Single family-Vancouver	Calculated in GIS using SkyTrain Shapefiles
Alignment of closest SkyTrain Station	Alignment of the closest SkyTrain Station	Categorical: Ground-level, Underground, Elevated, Elevated but covered, Partly elevated-partly underground	Apartment-Vancouver Single family-Vancouver	Measured using Google Earth, Google Maps, and fieldwork analysis

Variable	Description	Type	Property Type and City	Source of Data
Distance to SkyTrain Station (m)	Euclidean distance from property to closest SkyTrain Station	Quantitative	Apartment-Vancouver Single family-Vancouver	Calculated in GIS using SkyTrain Shapefiles
Distance to SkyTrain rail (m)	Euclidean distance from property to closest exposed section of SkyTrain track	Quantitative	Apartment-Vancouver Single family-Vancouver	Calculated in GIS using National Railway Network - NRWN - GeoBase Series
Buffer	Buffer in which the property is located	Categorical: First (if property located closer than 250 m from the closest TTC Subway or SkyTrain Station) Second (if property located between 250 m and 750 m from the closest TTC Subway or SkyTrain Station) Third (if property located further than 750 m from the closest TTC Subway or SkyTrain Station)	All	Calculated in Excel using distance to closest TTC Subway Station (Toronto properties) an distance to closest SkyTrain Station (Vancouver properties)
Distance to GO Stop (m)	Euclidean distance from property to closest GO Transit Stop	Quantitative	Apartment-Toronto Single family-Toronto Townhouse-Toronto	Calculated in GIS
Distance to GO rail (m)	Euclidean distance from property to closest GO Transit track	Quantitative	Apartment-Toronto Single family-Toronto Townhouse-Toronto	Calculated in GIS using National Railway Network - NRWN - GeoBase Series
Distance to West Coast Express Station (m)	Euclidean distance from property to closest WCE Station	Quantitative	Apartment-Vancouver Single family-Vancouver	Calculated in GIS
Distance to WCE rail (m)	Euclidean distance from property to closest WCE track	Quantitative	Apartment-Vancouver Single family-Vancouver	Calculated in GIS using National Railway Network - NRWN - GeoBase Series
Distance to freight rail	Euclidean distance from property to closest heavy railway track	Quantitative	All	Calculated in GIS using National Railway Network - NRWN - GeoBase Series
Distance to expressway (m)	Euclidean distance from property to closest expressway	Quantitative	All	Calculated in GIS using Statistics Canada's Road Network File
Distance to expressway ramp (m)	Euclidean distance from property to closest expressway ramp	Quantitative	All	Calculated in GIS using Statistics Canada's Road Network File
Number of bus routes	Number of bus routes with arrival or departure from the closest TTC Subway Station (Toronto properties) and SkyTrain Station (Vancouver properties)	Quantitative	All	Calculated using route information from TTC and TransLink websites
Walk Score	Walk Score for the location of the property	Quantitative	All	Walk Score website
Bike Score	Bike Score for the location of the property	Quantitative	All	Walk Score website
Median household income of CT ($)	Median household income of the census tract in which the property is located	Quantitative	All	Each property was assigned to a Census Tract in GIS using 2016 Census Tract Boundary Files. Income from Census Tract Profile-Statistics Canada 2016 Census

Table 3: Summary of quantitative variables, Toronto single family properties

Variable	Mean	St. Dev.	Minimum	Maximum
Number of bedrooms	4.66	1.57	0.00	12.00
Number of bathrooms	3.76	2.00	1.00	13.00
Number of floors	1.80	0.60	1.00	3.00
Listing price ($)	1,941,760.00	2,243,180,000.00	389,000.00	19,500,000.00
Natural log of listing price	14.13	0.75	12.87	16.79
Number of parking spaces	4.09	2.51	1.00	20.00
Land area (sqm)	1,329.21	3,186,722.00	77.00	45,276.00
Distance to CBD (m)	11,785.87	4,902.70	1,220.44	26,009.53
Distance to TTC Subway Station (m)	2,312.09	1,630.79	83.32	8,522.07
Distance to TTC Line (m)	2,228.06	1,670.53	2.47	8,502.24
Distance to GO Stop (m)	2,054.02	1,100.64	147.13	5,410.37
Distance to GO rail (m)	1,421.77	1,186.63	0.64	6,452.40
Distance to freight rail	1,408.41	1,076.84	12.57	4,778.63
Distance to expressway (m)	2,269.90	1,440.76	33.22	7,553.37
Distance to Expressway ramp (m)	2,329.07	1,457.31	38.29	7,897.46
Distance to shoreline (m)	7,346.18	4,591.90	10.99	17,229.70
Number of bus routes	8.79	10.90	0.00	45.00
Walk Score	62.15	20.73	1.00	99.00
Bike Score	66.66	18.76	24.00	100.00
Median Household Income of CT ($)	84,303.94	40,870.71	22,208.00	289,792.00

Table 4: Summary of quantitative variables, Toronto apartment properties

Variable	Mean	St. Dev.	Minimum	Maximum
Number of bedrooms	1.94	0.77	0.00	6.00
Number of bathrooms	1.56	0.65	1.00	5.00
Number of floors	1.02	0.13	1.00	3.00
Listing price ($)	563,231.00	758,119.40	60,000.00	14,900,000.00
Natural log of listing price	13.03	0.54	11.00	16.52
Number of parking spaces	1.12	0.38	0.00	4.00
Distance to CBD (m)	7,947.68	6,174.29	164.40	22,126.47
Distance to TTC Subway Station (m)	1,226.92	1,294.90	20.53	6,929.97
Distance to TTC Line (m)	1,142.31	1,317.96	0.02	6,923.37
Distance to GO Stop (m)	1,498.47	1,201.04	14.41	5,504.05
Distance to GO rail (m)	1,179.20	1,305.45	0.19	5,414.58
Distance to freight rail	1,160.77	1,159.12	1.09	4,648.96
Distance to expressway (m)	1,211.94	1,108.95	27.40	5,998.80
Distance to Expressway ramp (m)	1,196.50	115.40	12.43	6,036.40
Distance to shoreline (m)	5,555.88	5,271.79	41.81	17,718.05
Number of bus routes	10.79	14.92	0.00	65.00
Walk Score	83.85	16.31	14.00	100.00
Bike Score	71.27	18.75	26.00	100.00
Median household income of CT ($)	67,805.43	18,278.94	22,208.00	235,776.00

Table 5: Summary of quantitative variables, Toronto townhouse properties

Variable	Mean	St. Dev.	Minimum	Maximum
Number of bedrooms	3,182.00	0.99	0.00	8.00
Number of bathrooms	2.57	0.85	1.00	5.00
Number of Floors	2.00	0.82	1.00	3.00
Listing price ($)	736,884.60	569,737.90	99,000.00	6,250,000.00
Natural log of listing price	13.33	0.57	11.50	15.65
Number of parking spaces	1.37	0.57	1.00	5.00
Distance to CBD (m)	11,752.17	6,377.27	726.72	23,875.53
Distance to TTC Subway Station (m)	2,217.56	1,665.69	81.51	6,814.46
Distance to TTC Line (m)	2,144.31	1,707.44	650.00	6,767.09
Distance to GO Stop (m)	1,897.93	1,159.96	55.90	5,216.05
Distance to GO rail (m)	1,461.34	1,408.96	2.08	6,252.18
Distance to freight rail	1,289.17	1,094.45	9.94	4,087.20
Distance to expressway (m)	1,877.39	1,244.20	38.78	6,011.18
Distance to Expressway ramp (m)	1,917.47	1,318.05	30.92	6,395.51
Distance to shoreline (m)	6,795.68	4,878.75	69.38	16,358.09
Number of bus routes	8.34	12.16	0.00	65.00
Walk Score	72.97	19.25	8.00	100.00
Bike Score	68.62	18.74	30.00	100.00
Median household income of CT ($)	69,081.45	25,025.96	25,736.00	198,656.00

Table 6: Summary of quantitative variables, Vancouver single family properties

Variable	Mean	St. Dev.	Minimum	Maximum
Number of bedrooms	4.40	1.53	0.00	11.00
Number of bathrooms	2,931.00	1,319.00	1.00	8.00
Listing price ($)	1,137,128.00	299,377.00	299,000.00	16,00,000.00
Natural log of listing price	13.91	0.28	12.61	14.29
Distance to CBD (m)	18,241.00	7,606.90	2,483.71	34,277.20
Distance to SkyTrain Station (m)	2,650.41	1,884.07	123.13	12,665.11
Distance to SkyTrain rail (m)	2,502.82	1,907.28	30.77	12,487.91
Distance to WCE Station (m)	8,030.56	4,011.19	221.88	16,861.71
Distance to WCE rail (m)	6,885.22	4,435.56	39.72	16,876.32
Distance to freight rail	1,573.26	1,089.00	25.61	5,491.78
Distance to expressway (m)	2,161.52	1,538.04	33.60	8,441.80
Distance to Expressway ramp (m)	1,430.73	870.74	31.60	5,766.39
Number of bus routes	7.68	4.87	1.00	21.00
Walk Score	52.22	21.94	0.00	98.00
Bike Score	60.25	26.37	0.00	100.00
Median household income of CT ($)	79,406.98	17,092.00	33,920.00	145,481.00

Table 7: Summary of quantitative variables, Vancouver apartment properties

Variable	Mean	St. Dev.	Minimum	Maximum
Number of bedrooms	1.65	0.62	0.00	4.00
Number of bathrooms	1.57	0.54	1.00	4.00
Living space (sqm)	76.82	22.66	17.82	234.45
Listing price ($)	580,613.60	279,664.20	99,900.00	1,600,000.00
Natural log of listing price	13.16	0.47	11.51	14.29
Distance to CBD (m)	11,444.64	8,350.44	21.43	32,495.01
Distance to SkyTrain Station (m)	1,289.91	1,666.90	13.17	10,174.27
Distance to SkyTrain rail (m)	1,161.27	1,687.14	1.08	10,190.53
Distance to WCE Station (m)	6,333.42	4,396.59	161.95	15,941.78
Distance to WCE rail (m)	5,537.41	4,295.00	20.54	15,941.48
Distance to freight rail	1,182.93	910.68	1.09	5,773.14
Distance to expressway (m)	3,169.64	2,053.93	38.40	10,080.00
Distance to Expressway ramp (m)	1,110.96	845.72	18.19	3,824.32
Number of bus routes	7.25	5.73	1.00	30.00
Walk Score	81.89	16.88	10.00	100.00
Bike Score	79.99	19.03	3.00	100.00
Median household income of CT ($)	62,713.24	16,772.31	17,051.00	114,624.00

In order to measure the variance of listing prices of properties used in this study from actual sales prices, the average sales prices for each property type in each city was calculated using the final sales price data provided by Toronto and Vancouver real-estate boards. As summarized by the Toronto Real-Estate Board, the average sales price for detached and semi-detached residential properties in Toronto in 2016 was $1,045,671 (TREB, 2018). This average is considerably lower than the average price of single family properties in the sample[27] but this difference was smaller when compared with median of listing prices. The average price for apartments was $442,669, and the average price for townhouse properties was $622,968 (TREB, 2018). According to the Real Estate Board of the Greater Vancouver Area, the average sales price for detached residential properties in Vancouver in 2016 was $1,053,995. The average price for apartments

[27] Although this variance could be random and due to time period the sample properties were gathered, the exact reason behind this difference could not be detected.

was $490,965 (REBGV, 2018).

3.3 Statistical Modelling: Hedonic Price Analysis

The methodological approach for this study is hedonic price analysis. This method was developed partly based on Lancaster's (1966) argument that "[t]he good, per se, does not give utility to the consumer; it possesses characteristics, and these characteristics give rise to utility" (p. 134). It became a central tool in economic analysis with a seminal article by Rosen (1974) who argued that the functional relationship between the price of a differentiated product and its attributes can be interpreted as an equilibrium outcome from the interactions between all the buyers and sellers in a market (Rosen, 1974). Under the assumptions of his model, regressing product prices on their attributes can reveal consumers' marginal willingness-to-pay for individual attributes of a differentiated product. Accordingly, Rosen's hedonic model can be used to assess the monetary implications of changes in goods and services that are not explicitly traded in formal markets, but are conveyed through the choice of a property (Kuminoff, Parmeter, & Pope, 2010). Today, the hedonic price model is among the most widely used tools for assessing the economic impacts of policies that target the supply of environmental amenities (and dis-amenities) (Kuminoff et al., 2010).

Using a hedonic price model and assuming that houses are valued by consumers for their several attributes, property values can then be decomposed into various components to estimate what proportion of the price is due to each particular attribute. If we consider a residential property to comprise a bundle of attributes, then the implicit prices of these different attributes can be measured using hedonic price modelling. Like ordinary prices, these implicit prices reveal the marginal willingness-to-pay of consumers (Lazrak et al, 2013).

3.3.1 Log-Linear form

Most empirical studies dealing with hedonic price modelling use a log-linear form which was found to be the most suitable choice in several situations (Dubé et al., 2013). In the log-linear form, the log of the dependent variable is regressed against linear explanatory (independent) variables. In this study, the semi-logarithmic regression model proved a considerably better fit than a linear regression form in all the models developed for Toronto and Vancouver. Given the semi-logarithmic form, the coefficients are interpreted as the percent change in the dependent variable with a one unit increase (or decrease) in that independent variable.

3.3.2 Independent variables

The hedonic price model in this thesis uses three categories of independent variables together with the dependent variable of asking price (converted to its logarithm form): characteristics of the housing structure, neighbourhood characteristics, and characteristics of the housing location. Control variables related to housing structure included total number of bedrooms, number of bathrooms, living area, number of stories (number of floors), number of parking spots or whether the property has parking or not (binary variable), land area or living space and ownership type. Neighbourhood characteristic included median household income in 2016 of the census tract in which the property was located while characteristics of the location of the housing included distance to the CBD, type of the closest TTC subway or SkyTrain station, Euclidean distance to nearest TTC subway or SkyTrain station and track, number of bus departures from that station and whether the station has parking or not, Euclidean distance to the closest regional transit station, Euclidean distance to the closest commuter rail track or freight railway track, Euclidean distance to the nearest expressway ramp and to the closest expressway section, and Walk Score and Bike Score of the property listing.

Using these guidelines, I built a hedonic regression model as follows:

$$\ln(P_i) = \alpha_i + \Sigma_j \eta_{ji} S_{ji} + \Sigma_l \beta_{li} N_{li} + \Sigma_m \varphi_{mi} L_{mi} + \epsilon$$

Where

P_i is the dependent variable of the listed price for property i;

α, η, β, and φ are corresponding regression coefficients;

S is a vector of structure characteristics;

N is a vector of neighborhood attributes;

L is a vector of location attributes;

and

ϵ is a normally distributed random error.

One of the objectives of this study was to calculate the relationship between urban rail rapid transit station types and the value of apartments, single family houses, and townhouses in Toronto and Vancouver. This was achieved through using three separate models for each one of the property databases (each property type in each city) that were explained in section 3.1. The need for using different models for different property types was suggested by Duncan (2008) who compared effects of rail transit on different types of residential properties (condominiums and single-family homes). His findings suggested that proximity to a rail station had a much greater impact on condominiums than it did on single-family homes in both raw dollar amount and percentage terms (Duncan, 2008). The premium for single family homes was within the range generally found in the literature (>10%) whereas the premium for condos was on the very high end of what has been reported previously (Duncan, 2008). These findings highlighted the need for using separate models for different types of residential properties in order to minimize research error.

Additionally, to account for distance to the closest TTC subway or SkyTrain station, two sets of models (one using the distance variable and one using the buffer variable) were used for each property type in each city. As explained in section 3.2, this was to test whether the impact of proximity to a rail rapid transit station on housing prices was best explained using the distance or buffer zone method.

The final step of the process was to analyze the data using the R software. For Toronto and Vancouver combined, 70 models were tested before the best performing buffer and distance models were selected for each property type in each city.

Following Belsley et al. (1980), a variety of regression diagnostic tests were performed on the models in order to check whether any of the regression assumptions had been violated. In analyzing spatial data, it is often necessary to determine whether or not identifiable spatial patterns exist. In relation to property values, this means investigating whether and to what extent properties with similar values are clustered together in space. There are many ways to test for the existence of such patterns; among the most widely applied is Moran’s I statistic, which is used to test the null hypothesis that there is no spatial auto-correlation. If the null hypothesis is rejected, the variable is said to be spatially autocorrelated and the variable is correlated with itself through space (Ord & Getis, 1995). In this study, Moran’s I was calculated for property listing values using weight matrices to quantify spatial autocorrelation and its strength. Table 8 presents results for Moran’s I calculations which were computed in R. In general, a statistically significant and positive coefficient indicates the dominance of similarity in spatial values (or existence of high-value clustering or low-value clustering), and a statistically significant negative coefficient indicates the dominance of dissimilarity between neighboring regions (Zhang & Lin, 2007).

As shown in Figures A1 to A15, the concentration of stations with the same type increases the probability of spatial auto-correlation among the properties included in the model. Table 8 demonstrates that the observed values for Moran's I are statistically significant and range between 0.07 and 0.25, suggesting that the null hypothesis of no spatial autocorrelation can be rejected. However, the positive spatial autocorrelation is relatively weak in most property types and does not present major concerns in terms of reliability of model findings.

Table 8: Moran's I calculations, Toronto and Vancouver property listings

City-Property Type	Observed	Expected	St. Dev.	P Value
Toronto-Apartment	0.06961	-0.00035	0.0061	< 0.0001
Toronto-Single Family	0.158639	-0.00096	0.00379	< 0.0001
Toronto-Townhouse	0.132117	-0.00289	0.00434	< 0.0001
Vancouver-Apartment	0.177212	-0.00047	0.000859	< 0.0001
Vancouver-Single Family	0.25415	-0.00057	0.003375	< 0.0001

Furthermore, Variance inflation factors (VIFs) were calculated in R to test for multicollinearity between explanatory variables. Low values for VIF suggest little or no multicollinearity within the explanatory variables while a high VIF value suggested a high multicollinearity. When a high VIF value was observed, the violating variables were removed from the model. This, along with the findings of the final hedonic price models, is explained in detail in Chapter 4.

4. Results

This chapter begins by presenting the final results from the 10 final hedonic price models. The last section offers a detailed analysis of the relationship between urban rail rapid transit station types and property listing prices using the findings from the final models.

4.1 Model Results

4.1.1 Apartment Property Listings

In total, 16 hedonic price models were developed for apartments in Toronto before one final model with the distance variable and one with the buffer variable were selected. In the final model with the distance variable, after conducting the Variance Inflation Factors (VIF) test it was observed that distance to TTC subway station and distance to closest TTC rail section, distance to closest expressway and distance to closest expressway ramp, as well as distance to downtown Toronto and distance to shoreline (Lake Ontario) were multicollinear. Consequently, these variables were removed individually and the model which showed a better goodness of fit was selected. In this process, number of bus departures, distance to the closest GO rail section as well as number of floors variables did not show the expected pattern (were statistically insignificant and/or wrong-sided) and were omitted from the final model.

As shown in Table A1 in the Appendix section, the following variables proved to be statistically significant in the final distance model for apartment listings in Toronto: number of bathrooms, number of bedrooms, distance to nearest TTC subway station, type of the closest TTC subway station, distance to downtown Toronto, distance to the nearest GO Station, distance to the closest expressway section, distance to the closest major railway section, and the 2016 median household income for the census tract the property is located in. With an adjusted R^2 value of

0.727 this model was able to predict 73% of the variation in the dependant variable (which is considered a high fit).

Table A2 shows the results for the final model of apartments in Toronto using the buffer variable. The adjusted R^2 value was 0.725, only slightly lower than the distance model. Number of bedrooms, number of bathrooms, TTC subway station type, TTC subway station buffer dummy, distance to downtown Toronto, distance to the closest exposed freight rail section, Bike Score of the property as well as median household income in 2016 were statistically significant and right-sided. Distance to the closest GO Stop was statistically significant but in the opposite direction than expected. In both models (distance and buffer) Walk Score of the property was right-sided but was not statistically significant. Although insignificant, the Walk Score variable was not eliminated from the final models because of its right-sidedness as well as its ability to capture various neighborhood characteristics that would otherwise not be represented in the model.[28]

In the final distance model for Toronto apartments, distance to the closest TTC subway station was statistically significant. Its coefficient of -0.0001 indicated that with a 1 meter increase in an apartment's distance to the closest TTC subway station, the average listing price of the apartment was expected to drop by 0.01%. In the final buffer model for Toronto apartments, both categories of the buffer variable were statistically significant. This means that apartment listings that were located in the second buffer (i.e. were between 800 and 1600 meters of a TTC Subway station) were 12% cheaper than apartment listings that were located in the first buffer (i.e. 800 meter or less than away from a TTC Subway station). Apartments that were located more than 1600 meters away from a TTC Subway station were expected to have a 25% cheaper listing price than

[28] Using a fully specified model that is consistent with theory is common in hedonic price modeling even if variable estimates do not always meet a strict definition of statistical significance (Bartik, 1988).

apartments located in the first buffer.

Similar to Toronto, two sets of models (one using the distance variable and one with the buffer variable) were used for each property type in Vancouver. For Vancouver apartments, 16 models were tested and the best two models were chosen. In the model using the distance variable, the VIF test indicated that the following variables were highly multicollinear: distance to the closest West Coast Express rail section and distance to the closest West Coast Express station, distance to the closest expressway and distance to the closest expressway ramp, as well as distance to the closest SkyTrain station and distance to the closest SkyTrain rail section. In the model with the buffer variable, variables for distance to West Coast Express rail and West Coast Express station, as well as the buffer dummy and distance to SkyTrain rail were highly multicollinear. These variables were removed one at a time and the most suitable models were selected. In process of determining the best fit, the following variables were proved to be statistically insignificant and were removed from the final models: distance to the closest major railway, number of bus departures from the closest SkyTrain station, as well as Bike Score of the property.

As shown in table A3, with the adjusted R^2 value of 0.723, the final model for Vancouver apartment listings using the distance variable was able to explain 72% of variation in the dependant variable. In this model, the following variables proved statistically significant: number of bathrooms, number of bedrooms, living space, type of the closest SkyTrain Station, distance to closest SkyTrain station, distance to the closest expressway ramp, distance to downtown Vancouver, distance to the closest West Coast Express station, Walk Score of the property and the 2016 median household income.

Results of the final model for Vancouver apartments using the buffer variable are summarized in table A4. This model had an adjusted R^2 value of 0.73, meaning that the model was able to explain 73% of the variation in the dependent variable. The variables number of bathrooms, number of bedrooms, living space, SkyTrain station type, buffer dummies, distance to closest expressway, distance to downtown Vancouver, distance to closest WCE station, property's Walk Score and 2016 median household income were statistically significant and right-sided.

In the distance model for Vancouver apartment listings, the variable representing distance to the closest SkyTrain station was statistically significant. With each 1 meter increase in distance to nearest SkyTrain station, apartment properties were expected to be listed at a 0.002% lower price. In the final buffer model for Vancouver apartments, both levels of the buffer variable were statistically significant. Apartment listings located in the second buffer (i.e. between 800 and 1600 meters from the closest SkyTrain station) were 6.3% cheaper than apartments located in the first buffer (i.e. less than 800 meters from a SkyTrain Station). Apartments that were more than 1600 meters away from the closest SkyTrain Station (third buffer) were expected to be 14% cheaper than apartments listings located in the first buffer.

4.1.2 Single Family Property Listings

In total, 14 models were developed and tested for single family properties in Toronto before two final models using the distance variable and the buffer variable were selected. Variables distance to closest expressway and closest expressway ramp as well as distance to closest TTC subway station and distance to closest TTC rail were multicollinear. These variables were one by one removed from the model and the best model was selected. In the process of testing for the best model, the following observations were made: number of bedrooms did not perform as expected. It was statistically insignificant and had a negative value. Number of bus departures and Bike Score of the property were statistically insignificant and were removed from the final models.

Table A5 shows the results of the final model for single family houses in Toronto using distance to the closest TTC subway station. In the final model, the following variables proved significant and right-sided: number of bathrooms, land area, TTC Subway Station type, distance to the nearest TTC Subway station, distance to downtown Toronto, distance to closest major railway section and number of bus departures from the closest TTC Subway station. Number of floors was right-sided but not statistically significant while Walk Score and distance to closest GO Rail section were statistically significant but wrong-sided. The 0.75 R^2 value demonstrates that 75% of the variation in the dependent variable could be explained using this model.

When using the buffer variable, similar to the distance model, the final model for single family properties in Toronto was able to explain 75% of variation in the dependent variable. As summarized in table A6, this model provided the following results: variables number of bathrooms, land area, TTC Subway station type, buffer category, distance to downtown Toronto, distance to the closest expressway ramp, distance to the closest exposed major rail section, number of bus departures from the closest TTC Subway station and 2016 median household income were statistically significant and right-sided. Distance to the closest GO Stop and GO rail section as well as Walk Score of the property were statistically significant but their direction was the opposite of what was expected.

In the final distance model for single family property listings in Toronto, the variable for distance to the closest TTC subway station was statistically significant. Its coefficient indicated that with addition of each 1 meter to distance to the closest subway station, the listing price of the single family home was expected to drop by 0.004% in average. In the final buffer model for Toronto single family property listings, both buffer categories were statistically significant. Single family houses that were located between 800 to 1600 meters from a TTC subway station were 10.9%

cheaper than properties located less than 800 meters from a subway station. On the other hand, houses that were more than 1600 meters away from a TTC Subway station were in average listed at 16.9% cheaper listing prices.

When modelling single family properties in Vancouver, 12 models were developed and tested. Variables distance to West Coast Express rail and West Coast Express station as well as distance to SkyTrain station and distance to SkyTrain rail were multicollinear. These variables were one by one removed from the model and the best two models were selected.

The adjusted R^2 value for the final model for Vancouver single family properties using the distance variable indicated that the model explained 60% of the variation in the dependent variable. As demonstrated in Table A7, the following variables were statistically significant and right sided in the final model: ownership type (strata and freehold), number of bathrooms, living space, SkyTrain station type (except for the partially underground-partially elevated type), distance to the closest SkyTrain station, distance to the closest major rail section, distance to expressway section and expressway ramp, distance to downtown Vancouver, distance to the closest West Coast Express station, Walk Score of the property and the 2016 median household income for that census tract. The variable Bike Score was statically significant but did not perform in the expected direction.

As shown in Table A8, in the final model for Vancouver single family houses using the buffer variable, ownership type (strata and freehold), number of bathrooms, living space, SkyTrain station elevation (expect for the UG/Elevated dummy), buffer dummies, distance to major rail section, distance to expressway and highway ramp, distance to downtown Vancouver, distance to WCE station, Walk Score and 2016 median household income were statistically significant and right sided in the final buffer model single family property listings. The variable Bike Score was statistically significant but did not perform in the expected direction. The adjusted R^2 value indicates that the model explained 61% of the variation in the dependent variable.

In the final distance model for Vancouver single family properties, the variable for distance to the closest SkyTrain station was statistically significant. From this model, it could be concluded that with each 1 meter increase in distance to the nearest SkyTrain station, a single family property in Vancouver would be expected to be listed at a 0.002% more expensive price. In the final buffer model for single family properties in Vancouver, both buffer categories were statistically significant. Single family houses that were located in the second buffer were listed at a 6.3% cheaper price than properties located in the first buffer. On the other hand, houses that were more than 1600 meters away from the closest SkyTrain Station were expected to be 8.5% cheaper than houses located in the first buffer.

4.1.3 Townhouses

In total, 12 models were developed and tested for townhouses in Toronto. Table A9 and A10 show the final results of the model used for townhouse properties in Toronto. When using distance to TTC Subway Station, the following variables proved significant and right-sided: number of bathrooms, property ownership type (freehold or strata), type of the closest TTC subway station (except for partially underground-partially ground-level type), distance to the closest TTC subway station, distance to downtown Toronto, Walk Score and Bike Score. The 0.7 adjusted R^2 shows that the model was able to predict 70% of the variance in the data.

When the buffer variable was used, number of bathrooms, property ownership (freehold and strata), number of stories, buffer dummies, distance to downtown Toronto, Walk Score, Bike Score and 2016 median household income were statistically significant and right sided. The adjusted R^2 value of 0.67 indicates that this model was able to capture 67% of the variation in the dependent variable.

In the final distance model for townhouse listings in Toronto, the variable for distance to closest TTC subway station was statistically significant at the 0.01 level. Its coefficient indicated that with addition of each 1 meter to distance to the closest subway station, the listing price of the average townhouse property listing was expected to drop by 0.01%. In the final buffer model for Toronto townhouse property listings, the third buffer category was statistically significant at the 0.01 level while the second buffer category was not. Their coefficients showed that townhouses that were located in the second buffer were 1.4% cheaper than properties located in the first buffer (reference category) while townhouses that were more than 1600 meters away from a TTC Subway station were in average listed at 19.8% cheaper listing prices.

4.2 TTC subway and SkyTrain Station types[29]

When using categorical (or dummy) variables, one of the categories is always used as reference. The coefficients of the comparison category in a semi-logarithmic model can then be interpreted as the percentage change in the dependent variable (listing price) when the reference category is converted to the comparison category.

In this study, the ground-level type was selected as the reference group in both cities with the assumption that compared to other types, ground-level stations create the highest level of negative externalities. In other words, when a station and its surrounding tracks are located at ground-level, there are fewer mitigating factors protecting the surrounding properties from externalities created by transit operations.

[29] A summary of station type coefficients is provided in tables A11-A15 in the Appendix section.

4.2.1 Apartments

In the distance model for Toronto apartments, all levels of the subway station type variable were statistically significant. Compared to apartments which their closest TTC subway station was located at ground-level (reference category), apartments that were closest to an underground subway station were expected to have approximately 24.3% higher listing prices. Apartments closest to subway stations that were partially underground and partially at ground-level were expected to have a 19% higher listing price while apartments that were closest to an elevated subway station were expected to be listed at a 17.1% higher price. Apartments closest to an underground but uncovered subway station were expected to be 11.7% more expensive (compared to the reference group).

In final model for Toronto apartments using the buffer variable, all station type categories were statistically significant. Compared to apartment listings that were closest to a ground-level subway station, apartments that their closest subway station was located underground were expected to be 23.7% more expensive. Apartments that were closest to an elevated subway station were in average listed at an 18.4% higher listing price while apartments closest to stations that are partially underground and partially at ground-level were expected to be 18.2% more expensive than the reference group. Apartment listings closest to an underground but uncovered subway station were expected to be 14.7% more expensive (compared to the reference category).

In the final distance model for Vancouver apartments, all three categories of the SkyTrain station type were statistically significant. Using apartments that were closest to a ground-level SkyTrain station as the reference category, apartments closest to an underground SkyTrain station were expected to be 28.7% more expensive. Apartments that their closest SkyTrain station was elevated were expected to be 22.8% more expensive while apartments which were closest to a partially underground and partially elevated SkyTrain station were expected to be 19% more expensive. Finally, apartments that were closest to SkyTrain stations that were elevated and covered were expected to be 17.9% more expensive.

In the buffer model for Vancouver apartments, all SkyTrain station types were statistically significant. Using the ground-level types as the reference group, apartments closest to an underground SkyTrain station were expected to be 28.5% more expensive. Apartments that their closest SkyTrain station was elevated were expected to be 20.9% more expensive while apartments closest to a partially underground and partially elevated SkyTrain station were expected to be 17.8% more expensive than the reference group. Apartments closest to a SkyTrain station that was elevated and covered were expected to be 16.4% more expensive.

4.2.2 Single Family Property Listings

In the final model for single family properties in Toronto using the distance variable, all categories of the subway station type variable were statistically significant. Compared to single family properties that were closest to a ground-level TTC subway station (reference category), single family houses that were closest to an underground but uncovered subway station were 35.2% more expensive. Properties that their closest subway was located underground were expected to be 25.2% more expensive while properties that their closest subway station as partially underground and partially at ground-level were expected to be listed at a 19.1% higher price. Single family properties that their closest subway station was elevated were listed at 5.6% higher.

In the final model for single family properties using the buffer variable, all station types were statistically significant. Their coefficients indicated that compared to the single-family properties that were closest to ground-level TTC subway stations, properties that their closest subway station was underground but uncovered were 34.8% more expensive. Properties that their closest subway was located underground were expected to be 25% more expensive while properties that their closest subway station was partially underground, partially at ground-level were expected to be 19.4% more expensive. Single family property listings that were closest to an elevated station were in average listed at a 4% more expensive listing price compared to the reference group.

In the final distance and buffer models for Vancouver single family properties, all SkyTrain station types but the partially underground, partially elevated type were statistically significant. In the distance model, the statistically significant station type coefficients could be interpreted as follows: compared to single family property listings that were closest to a ground-level SkyTrain station (reference category), single family properties that were closest to an underground SkyTrain station were expected to be 21.7% cheaper. Houses closest to a SkyTrain station that was elevated but covered were expected to be 11.7% cheaper. Single family houses that their closest SkyTrain station was elevated were expected to be 6.8% cheaper.

In the buffer model, compared to houses that were closest to a ground-level SkyTrain station, houses closest to an underground SkyTrain station were expected to be 23.7% cheaper while single family houses closest to a SkyTrain station that was elevated but covered were expected to be 12.9% cheaper. Single-family houses that their closest SkyTrain station was elevated were expected to be 8.2% cheaper.

4.2.3 Townhouses

In the final model for Toronto townhouses using the distance variable, all categories of the TTC subway station type were statistically significant. Compared to townhouse properties that were closest to a ground-level TTC subway station, townhouses that were closest to an underground but uncovered subway station were 60.9% more expensive. Properties that their closest subway was located underground were expected to be 32.2% more expensive while properties that their closest subway station was partially underground and partially at ground-level were expected to be listed at a 25.5% higher price. Properties that their closest subway station was elevated were listed at a 22.1% higher listing price.

In the final model using the buffer variable, all subway station types were statistically significant. Their coefficients indicated that compared to townhouses that were closest to a ground-level TTC subway station, properties that their closest subway station was underground but uncovered were 60.9% more expensive. Properties that their closest subway was located underground were expected to be 33.5% more expensive while properties that their closest subway station was partially underground, partially at ground-level were expected to be 26.3% more expensive. Finally, townhouse property listings that were closest to an elevated station were in average listed at a 23.7% more expensive listing price compared to the reference category.

5. **Discussion**

This chapter begins by recapping the main findings of Chapter 4 and discussing in detail the relationship between rail rapid transit station types and property listing prices in Toronto and Vancouver based on the findings of the final models. It begins by discussing how the type of the closest urban rail rapid transit station influenced listing prices for each property type in each city. At the same time, it provides a comparison of how the final hedonic price models performed in illustrating the impact of urban rail rapid transit station type on housing values in Toronto and Vancouver.

Although the variable of interest in this study is the urban rail rapid transit station type, variables do not perform independently in a hedonic price model. In order to evaluate the performance of the methodology and accuracy of findings, it is important to approach the hedonic price model as a whole by looking also at how other explanatory variables performed. [30] Accordingly, findings from control variables that did not perform according to expectation or those that should be interpreted with care are discussed in section 5.2. Section 5.3 and 5.4 discuss the limitations of this study and outline some policy implications of the research. Finally, Section 5.5 outlines important areas for future research.

5.1 Model findings: TTC Subway and SkyTrain Station types and Property Values: Discussion

5.1.1 Toronto

[30] The practice of reporting the performance of other explanatory variables is common in hedonic price studies. For example, in addition to reporting the main findings related to the effect of proximity to LRT stations on rental rates for commercial properties in Santa Clara County, California, Weinberger (2001) provided an explanation about performance of distance to highway. Similarly, Wang et al. (2015) discussed the performance of independent variables such as distance to CBD, floor area after examining the relationship between property prices and distance to bus stops in Cardiff, Wales.

The coefficients demonstrated that on average, proximity to a TTC subway station (of any type type) was positively correlated with listing prices. This relationship was weaker in single family properties than apartment and townhouse listings in Toronto. This could reflect different travel behaviour and density preferences of apartment and single family property dwellers (Cervero & Radisch, 1996; Plaut, 2005) and is in line with findings from similar studies which reported a higher capitalization of benefits from access to rapid transit in apartments than single family houses (Duncan, 2008).

The final models using the distance and buffer variables performed quite similarly with regards to the impact of type of the subway station on apartment listing prices. Model results showed that underground subway stations had the strongest positive correlation with listing prices of Toronto apartments. This was followed by partially underground partially ground-level, elevated and underground but uncovered types.

In the case of the relationship between subway station types and value of single-family properties, the distance and buffer models demonstrated very similar results. While Toronto apartment values experienced the biggest impact from being closest to an underground subway station, being closest to an underground but uncovered subway station had the largest positive impact on the value of single family properties. Similarly, in the case of Toronto townhouse properties, the strongest impact was from being close to an underground but uncovered station. This was followed by underground, partially underground partially ground-level underground but uncovered and elevated station types. The coefficient for elevated stations was positive, however, it did not have a statistically significant relationship with listing prices in the final models for single family properties.

The impact of being closest to an underground and uncovered subway station on single family and townhouse property values should be treated with care. In total, only 23 single family house listings had an underground but uncovered station as their closest subway station. These properties were located in proximity to Eglinton, Davisville, and Rosedale subway stations and in comparatively affluent neighbourhoods. The 2016 median household income of census tracts in which these properties were located was $127,000. This is while the 2016 median household income for the rest of the census tracts included in this study was $69,000.[31] As a result, it is possible that some of the other non-quantifiable neighbourhood qualities (such as status and other socio-economic characteristics) were incorrectly picked up by variables such as station type.

5.1.2 Vancouver

The final distance and buffer models for Vancouver apartment listings showed that, considered all together, properties which were closer to a SkyTrain station (of all types) had higher listing prices. Compared to the other models, Vancouver single family models produced very different results. Proximity to a SkyTrain station had an adverse impact on listing prices in the final distance model. However, being located closer to a SkyTrain station was reported as a benefit in the final buffer model.

In the case of Vancouver apartments, between all station types, being closer to an underground SkyTrain station had the largest positive impact on listing prices. In both the final buffer and distance models for Vancouver single family properties, being closer to an underground

[31] These findings conform with the results reported by the "2016 Census: Income" report published by the City of Toronto which shows that the highest median income neighbourhoods in Toronto were found in the centre of the city, roughly bounded by Bloor Street, Leslie Avenue, Wilson Avenue and Bathurst Street, as well as in the Royal York Road and Bloor Street West area (City of Toronto, 2017).

SkyTrain station had the strongest negative impact on the listing prices while being close to a partially underground partially elevated station had the least negative impact.

In this case, one of the possible explanations for the difference between the results of the distance and buffer models could be that distance to SkyTrain stations and single family property listing prices had a non-linear relationship. In other words, although being too close to a SkyTrain station is not desirable, being too far from one is also viewed as a dis-amenity. This hypothesis is somewhat consistent with the findings of Grube-Cavers and Patterson (2014), who reported a lack of correlation between gentrification and proximity to SkyTrain lines in Vancouver.

5.1.3 Toronto and Vancouver compared

With the exception of single family properties in Vancouver, proximity to an urban rail rapid transit station correlated positively with listing prices for all housing types in both cities. This relationship was the strongest in the model for Toronto apartment and townhouse properties, followed by Toronto single family properties and Vancouver apartments. Proximity to a SkyTrain station correlated negatively with listing prices of Vancouver single family properties when using Euclidean distance to the closest SkyTrain station.

Among all station types, underground stations had the strongest positive impact (second strongest in the case of Toronto single family and townhouse properties) on property values. In Toronto, this impact was the largest for townhouse properties while in Vancouver, underground SkyTrain stations had a larger positive impact on prices of apartments than single family houses.

No coherent conclusion could be made about the station type with the weakest impact on property values. In the case of Toronto single family houses and townhouses, being closest to an elevated TTC subway station had the smallest impact on property prices compared to other types. This is while underground but uncovered stations in Toronto and elevated but covered SkyTrain stations in Vancouver had the smallest impact on the prices of apartment properties.

Overall, results from the final hedonic price models confirm the initial hypothesis of this study which argued that if there are multiple stations offering the same accessibility benefits, housing prices should decrease when exposure to negative externalities such as noise, vibration, and unsightliness increases. In the case of Toronto and Vancouver, urban rail rapid transit station types which produced smaller negative externalities (i.e. stations that were located underground), had a larger positive impact on the values of their adjacent residential properties. This positive relationship was in general consistent for all property types and across both cities. Although the impact of urban rail rapid transit station types which were associated with larger negative externalities on property values was less clear, property listings that were closer to elevated TTC subway and SkyTrain stations had lower listing prices overall.

5.2 Model Findings: Other Explanatory Variables: Discussion

Among all the variables that were initially included in the models, number of bedrooms, distance to closest regional transit station, distance to closest freight railway, number of bus departures from the closest subway or SkyTrain station, Walk Score and Bike Score variables did not perform according to expectations.

With the exception of the final models for apartment properties in Toronto and Vancouver, the number of bedrooms variable was either wrong-sided (had a negative value) or was statistically insignificant in the rest of the models. At the same time, living space or lot size and number of bathrooms variables were statistically significant and performed according to expectation which could mean that some correlation between number of bedrooms and living space or land area exists. This correlation was also reported by Brown and Li (1980) and Boarnet and Chalermpong (2001) who argued that property prices were more influenced by dwelling size than by the number of bedrooms and that their observation about the negative coefficient on number of bedrooms was indicative of the presence of higher-priced, luxury home markets, with larger homes that have relatively fewer bedrooms (Boarnet & Chalermpong, 2001; Brown & Li, 1980).

In both Toronto and Vancouver, variables representing distance to the closest regional transit stop were insignificant in some cases and contradictory in others. Although access to regional transit could be beneficial to some commuters, due to spatial or "modal mismatch" (Foth, Manaugh & El-Geneidy, 2013, pg. 4),[32] it might not be regarded as a significant advantage for a lot of households residing in these two cities. Regional transit in Toronto and Vancouver has a limited schedule and operates mainly during rush hour periods on weekdays with large headways. In Toronto, GO Stops are spatially distributed along various major arterial roads and as a result, being in the proximity of the stops could simply be viewed undesirable due to the negative externalities that are created by automobile traffic. In Vancouver, West Coast Express connects the downtown area and Mission City Centre (which is 60 km to the west of Vancouver City Centre) and provides coverage that is limited mainly to the northern part of Metro Vancouver.

[32] The term modal mismatch has also recently entered the literature (Blumenberg and Manville, 2004; Grengs, 2010) and refers to the difficulty of reaching desired destinations without a car. While arguably already implicit in spatial mismatch theory, transportation and modal mismatch explicitly capture the fact that two areas in a city may not be separated by a great distance but may not be connected by reliable or viable public transit. Therefore, those reliant on public transit may not be able to access certain areas easily while car drivers can (Foth, Manaugh & El-Geneidy, 2013).

Although the variable representing distance to freight railway was statistically insignificant in the final models for Toronto townhouses and Vancouver apartments, proximity to freight rail was inversely correlated with asking prices of Toronto single family houses, and Vancouver single family houses. The exact reason for the difference in sensitivity of various property types to negative externalities created by freight rail could be identified using the current model.

The variable representing number of bus routes from the closest rail rapid transit station was not statistically significant in most of the models except for Toronto apartments (buffer model) and Toronto single family houses. In the case of Toronto apartments, its negative value was an indication that properties which were located closer to a TTC subway station with a higher number of bus routes had, in average, lower listing prices. Because this variable only represents the number of bus routes that a certain rail rapid station serves and not the frequency of service, this finding should be treated with care. Although in most cases stations which serve more routes would provide more accessibility than stations with fewer routes, a more accurate measure would captures number of routes and frequency together. Additionally, frequency of bus service from the closest bus stop to the property (and not at the closest rail rapid transit station) might have been a better measure of bus access.

In the case of single family houses in Toronto, the coefficient of Walk Score proved to be negative. The Bike Score variable had a positive relationship with property values in models for Toronto apartments and townhouses, while this relationship was negative in the case of Vancouver single family houses. In their study on the impact of bicycle sharing facilities on property values, El-Geneidy et al. (2015) found that the variable Walk Score was highly correlated with distance to city center. This is consistent with findings from the current study where some degree of multicollinearity was observed between Walk Score and distance to downtown. The VIF test for all of the models except for the single family properties model confirmed this multicollinearity. Additionally, although there are multiple benefits associated with walkability, current transportation planning practices tend to undervalue walking (Litman, 2017). Walkability is not as easily quantified and so tends to be undervalued in planning decisions. This is very prevalent in low-density areas that favor automobile use (Litman, 2017). As a result, walkability and biking friendliness might not be regarded highly in suburban areas (where single family properties are usually concentrated) and this could partially explain the negative relationship between the Walk Score and Bike Score variables with single family property values in this study.

5.3 Modelling Limitations

5.3.1 Hedonic Price Model

In spite of their usefulness, hedonic studies are not exempt from technical problems. Armstrong and Rodríguez (2006) pointed out three major concerns associated with hedonic price models: the problem of omitting variables, the problem of choosing the functional form and the problem of spatial autocorrelation in sample observations. The omission of theoretically relevant variables may bias the estimated parameters (Gujarati and Porter, 2009) and the omitted variables which were pointed out throughout this chapter are examples of this.

The problem of specifying the functional form is common to all hedonic studies. There is currently no theoretical basis which recommends using one particular functional specification rather than another, even if Cropper et al. (1988) showed that the linear form produced lower errors in cases where the model presented omitted variables. Malpezzi (2003) recommended the use of the log-linear form because it allows estimated parameters to be interpreted as semielasticities and has the capacity to reduce the problems derived from heteroscedasticity. To address this issue and as explained in Chapter 4, the linear and log-linear forms were tried for all models and in all cases, the long-linear form performed better.

Finally, the problem of spatial autocorrelation in the sample may lead to the estimation of parameters which are inefficient or even biased, requiring the use of spatial econometric models (LeSage et al., 2009). In order to check for presence of spatial autocorrelation in the listing data used in this study, Moran's I was calculated for all property listing values.

5.3.2 Mono-centric City Model

As argued earlier in this chapter, the assumption of a mono-centric city is questioned in the literature as with multiple-worker households working in multiple workplaces, sites offering accessibility to many employment nodes are more valuable (Heikkila et al., 1989). This is because, with the suburbanization of various services and higher levels of accessibility in other areas of the region, homebuyers value access and proximity to other centers in addition to the downtown core.[33]

In this study, distance to downtown (or CBD) was used with the assumption of a monocentric city. This decision was made for the sake of simplicity and because identifying centers other than CBD and developing a gravity based model were beyond the resources available for this study.

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[33] In urban areas, there are two major access(ibility) benefits for living in or in vicinity of downtown or the CBD:
1) Easier access to opportunities (employment, social, recreational, etc.) that are located in the downtown area: This holds true in locations where these opportunities are mainly concentrated in the central areas of the city. However, with suburbanization of employment (and to some extent commercial and recreational services) in recent years, it could be argued that downtown is not the only center of these services anymore (Shearmur & Coffey, 2001).
2) Higher accessibility to regional opportunities due to better transit (more frequent service and higher coverage) in downtown. However, the downtown core has lost this advantage slightly changed in recent years with accessibility improvements and development of various public transportation projects in suburban areas. A study of the Greater Toronto Area observed that between 1996 and 2006, higher levels of accessibility spread outward in the GTA while the downtown core still had the greatest access to employment opportunities (El-Geneidy et al., 2013).

As a result and due to the absence of other variables that represent access to other regional centres in a polycentric city, the effect of distance to downtown might have been multiplied and thus, should be treated with care.

5.3.4 Data limitations

There were four main limitations in terms of accessing data in this study: first, the issue with access to final sales or assessed value of the properties; Second, the issue with lack of access to longitudinal data; Third, including data for properties other than owner-occupied residential buildings; and fourth, the issue of spatial auto-correlation between the sample listings.

Due to the possible difference between the actual value of a property and the price it was listed for, ideally one would use assessed values or final sales prices for this study. Previous research has shown that asking prices have a high correlation to selling prices and generally represent 90% of the equilibrium price (Du & Mulley, 2007). With the exception of Toronto single family houses, it was observed that the average listing prices for properties included in this study and average sales prices reported by Toronto and Vancouver real-estate boards for the same time period were similar. As a result, although not ideal, use of property listing prices was not extremely concerning in the case of this study. Furthermore, the listed properties used in this study represented only a fraction of the entire housing stock available in Toronto and Vancouver during the data collection period. This could result reporting biased results for the population of residential properties (Diao, 2015).

Lack of publicly available historical data on property values limited the possibility of comparing price changes among properties located in different areas of Toronto and Vancouver over-time. It also prevented studying the change in real-estate prices over time to investigate the impact of new transit infrastructure (both during construction and after the transit infrastructure becomes operational). As argued by Bae et al (2003), the main capitalization of rail transit projects in property values happens only prior to the line's opening and it is only through using longitudinal data that one could investigate the temporal impact of station attributes on property values.

Since the early stages of this project, my interest has always been to focus on the housing market and accordingly, non-residential property types (commercial, industrial, and office buildings) were excluded from this research. Although including both rental and owner-occupied housing data in the analysis would give a more complete picture of the effect of urban rail rapid transit on the housing market, developing such a methodology proved complex and was not included in this study.

Lastly, as discussed in chapter 3, some degree of spatial auto-correlation exists among properties that were included in this study. In the presence of spatial auto-correlation, the conventional OLS results may produce biased, inconsistent or inefficient results depending on the type of spatial autocorrelation (Diao, 2015; Anselin, 1988). In addition to the typical spatial auto-correlation that could exist between properties that are located in proximity to one another, the uneven distribution of urban rail rapid transit stations sharing the same type across the city also proved to be problematic in the case of this study. Although including neighbourhood and location variables such as distance to downtown, and WalkScore in the model was done with the goal of reducing the risk of spatial auto-correlation, the issue of spatial auto-correlation still exists and might result in bias in valuing transit accessibility and distort the reported impact of station types.

5.4 Policy Implications

The findings of this research showed that, on average, proximity to rail rapid transit stations (of any type) in Toronto and Vancouver Metropolitan Areas was capitalized in higher residential property values and that the type of the closest urban rail rapid station was among the factors determining the amount of this capitalization. In other words, not all stations had the same effect on listing prices of properties that were included in the sample. This relationship however, varied based on the city, characteristic of the neighbourhood, those of the transit infrastructure and the property itself. Policy makers seeking to address land use and transportation planning issues should therefore ensure that policies acknowledge, properly measure and account for positive and negative externalities created by urban rail transit stations. One area where the positive benefits of access to urban rail rapid transit could be captured is financing the transit infrastructure. Perhaps more importantly, policy makers should engage in developing and reviewing mechanisms that mitigate the disadvantages created by the transit infrastructure.

The results of this study provide an insight into the necessity for the comprehensive evaluation of urban rail rapid transit cost-effectiveness. As argued by Dubé et al. (2013), part of the process of financing public transit may include studying the connection between accessibility to the transit infrastructure and real estate markets since the former may generate externalities that are in turn reflected in building values and property taxes that could benefit municipalities. As demonstrated in this chapter, there is a clear profit advantage to owners of properties with higher access to underground urban rail rapid transit stations, and so consideration of these benefits should be included in the economic assessment for any future transit infrastructure project. Additionally, although building underground transit infrastructure is costlier than other types (Flyvbjerg et al., 2008), if transportation improvements are financed using public funds, the revenues generated through property taxes near underground stations in the long term could justify the higher cost (El-Geneidy et al., 2015). Additionally, transit value capture models such as Hong Kong's 'Rail + Property' development model show that when the effective policies and procedures are in place, a potential increase in property values due to the accessibility provided by the transit infrastructure could be captured using development charges and this could in turn be used to finance the transit project (Cervero & Murakami, 2009).

In terms of mitigating the negative externalities created by attributes or type of the transit infrastructure, policy makers should ensure that they address equity concerns as these decisions have immediate and long-term consequences for transit dependent populations and can determine where and when these groups can access various services and resources (Wellman, 2015). Addressing equity could be in the form of policies that ensure the reasonable and even distribution of future urban rail rapid transit stations which produce more negative externalities (such as elevated stations or those located at ground level). This could go one step further and appear in the form of balancing the difference in housing prices between areas of a city with disparate home values, in order to strategically benefit a low-income neighbourhood (Dai, Bai & Xu, 2016). Such a strategy may encounter opposition over fears that character of the neighbourhood and that of the community in the vicinity of the transit infrastructure will be disrupted. Research on infill projects and on NIMBYism (Not in My Backyard) in general suggests that pre-existing land use and zoning and community capital will influence what type of Transit Oriented Development evolves at each station area because transport agencies tend to avoid controversy and conflict (Atkinson-Palombo, 2010; Altshuler and Luberoff, 2003; Farris, 2001; Lake, 1993; Dear, 1992). This was evident in the case of the Broadway Avenue corridor in Vancouver where it was suggested (by some resident groups) to substitute a proposed ground-level urban rail rapid transit service along the Broadway corridor with a $2.8-billion rapid-transit line that would run underground, arguing that despite the higher cost, a subway is more efficient and less disruptive than a service that runs above ground (Hansen & Sinoski, 2012). This suggests the need for greater consideration of how transit planning, land use policy and land prices impact one another.

Additional policies might be those that encourage provision of special amenities and benefits for areas surrounding urban rail transit stations with larger negative externalities in order to compensate for the disadvantages created by the transit infrastructure. These interventions could also be in the form of modifications and additions to the physical design of the city that would mitigate the negative environmental impacts of the transit infrastructure such as noise and vibration barriers (including sound-proof walls), beautification projects, and so on.

5.5 Areas for Future Research

Despite the extensive literature on the relationship between transportation infrastructure and property values, to my knowledge this research is among the few studies that examine the effect of the characteristics of the transit infrastructure and stations on housing values in North America. As a result, there remain a number of limitations to this research which could also be turned into opportunities for future research. The first limitation of this research is the use of listing prices instead of final sales prices which was dictated by a lack of access to official databases containing property sale prices. If and when the final sales price data become available to the general public, it would be valuable to use the same methodology with the newly available final sales price data.

Due to time and resource limitations and the difficulty of obtaining data on residential property values over time, a cross-sectional research design was selected for this study. Using temporal data would allow the relationship between urban rail rapid transit station type and housing values to be studied over time, specifically through comparing housing prices before and after construction and operation of an urban rail rapid transit system or during a specific time period. Such methodology would also need to capture changes in other variables impacting the value of a property such as changes in the physical structure of the house during that time period (for example renovations) or changes in the neighbourhood (such as median household income, neighbourhood amenities, and so on). Although access to real-estate data over time might be challenging, the longitudinal methodology may be more manageable if the research is limited to certain stations within the transit network or to one city.

To correct for the issue of spatial auto-correlation among sample properties, additional location-specific dummy variables could be added to the model which will allow capturing the importance of an observation's location in a particular neighborhood (Rogerson, 2001). In this study variables such as distance to downtown, WalkScore, and median household income were added to account for characteristics of the neighbourhood the property is located in. Besides including additional neighbourhood variables, two types of spatial auto- regressive terms could also be added to the model. To solve the spatial auto-correlation issue when the value of a property is influenced by the characteristics of its neighbouring properties, a spatially lagged dependent variable could be added to the regression (Diao, 2015). Spatial auto-correlation might also exist when variables that are omitted from the model are spatially correlated. This could be corrected for by adding a spatially lagged error term to the model (Diao, 2015).

The assumption that access to any TTC subway or SkyTrain station on the network is equally valuable is another limitation of this study. Research has been argued that stations serve different functions within a given transit system (Dittmar & Poticha, 2003). Variations in station function were captured by Dittmar and Poticha (2003) in a typology that defined six common classes of Transit Oriented Development and distinguished their roles within regional systems. Categorizing the urban rail rapid transit stations included in this study in similar classes would account for different functions and characteristics of each station. Furthermore, although this analysis based the choice of explanatory variables in the hedonic price model on previous studies, including additional spatial, accessibility and structural attributes in the model would help develop a more accurate understanding of the residential property listing prices in Toronto and Vancouver.

As argued earlier in this chapter, distance to downtown (or CBD) was used in this study with the assumption of a monocentric city for the sake of simplicity. Although the variables representing distance to various transit modes were aimed at capturing transit accessibility, future studies could include other important destinations such as entertainment district and employment centers (for example the Pearson International Airport Growth Region). Developing such an advanced gravity model was beyond the scope of this study.

Other than including variables that account for distance to the downtown area, walkability, and bike-friendliness, this study does not make a clear distinction between urban and suburban neighbourhoods. This is while one could speculate that the benefits and disadvantages of transit infrastructure are different in urban and suburban areas. One way of addressing this would be to compare the externalities of a transit infrastructure located in a suburban neighbourhood such as the recently operational TTC subway extension (TYSSE) in the neighbourhood of Vaughan, with TTC subway stations that are located in urban areas.

Last but not least, this research does not explore how the relationship between housing values and transit infrastructure is affected by socioeconomic characteristics other than the median household income. Although household income is usually an effective measure for capturing social divisions, including variables representing race, ethnicity, immigration status, education, gender, and sexual orientation would be very important and beneficial additions to any future research. These characteristics could capture how different groups of residents value housing and transit differently and including them in the study would allow for a more complete, through and realistic analysis of the impacts of transit infrastructure on housing values.

6. Conclusion

The findings of this research demonstrated that, on average, proximity to urban rail rapid transit stations in Toronto and Vancouver Metropolitan Areas led to higher residential property values and that the type of the closest urban rail rapid station was among the factors determining the amount of this capitalization. The specific research questions that were addressed in this thesis were: first, to what extent and how strongly does proximity to urban rail rapid transit stations affect housing prices in Toronto and Vancouver? Second, to what extent is that positive (or negative) impact related to whether stations and track are underground, elevated, or at ground-level? And finally, how transferrable are the methods? Does the same method work in two different cities? Are similar results found in two different cities? What are the prospects for using the same method in a more different context?

Answering these questions contributes to a more complete and detailed understanding of the relationship between transit infrastructure and housing values. This research was prompted by the ongoing debates around whether urban rail rapid transit stations and their surround tracks should be at ground level, elevated or underground. To date, the literature on the relationship between transportation infrastructure and residential property values has mostly remained silent on the impact of the environmental externalities of the transit infrastructure, especially how station types affect housing values. The importance of studying this relationship is twofold: first, due to the long-term nature of home selection, housing values have always been among the most efficient indexes of the effects of various planning interventions on the well-being of communities; and second, the substantial cost difference between the underground and ground-level transit infrastructure proposes the question whether this amount justifies the cost difference between the types. Toronto and Vancouver were ideal candidates for this study because in each of these metropolitan areas there has been discussion and debate concerning which types of urban railways and stations to build. Additionally, real estate markets in Toronto and Vancouver share various similarities and both cities feature an extensive urban rail rapid transit system which include a variety of different station types.

In order to answer these questions, it was necessary to design a methodology to isolate the effect of proximity to urban rail rapid transit as well the alignment of tracks and station types on housing values. This was made through using hedonic price models. The data required for conducting the hedonic price analysis was gathered in several stages: first, information on 8160 property listings was compiled from realtor.ca. This included data on asking price, type of property, number of bedrooms and bathrooms, living area, and presence of parking. The next step was to geocode each property using the postal code provided in the listing. Then, a database of all of the urban rail rapid stations in Toronto and Vancouver Metropolitan Areas and their characteristics (station type, number of bus routes, and presence of parking at the station) was constructed. Each property was then assigned to the closest urban rail rapid station. In order to capture the impact of location and accessibility, variables such as WalkScore, BikeScore, distance to various transportation infrastructure such as commuter transit and highways, as well as distance to downtown were calculated for each property. Furthermore, the 2016 median household income for the census track corresponding with each property was also added to the database. Finally, using this database, hedonic price models were designed and statistical tests were conducted to examine the relationship between residential listing prices and station types in these two cities.

To answer the first and second questions posed by this research, results of the final hedonic price models demonstrated that proximity to any kind of urban rail rapid transit station resulted in higher listing prices for all property types in both cities except for Vancouver single family. Property listings that were closer to elevated TTC subway and SkyTrain stations had, on average, lower listing prices while properties located in proximity to underground stations had higher listing prices.

The last research question aimed at exploring the transferability of the same methodology between different cities. Similarities between Toronto and Vancouver's urban rail transit systems (mainly in terms of network coverage and the variety of station types) and real-estate markets made it possible to apply a similar methodology (with minor modifications) to both cities. Additionally, the R^2 value of all final models in both cities was relatively high, demonstrating the transferability of the research design between Toronto and Vancouver.

Among the limitations of this research project are the technical problems associated with hedonic price models. These include the problem of omitted variables such as age of the property, access to different regional centers, and broader socio-economic characteristics of the neighbourhood. Another issue associated with hedonic price analysis is the functional form. Additional caveats of this study include lack of access to longitudinal and final sales price data.

These caveats could also be viewed as opportunities for future research. Considering the recent court ruling which made the final sales price available to the general public (The Star, 2017), it would be valuable to use the same methodology with the newly available final sales price data. Furthermore, if limited to one city, using temporal data would allow the relationship between urban rail rapid transit station type and housing values to be studied over time. Lastly, future studies could include other important destinations and regional centers such as entertainment district and employment centers as well as indicators representing a broader range of socio-economic characteristics.

The findings of this research demonstrated that, on average, proximity to rail rapid transit stations (of any type) in Toronto and Vancouver was capitalized in higher residential property values and that the type of the closest urban rail rapid station played a role in determining the amount of this capitalization. This relationship however, varied based on the city, characteristic of the neighbourhood, those of the transit infrastructure and the property itself. These findings demonstrate the need for policies and procedures that acknowledge, measure and account for positive and negative externalities created by urban rail transit stations. This could be in the form of policies which aim at financing the transit infrastructure, those that ensure the even distribution of stations with different station types as well as methods to mitigate the impact of stations with higher negative externalities.

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Appendix I

Table A1: Model results for Toronto apartment listings using the distance variable

Independent Variable	Coefficient	Significance	Std. Error
Number of bathrooms	0.45	***	0.01
TTC Subway Station type elevated	0.171	***	0.03
TTC Subway Station type underground	0.243	***	0.02
TTC Subway Station type underground but uncovered	0.117	***	0.04
TTC Subway Station type partially underground partially ground-level	0.19	***	0.04
Distance to closet TTC subway station	-0.0001	***	0.00
Number of bedrooms	0.102	***	0.01
Distance to CBD (First Canadian Place)	-0.00003	***	0.00
Distance to closest GO Stop	0.00003	***	0.00
Distance to expressway	0.00002	***	0.00
Distance to heavy rail	0.00004	***	0.00
Walk Score	0.001		0.00
Bike Score	0.001		0.00
Median HH income of CT	0.00000	***	0.00
Constant	11.796	***	0.07
Observations	2887		
R squared	0.728		
Adjusted R squared	0.727		
Residual Std. Error	0.281 (df = 2872)		
F Statistic	549.449	***	(df = 14;2872)
Note: *p<0.1; **p<0.05; ***p<0.01			

Table A2: Model results for Toronto apartment listings using the buffer variable

Independent Variable	Coefficient	Significance	Std. Error
Number of bathrooms	0.45	***	0.01
TTC Subway Station type elevated	0.184	***	0.03
TTC Subway Station type underground	0.237	***	0.02
TTC Subway Station type underground but uncovered	0.147	***	0.04
TTC Subway Station type underground/ground-level	0.182	***	0.04
Buffer Second	-0.128	***	0.17
Buffer Third	-0.239	***	0.02
Number of bedrooms	0.102	***	0.01
Distance to CBD (First Canadian Place)	-0.00003	***	0.00
Distance to closest GO Stop	0.00002	***	0.00
Number of bus routes	-0.001	***	0.00
Distance to heavy rail	0.0001	***	0.00
Bike Score	0.001	*	0.00
Median HH income of CT	0.00000	***	0.00
Constant	11.862	***	0.04
Observations	2887		
R squared	0.725		
Adjusted R squared	0.723		
Residual Std. Error	0.283 (df = 2872)		
F Statistic	539.661	***	(df = 14;2872)
Note: *p<0.1; **p<0.05; ***p<0.01			

Table A3: Model results for Vancouver apartment listings using the distance variable

Independent Variable	Coefficient	Significance	Std. Error
Number of bathrooms	0.266	***	0.02
Living area	0.007	***	0.00
SkyTrain Station type elevated	0.228	***	0.07
SkyTrain Station type elevated but covered	0.179	**	0.08
SkyTrain Station type underground	0.287	***	0.08
SkyTrain Station type underground-elevated	0.191	**	0.08
Distance to closets SkyTrain Station	-0.00002	***	0.00
Number of bedrooms	0.04	***	0.02
Distance to CBD (Shangri La Hotel)	-0.00003	***	0.00
Distance to closest WCE Station	0.00000	**	0.00
Distance to expressway ramp	-0.00001	*	0.00
Walk Score	0.002	***	0.00
Median HH income of CT	0.00000	***	0.00
Constant	12.031	***	0.09
Observations	2113		
R squared	0.725		
Adjusted R squared	0.723		
Residual Std. Error	0.248 (df = 2099)		
F Statistic	425.175	***	(df = 13;2099)
Note: *p<0.1; **p<0.05; ***p<0.01			

Table A4: Model results for Vancouver apartment listings using the buffer variable

Independent Variable	Coefficient	Significance	Std. Error
Number of bathrooms	0.261	***	0.02
Living area	0.007	***	0.00
SkyTrain Station type elevated	0.209	***	0.07
SkyTrain Station type elevated but covered	0.164	**	0.08
SkyTrain Station type underground	0.285	***	0.08
SkyTrain Station type underground-elevated	0.178	**	0.08
Buffer Second	-0.063		0.02
Buffer Third	-0.142	***	0.02
Number of bedrooms	0.044	***	0.01
Distance to CBD (Shangri La Hotel)	-0.00003	***	0.00
Distance to closest WCE Station	0.00000	***	0.00
Distance to expressway	0.00001	**	0.00
Walk Score	0.001	**	0.00
Median HH income of CT	0.00000	***	0.00
Constant	12.105	***	0.09
Observations	2113		
R squared	0.733		
Adjusted R squared	0.731		
Residual Std. Error	0.245 (df = 2098)		
F Statistic	411.036	***	(df = 14; 2098)
Note: *p<0.1; **p<0.05; ***p<0.01			

Table A5: Model results for Toronto single family listings using the distance variable

Independent Variable	Coefficient	Significance	Std. Error
Number of bathrooms	0.194	***	0.01
TTC Subway Station type elevated	0.056		0.05
TTC Subway Station type underground	0.252	***	0.03
TTC Subway Station type underground but uncovered	0.352	***	0.09
TTC Subway Station type underground/ground-level	0.191	***	0.05
Distance to closet TTC subway station	-0.00004	***	0.00
Land area	0.00001	***	0.00
Distance to CBD (First Canadian Place)	-0.00003	***	0.00
Distance to closest GO track	-0.00003	***	
Distance to expressway ramp	-0.00002	**	0.00
Distance to heavy rail	0.0001	***	0.00
Number of bus routes	0.004	***	0.00
Walk Score	-0.005	***	0.00
Median HH income of CT	0.00000	***	0.00
Constant	13.677	***	0.10
Observations	1040		
R squared	0.753		
Adjusted R squared	0.749		
Residual Std. Error	0.376 (df = 1025)		
F Statistic	22.873	***	(df = 14; 1025)
Note: *p<0.1; **p<0.05; ***p<0.01			

Table A6: Model results for Toronto single family listings using the buffer variable

Independent Variable	Coefficient	Significance	Std. Error
Number of bathrooms	0.193	***	0.01
TTC Subway Station type elevated	0.044		0.05
TTC Subway Station type underground	0.25	***	0.03
TTC Subway Station type underground but uncovered	0.348	***	0.09
TTC Subway Station type underground/ground-level	0.194	***	0.05
Buffer Second	-0.109	***	0.04
Buffer Third	-0.169	***	0.04
Land area	0.00001	***	0.00
Distance to CBD (First Canadian Place)	-0.00003	***	0.00
Distance to closest GO track	-0.00003	***	0.00
Distance to expressway ramp	-0.00001	**	0.00
Distance to heavy rail	0.0001	***	0.00
Number of bus routes	0.004	***	0.00
Walk Score	-0.005	***	0.00
Median HH income of CT	0.00000	***	0.00
Constant	13.753	***	0.11
Observations	1040		
R squared	0.754		
Adjusted R squared	0.75		
Residual Std. Error	0.375 (df = 1024)		
F Statistic	209.235	***	(df = 15; 1024)
Note: *p<0.1; **p<0.05; ***p<0.01			

Table A7: Model results for Vancouver single family listings using the distance variable

Independent Variable	Coefficient	Significance	Std. Error
Ownership-Strata	-0.109	***	0.02
Number of bathrooms	0.021	***	0.01
Living area	0.002	***	0.00
SkyTrain Station type elevated	-0.068	**	0.03
SkyTrain Station type elevated but covered	-0.117	***	0.04
SkyTrain Station type underground	-0.217	***	0.04
SkyTrain Station type underground-elevated	-0.047		0.06
Distance to closest SkyTrain Station	0.00002	***	0.00
Distance to CBD (Shangri La Hotel)	-0.00003	***	0.00
Distance to closest WCE Station	-0.00001	****	0.00
Distance to expressway ramp	-0.00003	***	0.00
Distance to expressway	0.00003	***	0.00
Distance to heavy rail	0.00002	***	0.00
Walk Score	0.001	***	0.00
Bike Score	-0.001	***	0.00
Median HH income of CT	0.00000	*	0.00
Constant	14.091	***	0.06
Observations	1653		
R squared	0.611		
Adjusted R squared	0.608		
Residual Std. Error	0.177 (df = 1636)		
F Statistic	160.889	***	(df = 16;1636)
Note: *p<0.1; **p<0.05; ***p<0.01			

Table A8: Model results for Vancouver single family listings using the buffer variable

Independent Variable	Coefficient	Significance	Std. Error
Ownership-Strata	-0.117	***	0.02
Number of bathrooms	0.022	***	0.01
Living area	0.001	***	0.00
SkyTrain Station type elevated	-0.082	**	0.03
SkyTrain Station type elevated but covered	-0.129	***	0.04
SkyTrain Station type underground	-0.237	***	0.04
SkyTrain Station type underground-elevated	-0.062		0.06
Buffer Second	-0.063	***	0.02
Buffer Third	-0.085	***	0.02
Distance to SkyTrain track	0.00003	***	0.00
Distance to CBD (Shangri La Hotel)	-0.00003	***	0.00
Distance to closest WCE Station	-0.00001	***	0.00
Distance to expressway ramp	-0.00003	***	0.00
Distance to expressway	0.00003	***	0.00
Distance to heavy rail	0.00003	***	0.00
Walk Score	0.001	***	0.00
Bike Score	-0.001	***	0.00
Median HH income of CT	0.00000	*	0.00
Constant	14.161	***	0.05
Observations	1653		
R squared	0.618		
Adjusted R squared	0.614		
Residual Std. Error	0.176 (df = 1634)		
F Statistic	146.724	***	(df = 18; 1634)
Note: *p<0.1; **p<0.05; ***p<0.01			

Table A9: Summary of final model for Toronto townhouse listings using the distance variable

Independent Variable	Coefficient	Significance	Std. Error
Number of bathrooms	0.241	***	0.02
Property Ownership-Freehold	0.259	***	0.04
TTC Subway Station type elevated	0.221	***	0.06
TTC Subway Station type underground	0.322	***	0.04
TTC Subway Station type underground but uncovered	0.609	***	0.12
TTC Subway Station type underground/ground-level	0.255	**	0.12
Distance to closet TTC subway station	-0.0001	***	0.00
Distance to CBD (First Canadian Place)	-0.00003	***	0.00
Walk Score	0.002	**	0.00
Bike Score	0.003	****	0.00
Median HH income of CT	0.00000	***	0.00
Constant	12.292	***	0.11
Observations	347		
R squared	0.721		
Adjusted R squared	0.712		
Residual Std. Error	0.304 (df = 335)		
F Statistic	78.805	***	(df = 11;335)
Note: *p<0.1; **p<0.05; ***p<0.01			

Table A10: Summary of final model for Toronto townhouse listings using the buffer variable

Independent Variable	Coefficient	Significance	Std. Error
Number of bathrooms	0.214	***	0.02
Number of floors	0.067	***	0.02
Property Ownership-Freehold	0.206	***	0.04
TTC Subway Station type elevated	0.237	***	0.06
TTC Subway Station type underground	0.335	***	0.04
TTC Subway Station type underground but uncovered	0.609	***	0.12
TTC Subway Station type underground-ground level	0.263	**	0.11
Buffer Second	-0.014		0.05
Buffer Third	-0.198	***	
Walk Score	0.002	**	0.00
Bike Score	0.004	****	0.00
Median HH income of CT	0.00000	***	0.00
Constant	12.208	***	0.11
Observations	347		
R squared	0.735		
Adjusted R squared	0.725		
Residual Std. Error	0.297 (df = 333)		
F Statistic	71.009 (df = 13;333)	***	
Note: *p<0.1; **p<0.05; ***p<0.01			

Table A11: Station type coefficients: distance and buffer models for Toronto apartments

Independent Variable	Coefficient Distance model	Significance	Standard Error	Coefficient Buffer model	Significance	Standard Error
TTC Subway Station type Elevated	0.17100	***	0.03	0.18400	***	0.03
TTC Subway Station type Underground	0.24300	***	0.02	0.23700	***	0.02
TTC Subway Station type underground but uncovered	0.11700	***	0.04	0.14700	***	0.04
TTC Subway Station type underground/at-level	0.19000	***	0.04	0.18200	***	0.04

Note: *p<0.1; **p<0.05; ***p<0.01

Table A12: Station type coefficients: distance and buffer models for Toronto single family properties

Independent Variable	Coefficient Distance model	Significance	Standard Error	Coefficient Buffer model	Significance	Standard Error
TTC Subway Station type Elevated	0.05600		0.05	0.04400		0.05
TTC Subway Station type Underground	0.25200	***	0.03	0.25000	***	0.03
TTC Subway Station type underground but uncovered	0.35200	***	0.09	0.34800	***	0.09
TTC Subway Station type underground/at-level	0.19100	***	0.05	0.19400	***	0.05

Note: *p<0.1; **p<0.05; ***p<0.01

Table A13: Station type coefficients: distance and buffer models for Toronto townhouse properties

Independent Variable	Coefficient Distance model	Significance	Standard Error	Coefficient Buffer model	Significance	Standard Error
TTC Subway Station type Elevated	0.22100	***	0.06	0.23700	***	0.06
TTC Subway Station type Underground	0.32200	***	0.04	0.33500	***	0.04
TTC Subway Station type underground but uncovered	0.60900	***	0.12	0.60900	***	0.12
TTC Subway Station type underground/at-level	0.25500	**	0.12	0.26300	**	0.11

Note: *p<0.1; **p<0.05; ***p<0.01

Table A12: Station type coefficients: distance and buffer models for Vancouver apartments

Independent Variable	Coefficient Distance model	Significance	Standard Error	Coefficient Buffer model	Significance	Standard Error
SkyTrain Station type Elevated	0.22800	***	0.07	0.20900	***	0.07
SkyTrain Station type Elevated but covered	0.17900	**	0.08	0.16400	**	0.08
SkyTrain Station type Underground	0.28700	***	0.08	0.28500	***	0.08
SkyTrain Station type Underground-Elevated	0.19100	**	0.08	0.17800	**	0.08

Note: *p<0.1; **p<0.05; ***p<0.01

Table A13: Station type coefficients: distance and buffer models for Vancouver single family properties

Independent Variable	Coefficient Distance model	Significance	Standard Error	Coefficient Buffer model	Significance	Standard Error
SkyTrain Station type Elevated	-0.06800	**	0.03	-0.08200	**	0.03
SkyTrain Station type Elevated but covered	-0.11700	***	0.04	-0.12900	***	0.04
SkyTrain Station type Underground	-0.21700	***	0.04	-0.23700	***	0.04
SkyTrain Station type Underground-Elevated	-0.04700		0.06	-0.06200		0.06

Note: *p<0.1; **p<0.05; ***p<0.01

Figure A1: Distribution of Toronto apartment listings in relation to TTC subway station types: ground-level and underground

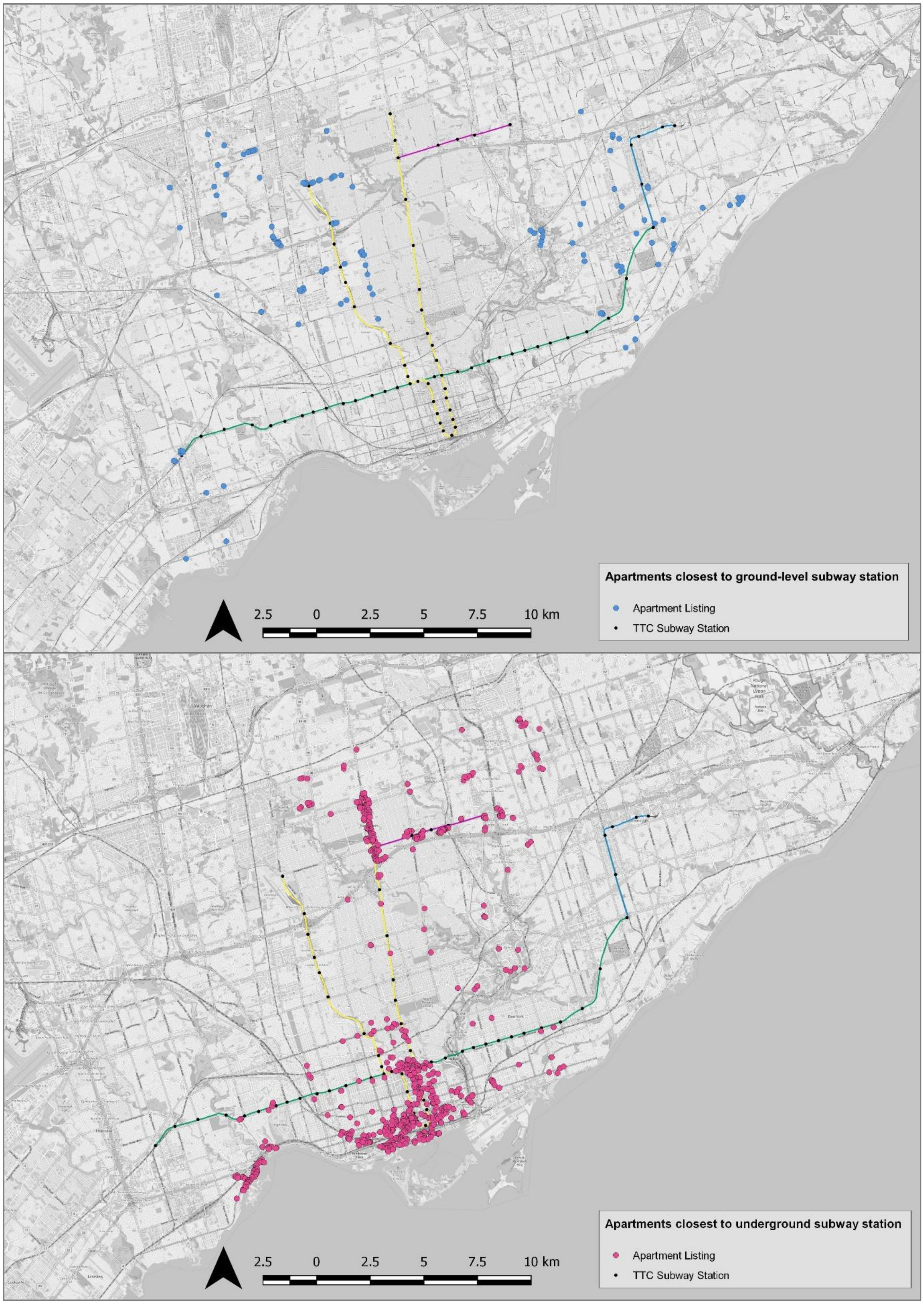


Figure A2: Distribution of Toronto apartment listings in relation to TTC subway station types: partially underground, partially ground-level and elevated

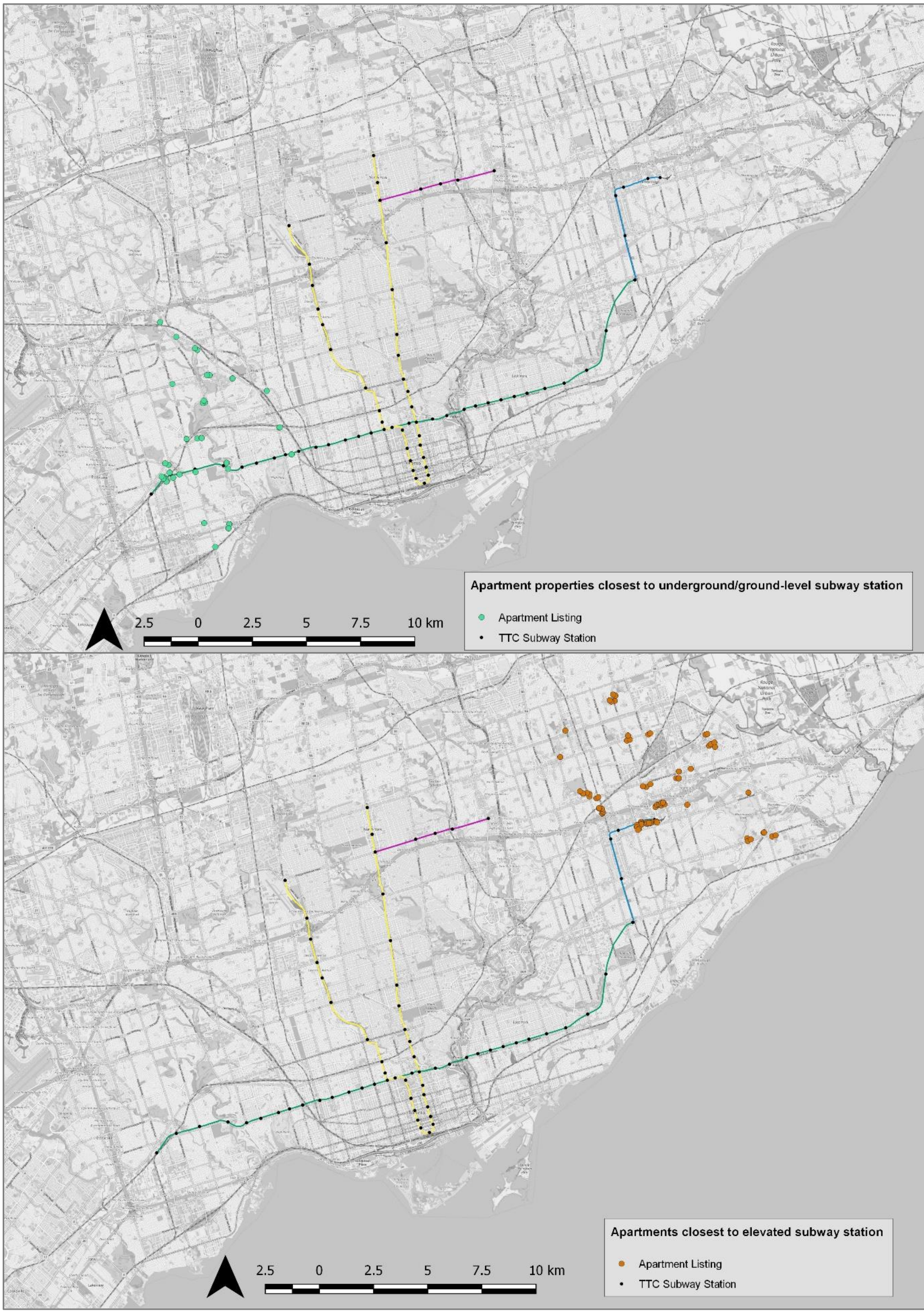


Figure A3: Distribution of Toronto apartment listings in relation to TTC subway station type: underground but uncovered

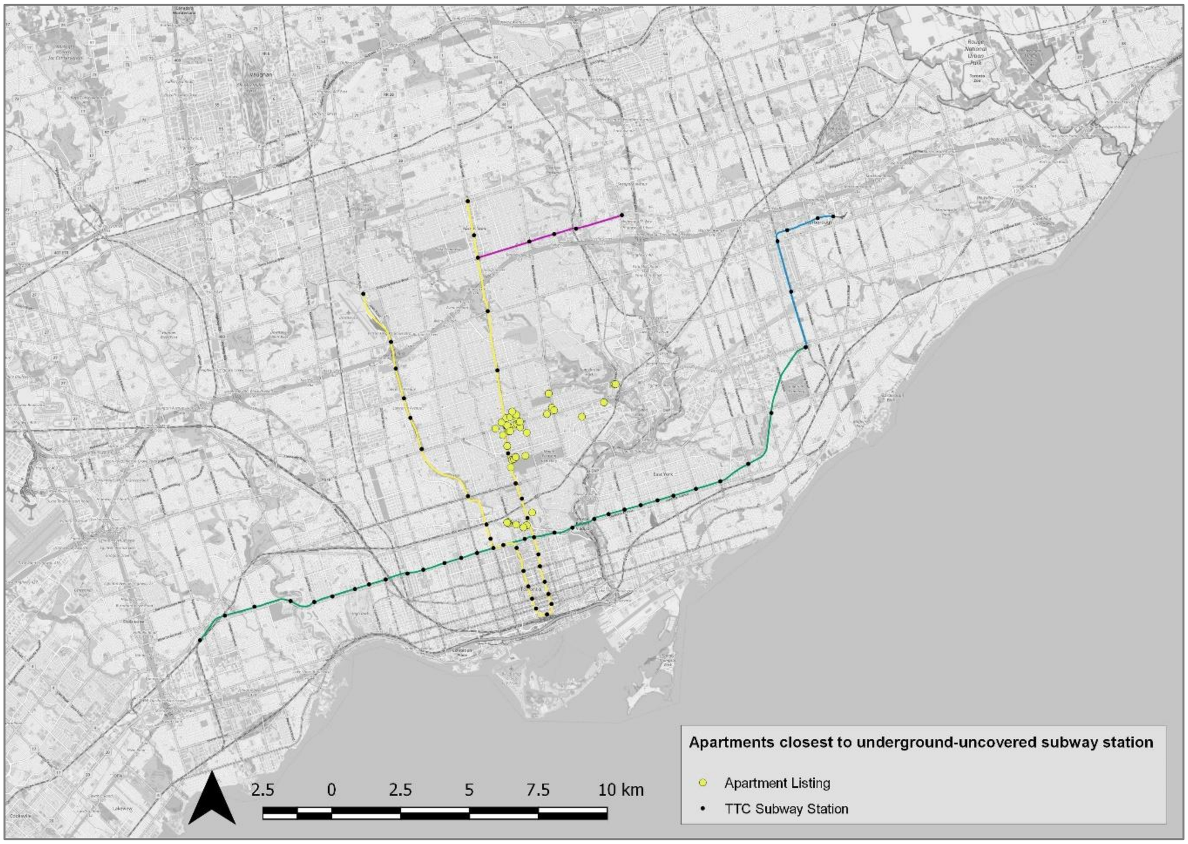


Figure A4: Distribution of Toronto single family listings in relation to TTC subway station types: ground-level and underground

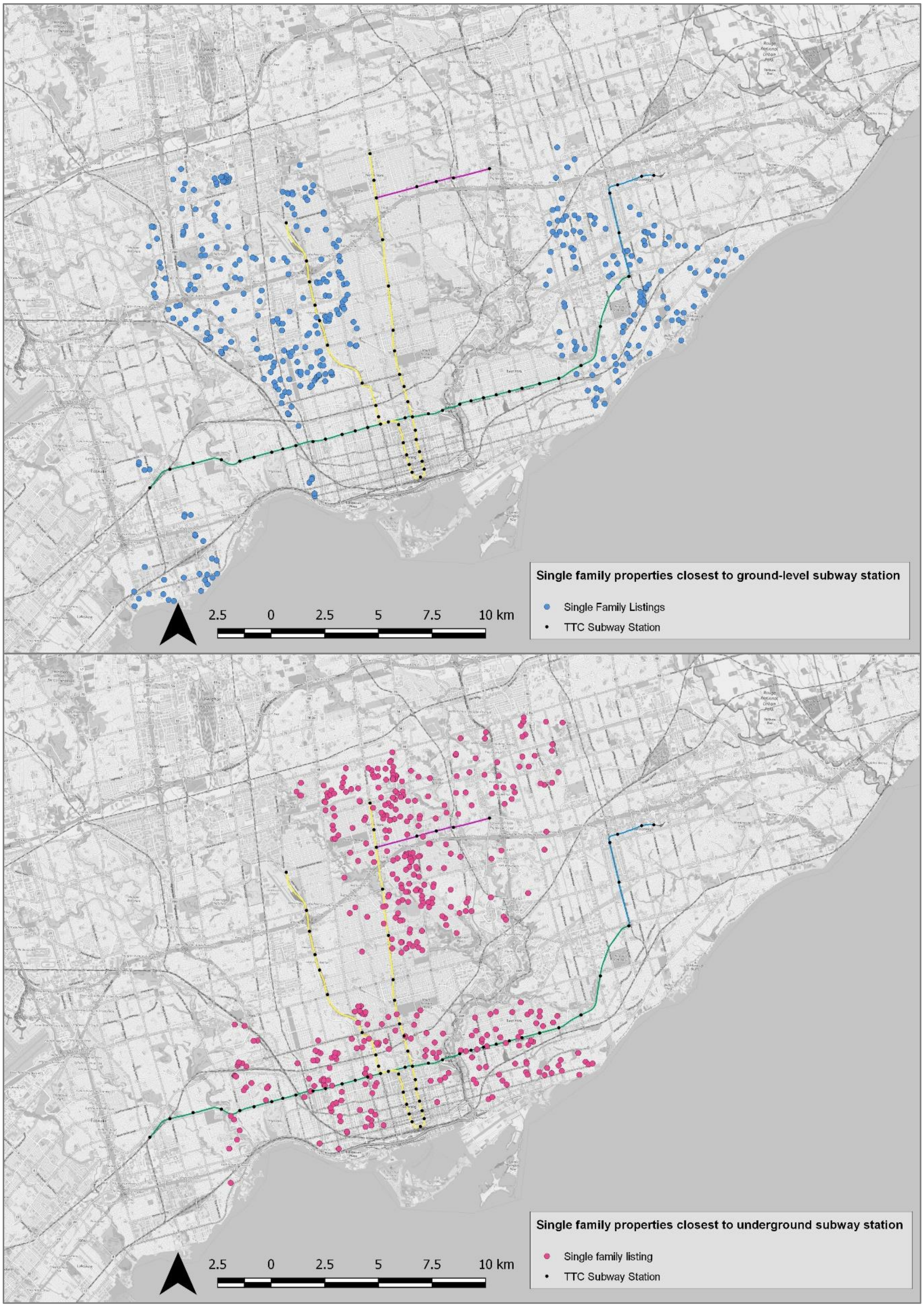
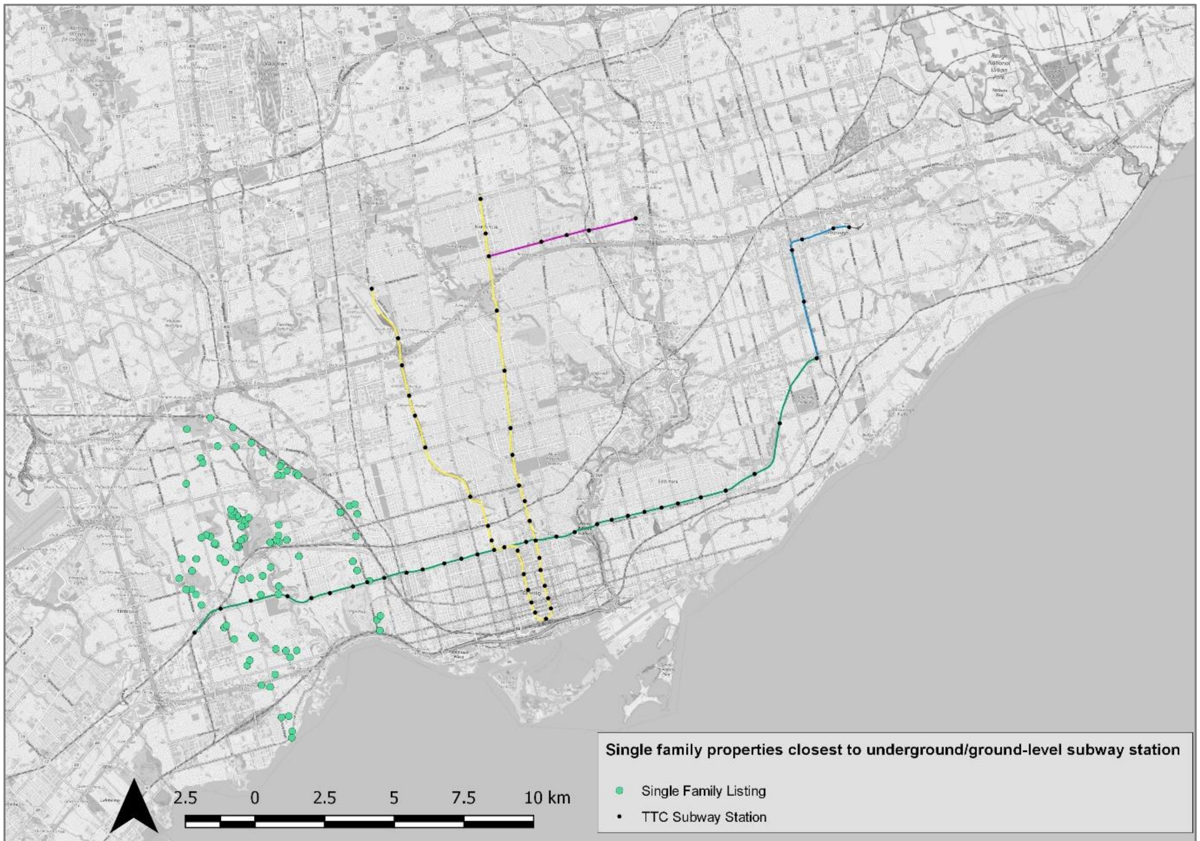


Figure A5: Distribution of Toronto single family listings in relation to TTC subway station types: partially, underground partially ground-level and elevated



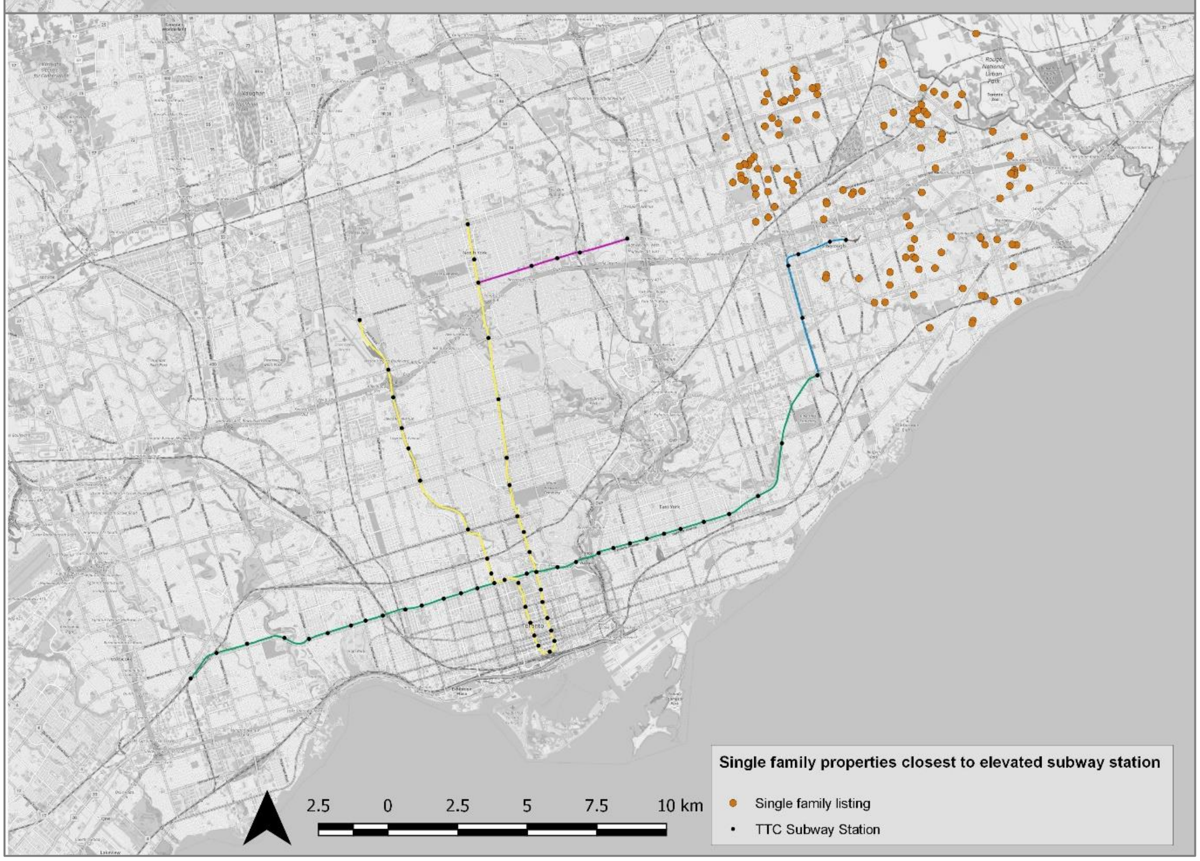


Figure A6: Distribution of Toronto single family listings in relation to TTC subway station type: underground but uncovered

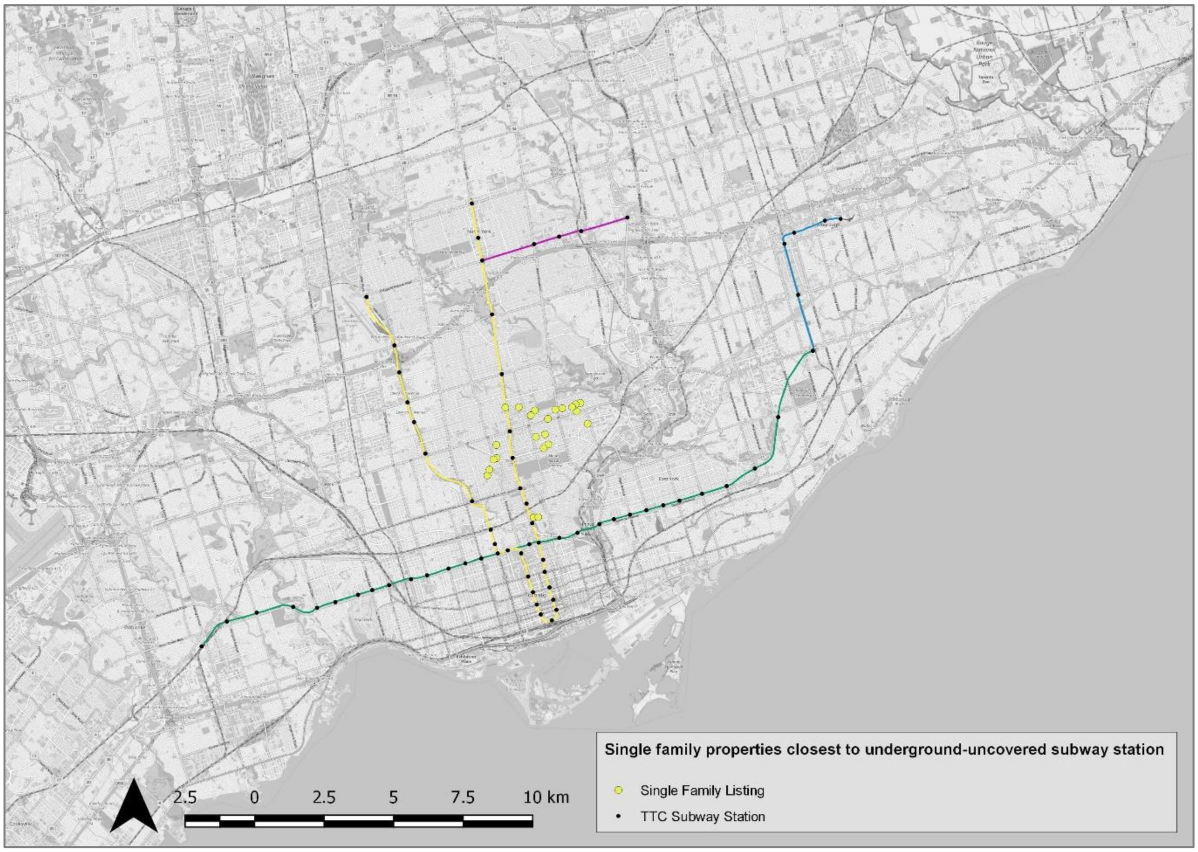
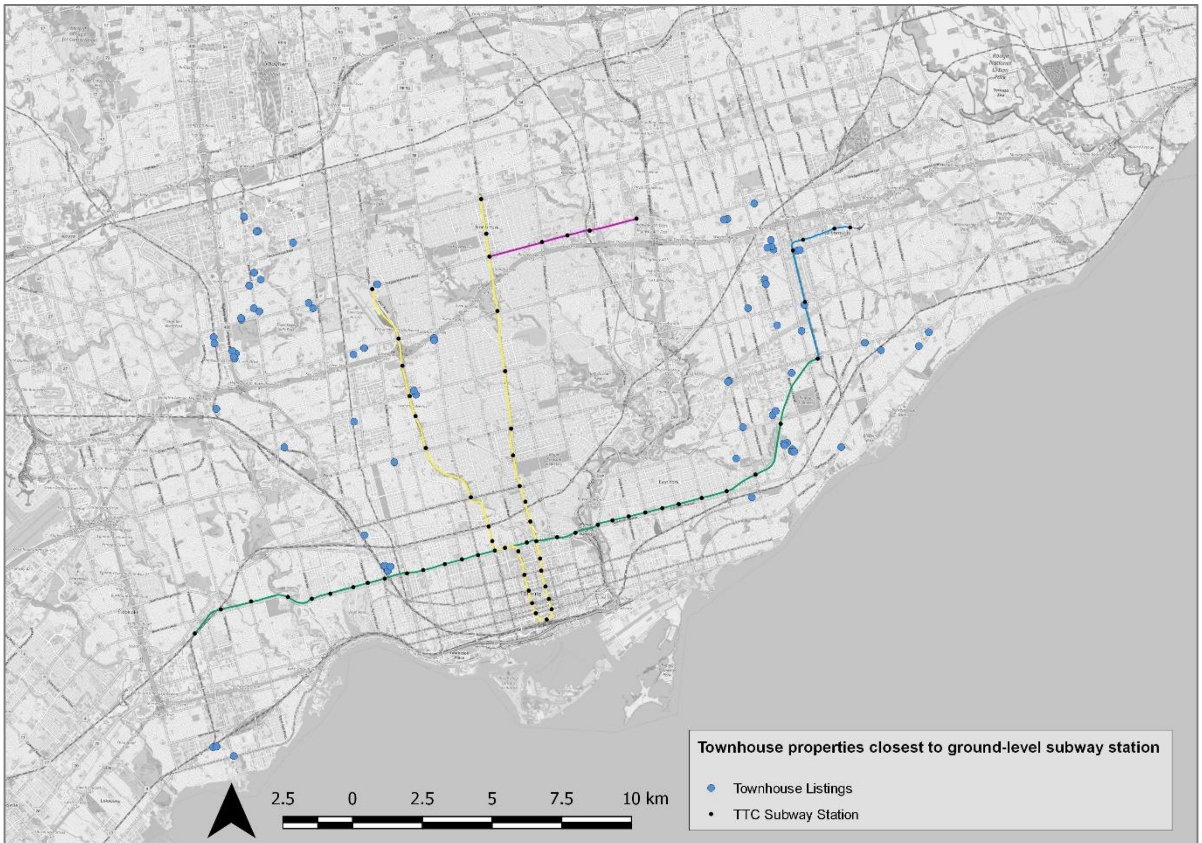


Figure A7: Distribution of Toronto Townhouse listings in relation to TTC subway station types: ground-level and underground



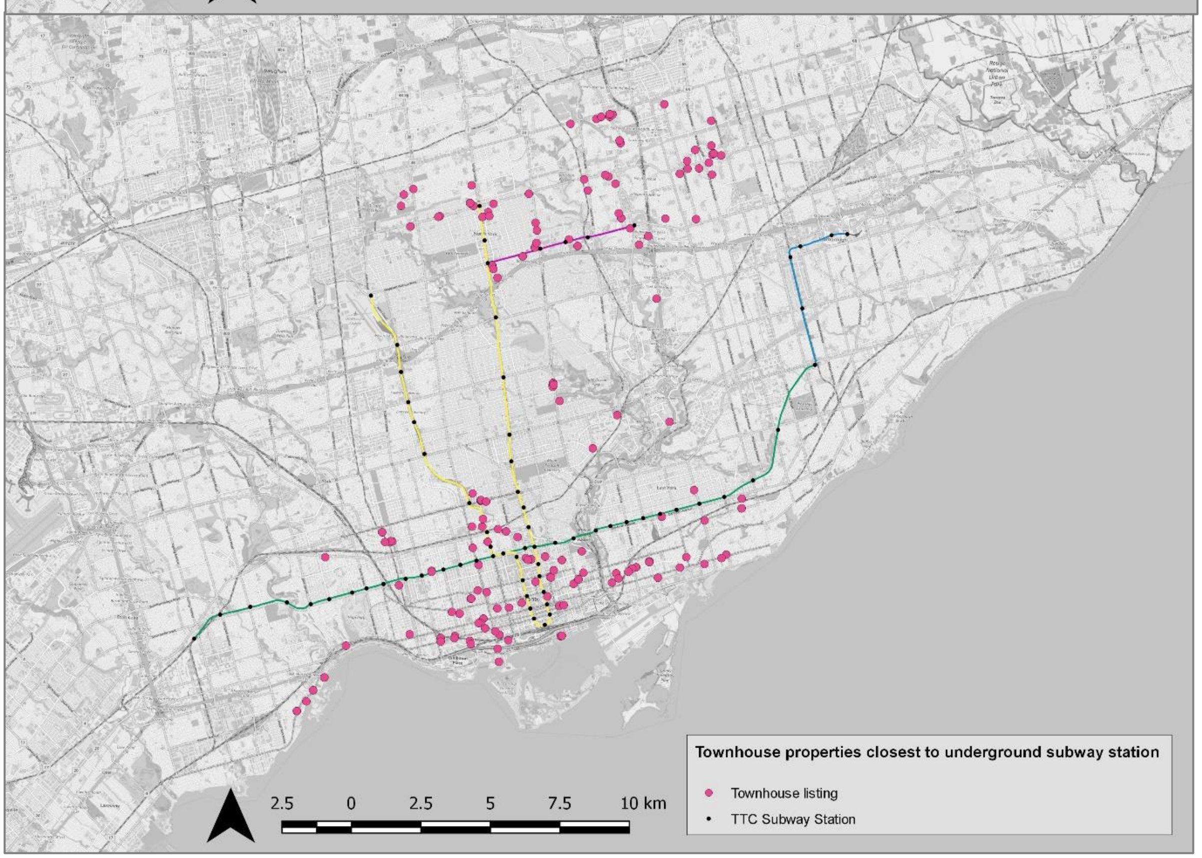


Figure A8: Distribution of Toronto townhouse listings in relation to TTC subway station types: partially underground, partially ground-level and elevated

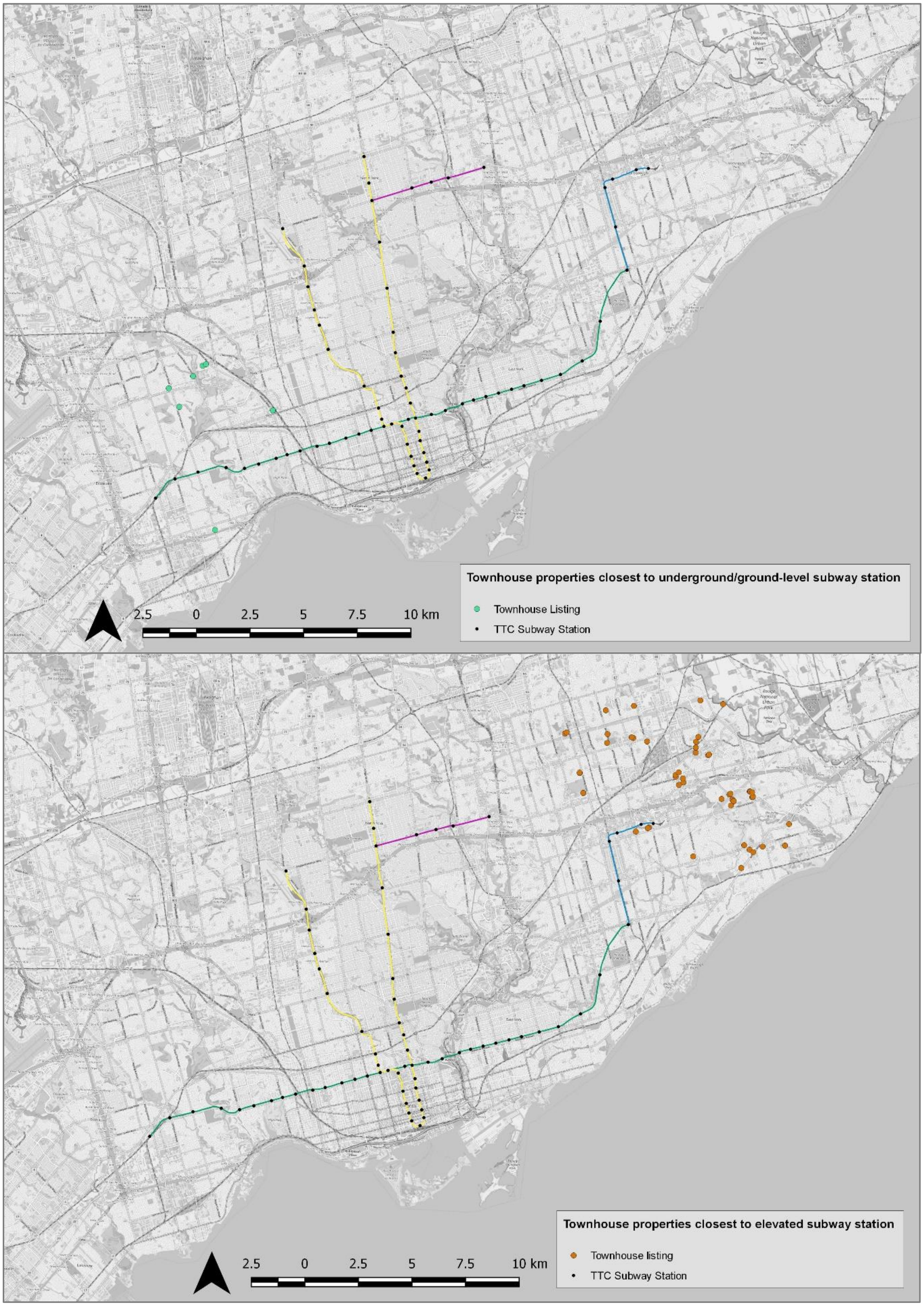


Figure A9: Distribution of Toronto townhouse listings in relation to TTC subway station type: underground but uncovered

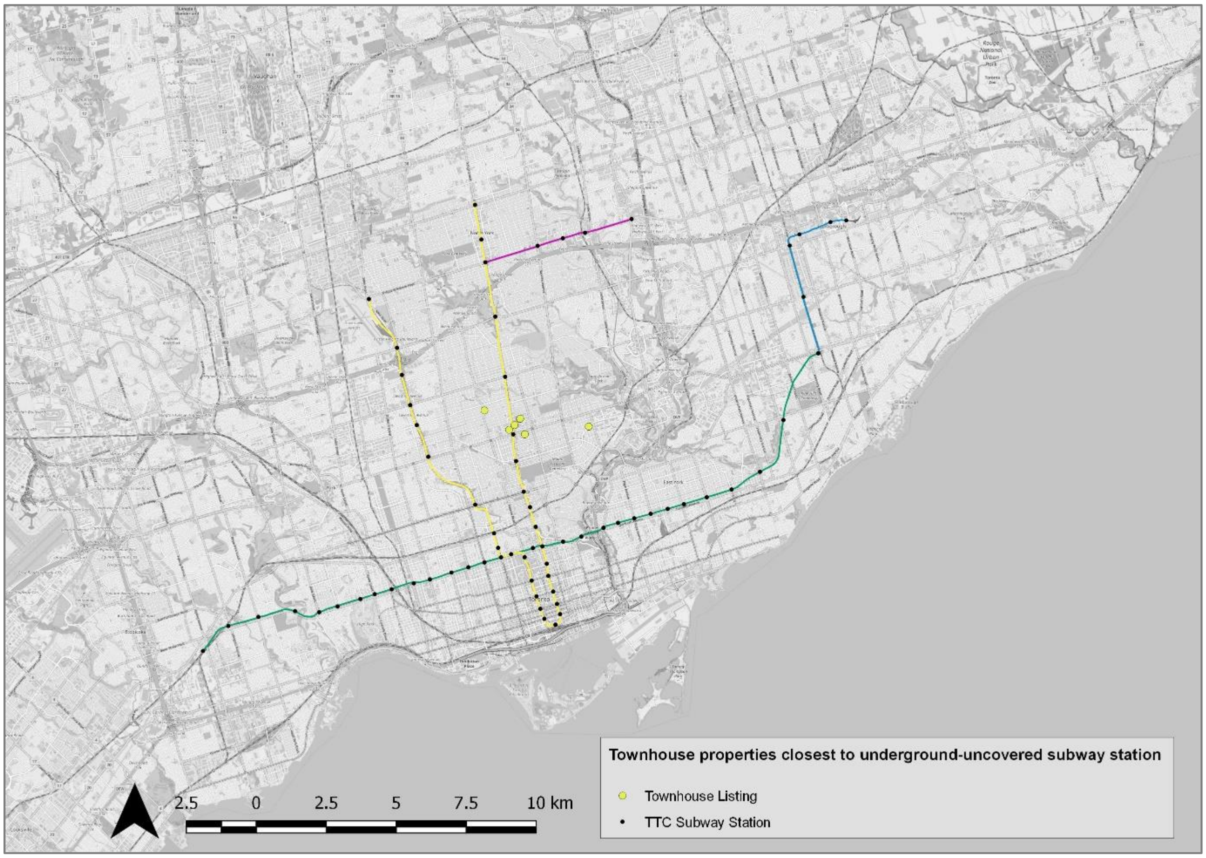


Figure A10: Distribution of Vancouver apartment listings in relation to SkyTrain station types: ground-level and underground

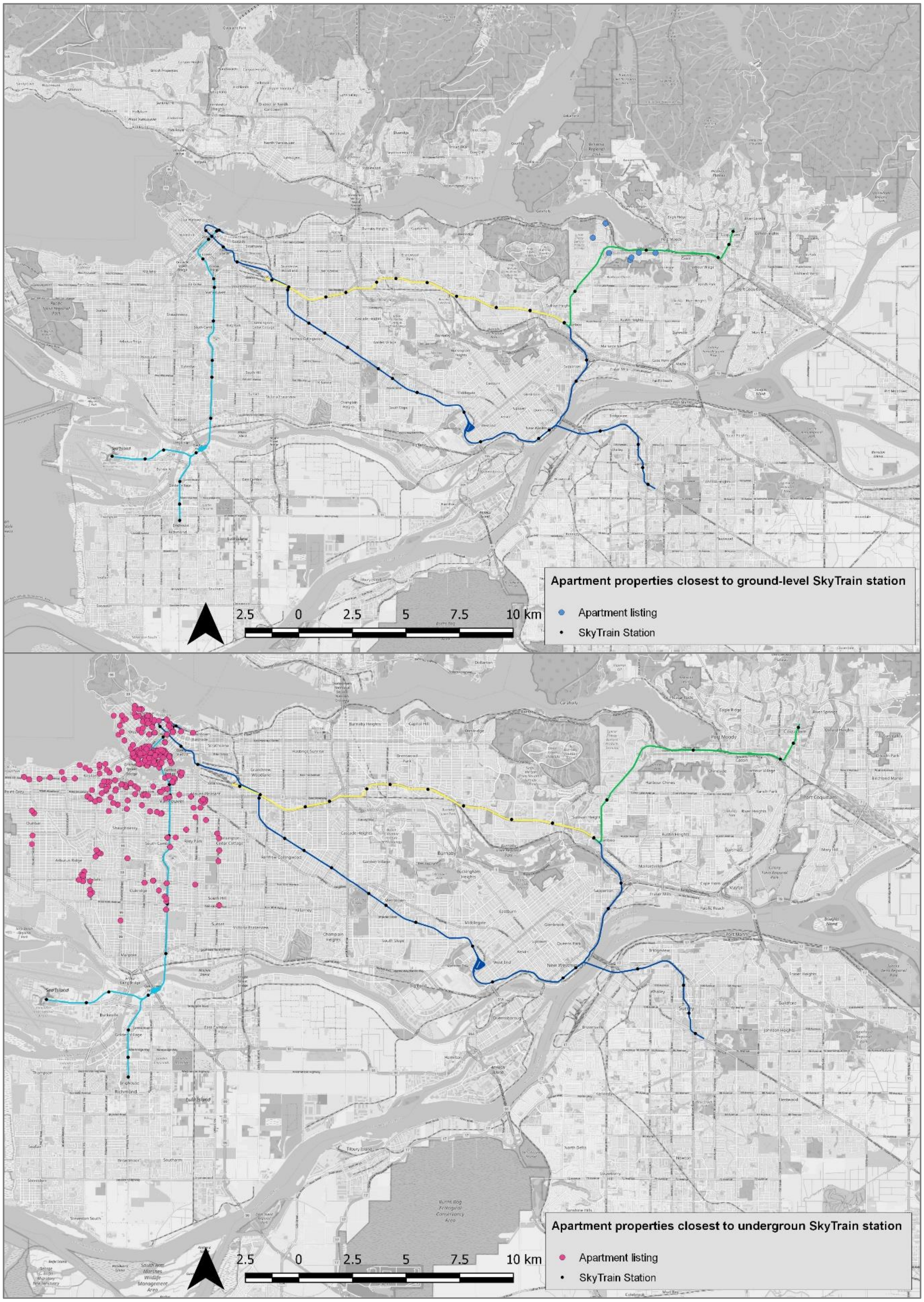


Figure A11: Distribution of Vancouver apartment listings in relation to SkyTrain station types: partially underground, partially elevated and elevated

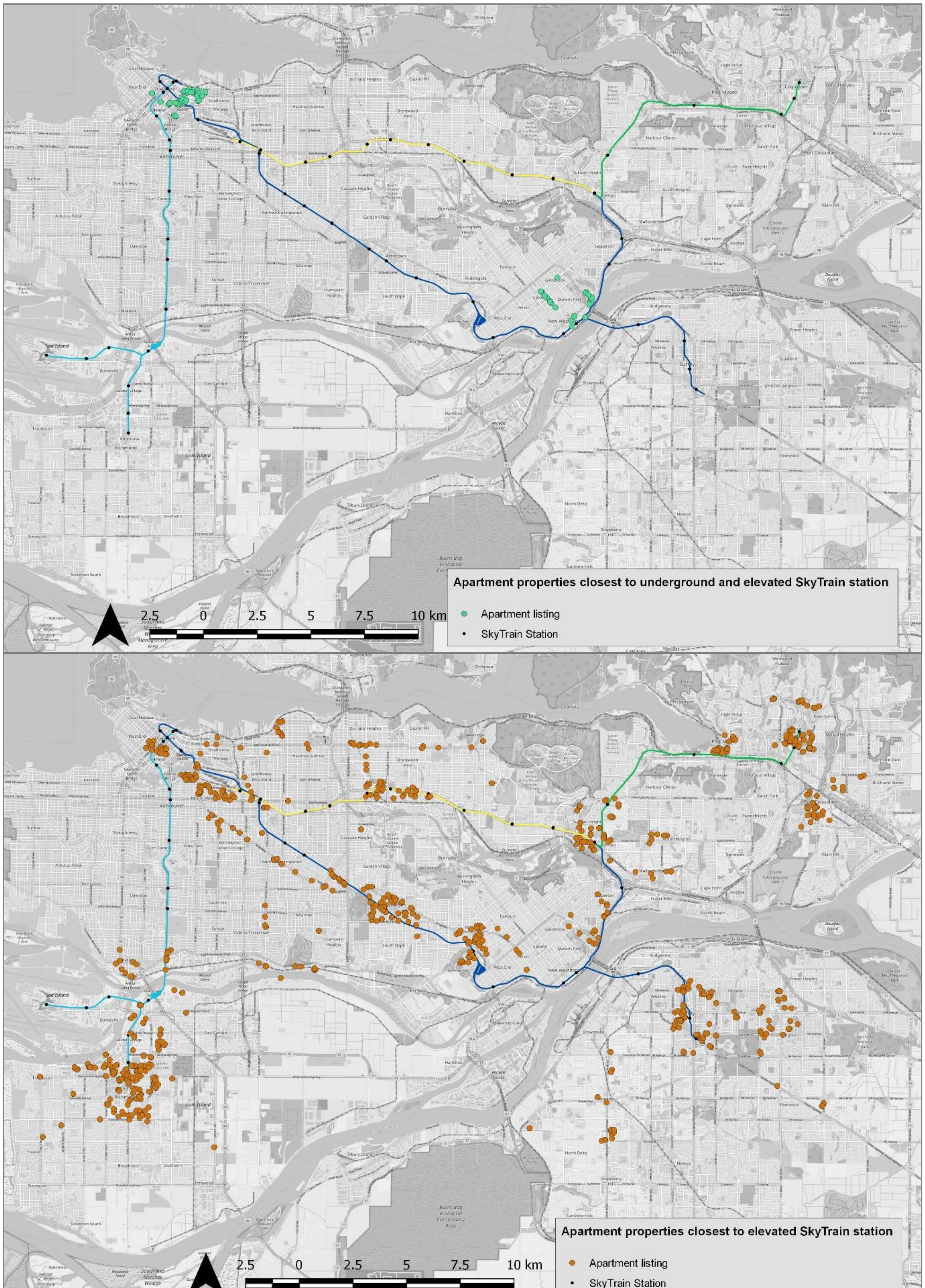


Figure A12: Distribution of Vancouver apartment listings in relation to SkyTrain station type: elevated but covered

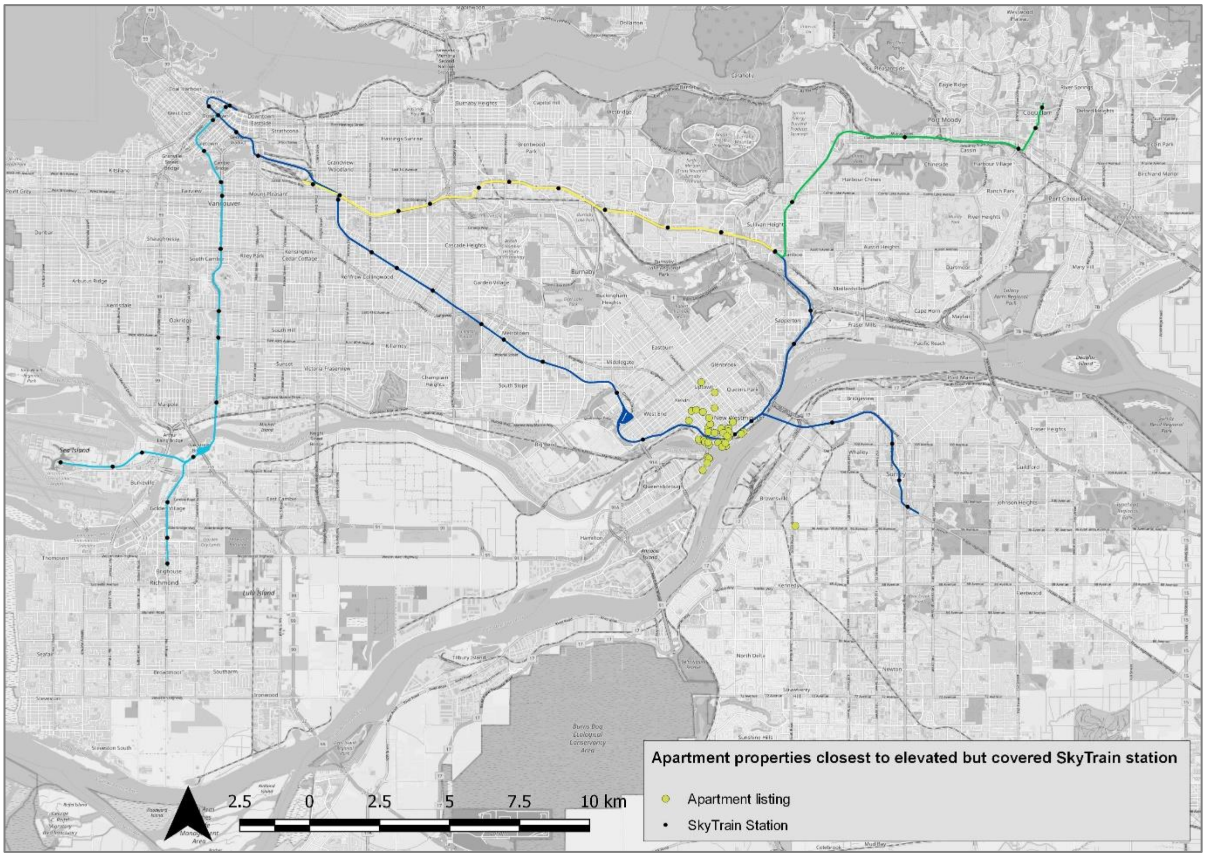


Figure A13: Distribution of Vancouver single family listings in relation to SkyTrain station types: ground-level and underground

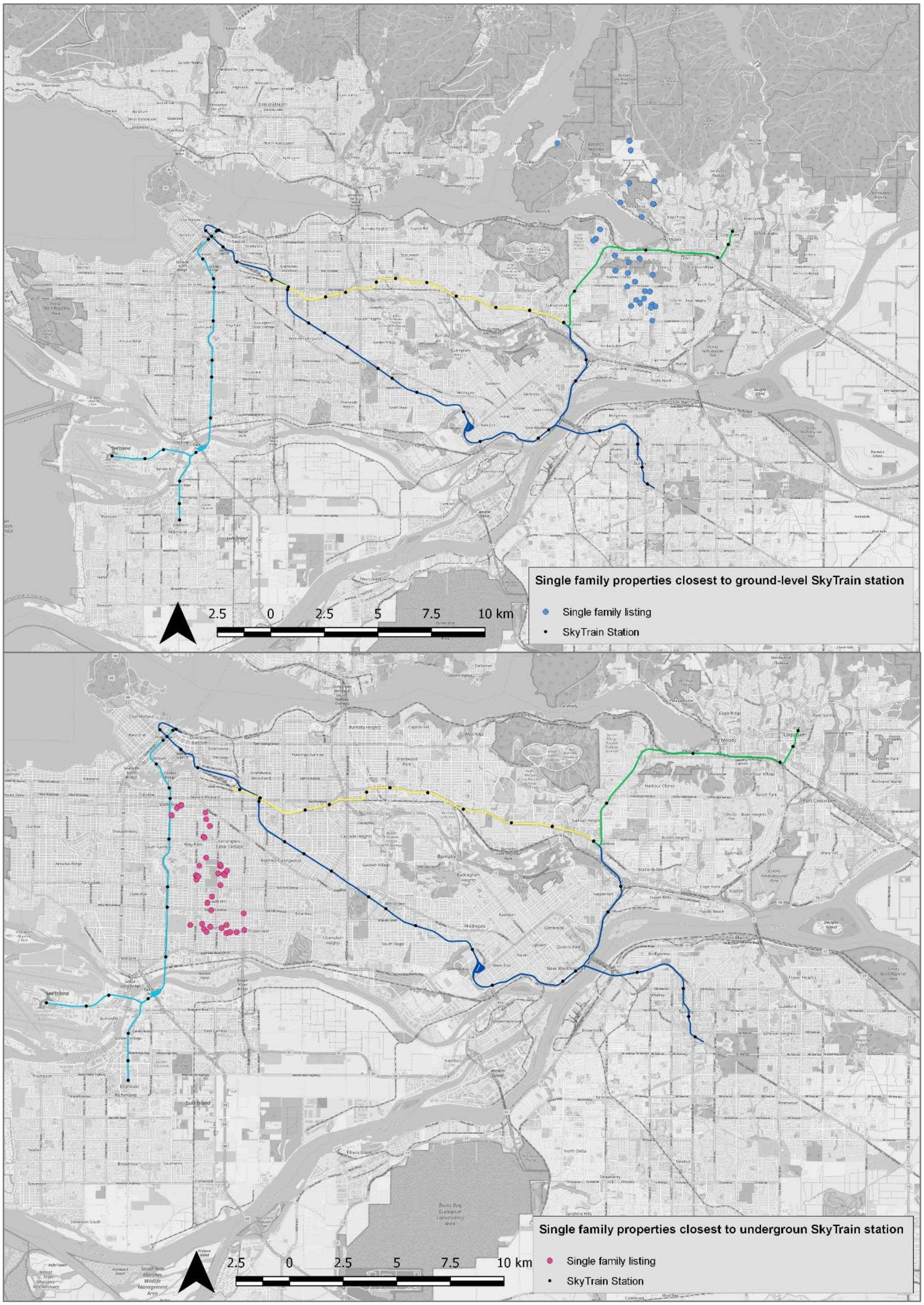
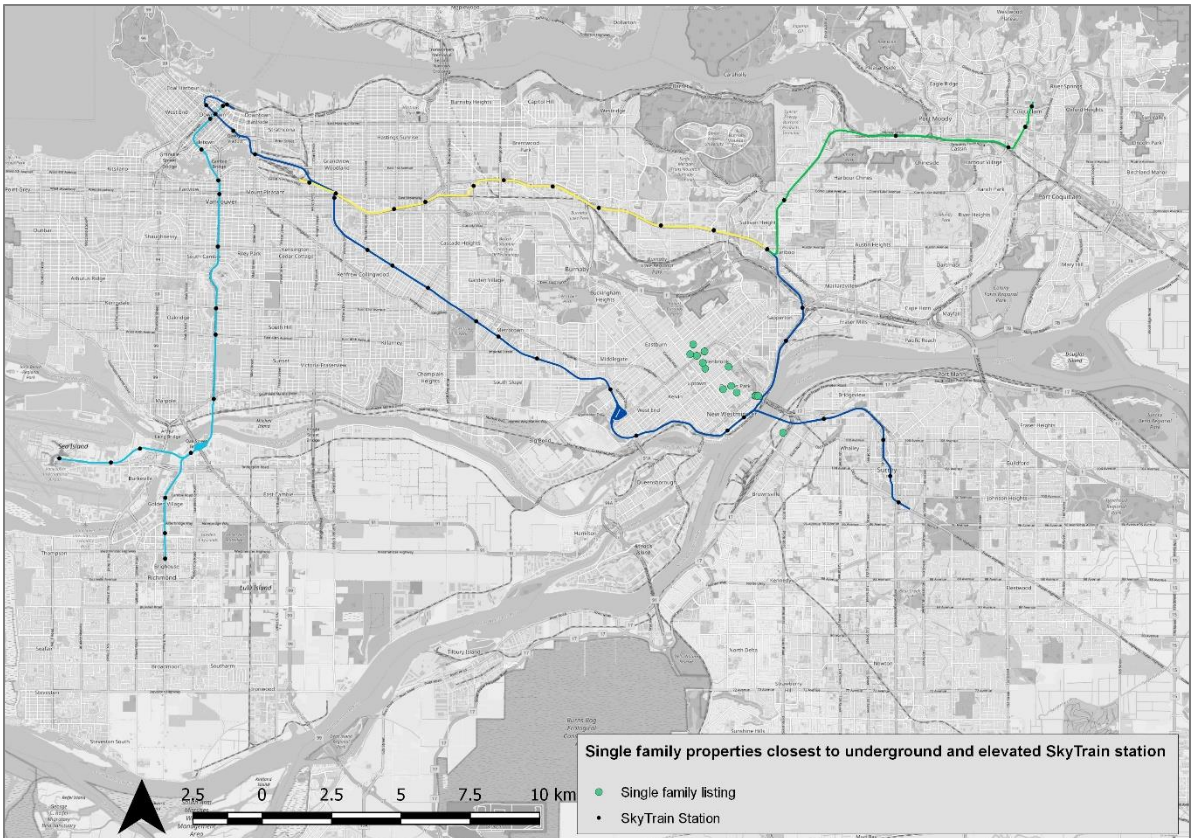


Figure A14: Distribution of Vancouver single family listings in relation to SkyTrain station types: partially underground, partially elevated and elevated



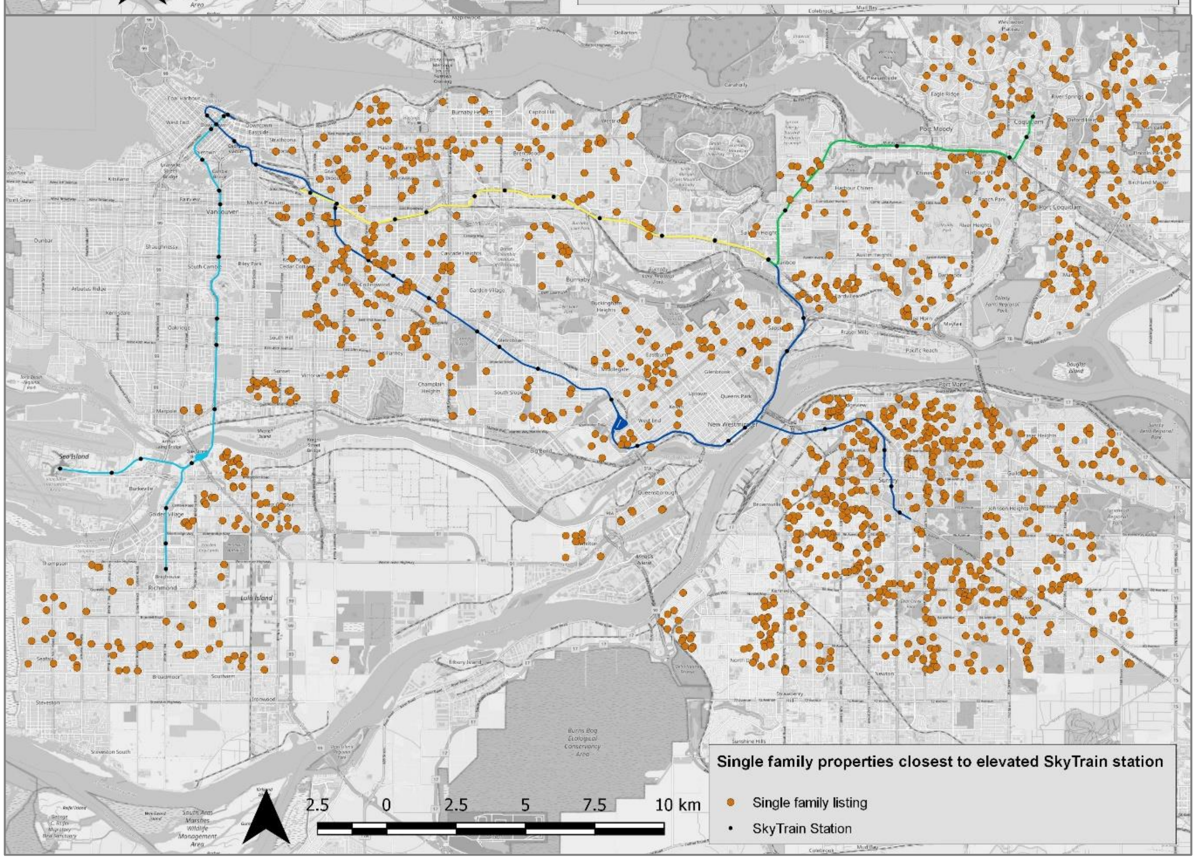


Figure A15: Distribution of Vancouver single family listings in relation to SkyTrain station type: elevated but covered