Regional Express Rail's Impact on Housing Affordability in the Greater Golden Horseshoe

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CANADIAN CENTRE FOR ECONOMIC ANALYSIS

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EXECUTIVE SUMMARY

The relationship between transportation infrastructure, land value, real estate prices and housing affordability is complex. International experience reflects a mixed picture, suggesting that provision of and access to transportation networks can have an uncertain effect on shelter affordability. For example, while integrated transportation networks can reduce affordability pressure by incentivizing households to migrate away from core employment centres (such as downtown Toronto), urban sprawl can generate greater transportation costs (including the building and maintaining of the infrastructure). If these costs are passed onto households without compensating benefits, housing becomes less affordable.

Further complicating the issue is the measurement of housing affordability itself. Many affordability indexes consider housing prices as the key determinant of housing affordability and do not capture the breadth of costs that households incur to make a structure a home (such as transportation). For this reason, and inspired by recent developments in economic modelling, CANCEA developed the *Shelter Consumption Affordability Ratio* (SCAR) index, which compares the full cost accounting of using shelter with a household's ability to pay for it (including the costs of transportation). The SCAR index more completely reflects both the consumption costs of satisfying shelter needs and households' actual disposable income, by dividing shelter-related consumption costs by discretionary net income after other necessities:

> Housing affordability is complex and is not just about housing prices. The SCAR index is a full cost accounting of 'operationalizing' shelter to call it a home.

Shelter-related consumption costs: Unlike other affordability indices, the SCAR Index differentiates shelter consumption from ownership by considering rental costs for tenants, and imputed rent among homeowners who act as their own landlords[1]. Other shelter-related consumption costs in the SCAR index include utility expenses, maintenance and repair costs, and property taxes. In addition, as households must travel from their residence to reach necessary amenities and places of work, transportation expenses are also included.

Discretionary net income after other necessities: This represents income available to pay for the consumption costs of shelter. It is calculated as after-tax income less financial obligations (such as debt repayment) less other necessary expenses: food, clothing, private healthcare costs, and essential non-shelter employment costs.

[1] This concept is already in use as a component of GDP measurement by Statistics Canada.

Consistent with the SCAR index, literature on the matter suggests that in order for transit to have a positive impact on housing affordability, it needs to be accessible. But, to be clear, *proximity* to improved transit does not mean improved *accessibility* – transit needs to help you get where you want to go relatively quickly and at a lower cost than other surrounding transportation options (e.g., highways). It simply isn't enough to be located beside a transit hub. Unfortunately, outside of the downtown Toronto core and along the city's subway lines, individuals without access to a car can only easily access 5-10% of the jobs compared to those with access to a car. This means that ignoring a household's proximity and access to necessary amenities and jobs may overstate the affordability of shelter because transportation expenses are incurred by the household. By using the SCAR index as a measure of affordability, a more complete consideration of both the consumption costs of satisfying shelter needs (including transportation), and a households' ability to pay for it.

> Usefulness of transit hubs does not mean just proximity. Transit stations need to be a convenient and cheaper way to get you where you want to go versus the alternatives

Further, transit investment itself does not guarantee that development around transit hubs – critical to making the area desirable – will occur. Other factors such as local government land use policies, physical land characteristics, and social conditions, are equally, if not more important than the transit investment itself. On the whole, one thing that is clear is that the building of transit on its own is not sufficient – rather, building up complete communities (including greater density) *around* transit hubs (via transit-oriented development) is critical.

Focus of our study: Metrolinx' Regional Express Rail

Our study investigates Metrolinx' Regional Express Rail (RER) as it affects affordability as measured by the SCAR index in the areas surrounding commuter GO train stations. Investments made through RER will mean, over the next decade, five of the seven GO rail corridors transformed into services that operate all day, all week, and in both directions. Using CANCEA's 'big data' computer simulation platform, which models the behavior of – and interactions between – over 40 million virtual individuals, households, businesses, governments, and non-profit organizations, we simulate the connection between future potential housing cost increases and transportation cost decreases in 773 integrated communities across the Greater Golden Horseshoe (GGH).

> Metrolinx' Regional Express Rail will see five of the seven GO rail corridors transformed into services that operate all day, all week, and in both directions

Much of the analysis around transportation costs is dynamic, such that it shows the potential savings depending on the proportion of people who shift from driving to taking the GO train. This provides a sense of which communities will see the largest affordability impacts stemming from the introduction of RER.

Results at a glance

- **Transit-induced price premium of up to 12%:** Considering GGH housing prices only, the contribution of improved transit access is shown to be always positive (controlling for other factors), with transit scores of 100[2] resulting in a price premium of about 12% over the reference case (with a transit score of 0). Increases in transit scores due to improved service therefore lead to housing price premiums of up to 12% (depending on the scale of the improvement.) However, premiums for regions and single-detached homes can sometimes overshadow the transit premium. For example, within the City of Toronto itself, increasing transit scores via RER has a much smaller impact as most of the city already has relatively high transit scores, with other location factors (e.g., walkability, average house size) driving area premiums.

- **RER impact on the household:** Based on Metrolinx' business case for RER, it is expected to entice about 10% of the population commuting to Toronto by car to use GO Train services (due to increased transit accessibility) but only 1% of car commuting residents of Toronto (because of relatively good existing transit). The importance of policy and local transit-oriented developments then becomes very clear. At the level of individuals who change their commute to work from a car to taking the GO train, the affordability benefits are significant (accounting for changes in the SCAR index such as changes in housing and transportation costs). Key highlights include potential improvements in housing affordability – relative to the no RER scenario – of:

    - 16% to 18% in Barrie, and Guelph;
    - 9% to 11% in Hamilton, King, Halton Hills, Oshawa, East Gwillimbury, Newmarket, and Whitchurch-Stouffville;
    - 5% to 8% in Toronto (TREB Districts W05, W09, E10), Burlington, Vaughan, Whitby, Ajax, Brampton, Pickering, Aurora, Bradford West Gwillimbury, Oakville, Markham, Richmond Hill, and Mississauga;
    - Under 5% in Toronto (TREB Districts E04, E08, E07, C15, W08, W06, W04, E02, W02, C01, C08), and Milton.

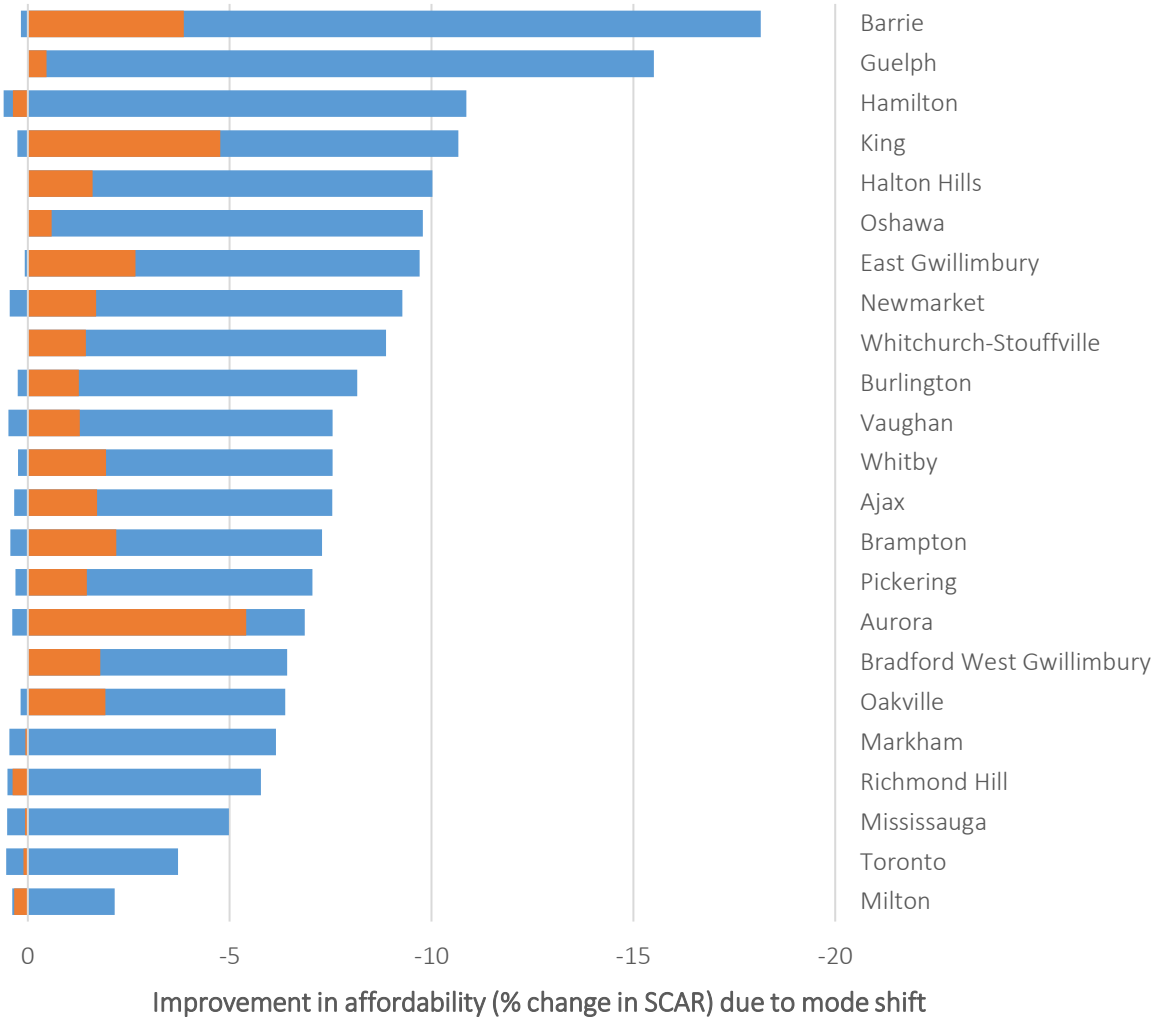
The potential for an individual to save costs is significant and a key policy metric to be considered by local and provincial governments, particularly in terms of local transit-oriented developments.

- **RER impact on aggregate commuter choices:** Aggregating these community-level expectations, the average potential change in SCAR by location shows a noticeable difference inside and outside Toronto proper:

[2] Using data from 'Walk Score', a Transit Score® for a specific point is calculated using an algorithm that summarizes the usefulness of nearby routes, including distance to the nearest stop, frequency of routes, and type of routes.

- **For households around GO stations outside Toronto:** Estimated improvement in affordability due to RER is 1.5% on average as changes in the cost of a home are more than offset by lower transportation costs (for those who stop commuting by car).
- **For households in Toronto:** A slight *worsening* in affordability (characterized by an increase in SCAR) of 0.1% on average as changes in the cost of a home due to better transportation alternatives are not offset by lowering already existing lower transportation costs.

More specifically, as can be seen in the following graph, the difference between the overall average change in affordability (orange bars) and the potential for an individual to improve affordability (blue bars) is significant and a key policy metric to be considered by local and provincial governments, particularly in terms of local transit-oriented developments.



Person-level changes in affordability (blue bars) and potential *average* changes in affordability (orange bars) show that mode shift is the driving factor of how housing affordability is affected (where the right end of each line is full mode shift; left end is no mode shift).

For example, if more residents of Guelph who commute to Toronto switched modes, then overall affordability in Guelph would improve disproportionately.

Conclusions

Many affordability indexes are focused upon housing prices, mortgage payments, and interest rates, and are therefore insensitive to the role and implementation of transportation alternatives. The affordability of a home is much more than just housing prices, which the SCAR Index is designed to accommodate.

Using SCAR index analysis combined with the simulation of 773 communities in the GGH region, we found that the value of households giving up their car for the GO train to get to work can have a significant effect upon the affordability of their shelter. Across the GGH, the impact of RER is generally positive, insofar as it improves affordability, but only for those who shift from driving to taking the GO train. Therefore, mode shift is the key driver of improved affordability.

The analysis highlights the value of RER combined with a focus upon local transit-oriented developments, and the communities in which this focus should be a high priority.

1.0 INTRODUCTION

It seems very common these days to see a new story published about public transit in the Greater Golden Horseshoe (GGH) region of Ontario (centred by Toronto). This should not be a surprise given that, for example, a quarter of the population in Toronto[3] commuted by public transit in 2011 and transit was highlighted as an important issue during the 2014 Toronto mayoral race[4] (Statistics Canada 2011, Suen 2014). "The Big Move", a regional transportation plan, emphasized the importance of reducing the region's dependence on automobiles by creating a user-friendly and integrated regional transportation system. It outlined the importance of some of major transit improvement, some currently under construction, such as the improvements and extensions to regional GO Transit rail services (Metrolinx 2008).

Government spending in recent years has tried to match the public's appetite for better transit. The Ontario government has gradually increased the amount it has spent on transit infrastructure. In 2016-17 alone, it is spending nearly $5.4 billion to transit, or roughly one-third of all its infrastructure expenditures[i], up from 15% in 2009-10[ii]. Furthermore, the federal government recently announced that it would be contributing $2.3 billion on average per year over the next 11 years to transit infrastructure across the country (Canada 2016). The City of Toronto itself plans to add over $1.3 billion more per year (including the Scarborough subway extension)[5], plus the potential costs of the mayor's signature "Smart Track" plan.

Transit investment could also have impacts beyond improving people's commute times and making the region as a whole more accessible. There could be unintended consequences on other regional aspects. For example, could transit affect the affordability of housing by making the region more accessible or by allowing households to reduce their transportation costs and therefore have more discretionary income leftover to spend on their 'wants'?

The next few sections outline what kind of impacts transit might have on housing affordability, as housing choice is a complex one for households.

1.1 Transportation and Affordability

The literature on the relationship between transportation infrastructure, land value, and real estate prices is extensive. International experience reflects a mixed picture, suggesting that provision of and access to transportation networks has an ambiguous effect on shelter affordability.

On the one hand, integrated transportation could reduce affordability pressure in metropolitan areas by incentivizing households to migrate away from core centres (such as Toronto) to cheaper areas (e.g., further away from work) that they might not have considered due to daily commuting[iv]. On the other hand, over time, diffusion of growth may generate greater costs on transportation infrastructure[6] and increased congestion[v], if transportation plans don't match the growth in non-core areas. If these costs are passed

[3] Census metropolitan area
[4] 49% of Toronto respondents in a survey reported it as the most important issue facing the City of Toronto.
[5] According to the TTC's proposed 2017-2026 Capital Budget (as of September 6, 2016)
[6] Such as construction, operation, and maintenance costs of transportation infrastructure.

onto households through higher transit fares or municipal fees or taxes, they would reduce discretionary income and make shelter in general (whether in core urban areas or otherwise) less affordable.

It is therefore important to recognize that transportation has an ambiguous impact on overall affordability, even in core areas where the diffusion effect is expected to relieve demand pressures. The expansion/renovation of transportation networks could lead to an appreciation in land value and real estate around transportation infrastructure because transportation infrastructure can act as differentiator of shelter[vi], leading to greater competition for shelter units situated nearby. Moreover, choosing shelter is a complex choice, so isolating the effect of transportation on affordability could prove difficult.

These effects are also difficult to pinpoint in practice, particularly in the GTHA. One of the reasons for this may be the underinvestment in the region's infrastructure in general, which could have historically limited effective spatial diffusion. In order to truly appreciate the relationship between transportation, shelter costs, and affordability, a systems approach to modeling the interaction across variables that uses areas such as the GGH for analysis should prove useful. Such analysis looks at an economy as an entire interconnected system, and appreciates that topics such as transit cannot be examined in isolation.

1.1.1 VALUE OF PROXIMITY, TRANSPORTATION COST, AND AFFORDABILITY

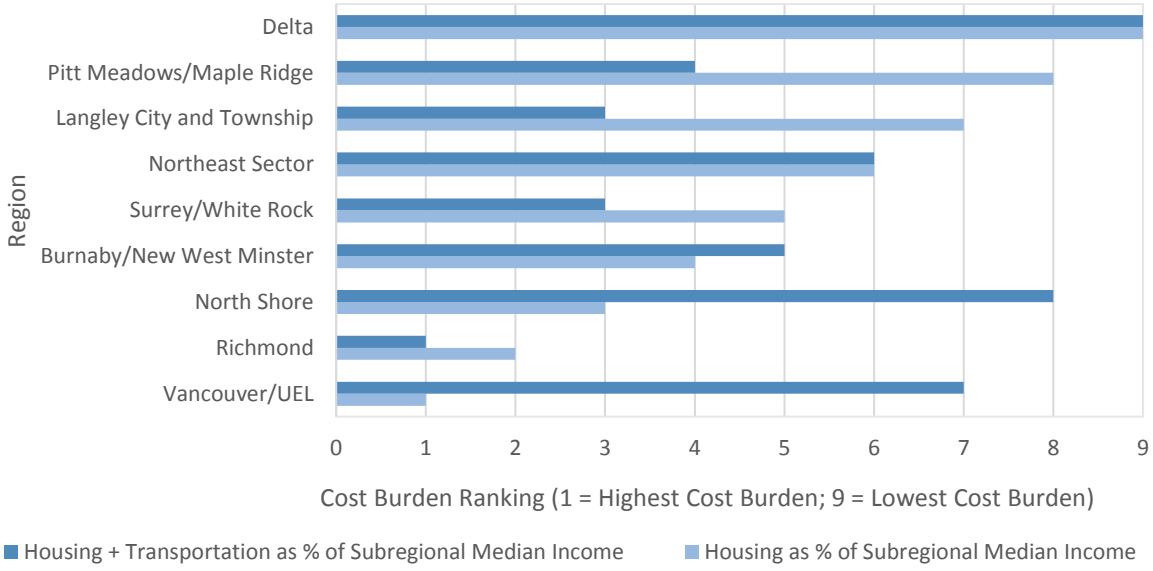
In order for households to be able to 'operationalize,' their shelter (i.e., ensure they are situated appropriately), they have to be able to reach critical destinations (e.g., their jobs). In that regard, transportation costs are incurred while still consuming the shelter that they need. This means that ignoring a household's distance from necessary amenities and jobs may overstate the affordability of shelter because transportation expenses are incurred by the household.

According to the Canadian Mortgage and Housing Corporation (CMHC), a traditional definition of 'affordable' housing is when the carrying costs[vii] for suitably-sized housing do not exceed 30% of pre-tax income (CMHC 2016). This is also a definition used often in the United States, whereby 69% of communities are considered affordable (CNT 2010). However, when transportation costs are taken into consideration and a 45% affordability benchmark (for both housing and transportation costs as a percent of pre-tax income) is applied, the number of affordable communities drops to 39% (CNT 2010). This implies that many households are dedicating an enormous amount of 'discretionary' income to operationalizing their shelter.

When considering affordability in Vancouver, a report by Metro Vancouver[viii] found that the affordability of a given area changed when transportation costs were considered. As illustrated in Figure 1, Vancouver/UEL[7] moves from being considered the least affordable area[ix] to becoming one of the most affordable when transportation costs are factored in (Metro Vancouver 2015). This is because Vancouver/UEL has the lowest transportation cost ($8,989 per year) of all the regions. Meanwhile, Pitt Meadows/Maple Ridge dropped from eighth in affordability to fourth when transportation costs were considered (Metro Vancouver 2015).

[7] Vancouver refers to the city of Vancouver area, while the University Endowment lands (UEL) is an area that lies to the west of the city of Vancouver composed of a regional park, University of British Columbia, and associated housing.

Figure 1 Transportation Factor on Cost Burden" Owners with Mortgages, *Source: The Metro Vancouver, 2015*



Similar results have been found in regions in the U.S. whereby households buy homes in rural areas ("drive until you qualify"), only to find out that transportation costs can equal or exceed housing costs (Lipman 2006). The lack of insight into these costs prior to finding shelter can leave these households in jeopardy (CNT 2010).[x]

1.2 Impacts of Transit on Affordability

The impact of transit systems on housing affordability is a topic that has been heavily researched but is yet to be concluded, largely because 'affordability' is such a complex concept. Multiple factors can contribute to evaluating affordability, such as those in CANCEA's *Shelter Consumption Affordability Ratio* (SCAR) index (discussed in greater details in section 2.3.1).

From a theoretical perspective, new transit infrastructure would decrease transportation costs for surrounding households – a locational advantage – which would cause people to bid up the price for such land[8] (Higgins and Kanaroglou 2016). Although the majority of studies find a positive relationship between transit and land values[xi], there is a large range in the expected uplift in land value, with some even finding negative impacts[9] (Higgins and Kanaroglou 2016).[xii] One reason for the vast differences in outcomes is that studies often consider many stations at once and provide an average land value uplift, when in reality neighbouring stations can see drastically different results, as shown in Table 1 below.

[8] Land value premiums from transit are typically expected over the distance covered by a 10-minute walk from the station, about 1 KM.
[9] The study assumed constant starting value for land and limit the distance from the station to 800 meters.

Table 1 Individual Station Area Variability

Transit Type	Land Value Change	Source
DART LRT in Dallas	-49% to +49%	(Weinstein and Clower 1999)
METRO LRT in Phoenix	-12% to +1639%	(Kittrell 2012)
Metro Rail LRT in Buffalo	-$26 to +$27 per foot closer to a station	(Hess and Almeida 2007)

Why such variability exists can depend on many things. For one, different studies examine different characteristics[xiii], such as transit type and housing type, which leaves gaps for differences such as land use (Higgins and Kanaroglou 2016). However, one major reason for the differences in these studies is the focus on proximity as the contributor to land value increases (Higgins and Kanaroglou 2016). There are two problems with this assumption:

1. **Proximity does not always mean accessibility[xiv]:** For proximity to be positively integrated into land value it must provide access to all locations that people value at an overall lower travel cost. Moreover, if a location is already efficiently serviced by other modes of transportation, such as pedestrian walkways, cycling lanes, or easily accessible highways, the addition of transit may not have a noticeable impact on accessibility (sometimes measured by proxy through ridership[10]) and therefore should not be expected to place a locational advantage on the land value[xv] (Higgins and Kanaroglou 2016).

> Proximity does not mean accessibility. Transit stations need to help you get where you want to go relatively quickly and at a lower cost than other surrounding transportation services (e.g., highways).

2. **External factors may play a larger role in land value uplifts:** Transit-oriented development (TOD) factors[11], can have positive impacts on land value (Bartholomew and Ewing 2011). Such factors create the environment around transit stations, which would provide a positive increase in land value. These other factors could explain the variation in land value appreciation by introducing another variable into the explanation (Higgins and Kanaroglou 2016).

Although the consensus is that transit generally increases land value, most studies really only take into consideration proximity to the transit hub. This produces a wide range of premiums or discounts, even within the same city. The reason for this is that proximity is only one factor of transit's impact. Other factors such as whether there is improved accessibility to amenities, land development policies, urban design, and crime could possibly play an equal or larger role.

[10] If a transit options offers competitive travel times and cost compared to other transportations means then it should be reflected in the use of the service (Higgins and Kanaroglou 2016)

[11] TOD factors include mixed-use zoning, open and public spaces, resource-rich neighbourhoods, and urban design including pedestrian-oriented street design.

1.2.1 LAND DEVELOPMENT AND NEIGHBOURHOOD CHARACTERISTICS

Along a similar theme, the impact of public transit investment on the development of neighbourhoods is still up for debate. Investment in transit infrastructure has the potential to influence neighbourhood characteristics through transit-oriented developments (TOD), which place an emphasis on relatively higher-density housing and proximity to transit alternatives, while dis-incentivizing automobile use and low-density housing (Topalovic, et al. 2012). Moreover, the improvements in travel time and costs made possible by these TODs not only makes housing more affordable through reduced transportation costs but also makes the surrounding region more attractive to both employers and future residents, bringing new employment opportunities and amenities to the region (Graham 2013, Dittmar and Ohland 2004). Among examples of TODs within Canada, surveyed occupants highlighted the proximity to amenities as the prime motivator for moving to the area and developers saw the access to local amenities as the major motivation for making investment decisions (CMHC 2009). It is important to note that when TODs did not succeed in meeting profit expectations, it was due to price increases and delays hindering demand for the area[12] (CMHC 2009)

That being said, theories have also been proposed suggesting that the impact of transit investment on a neighbourhood may work in reverse. By decreasing transportation costs and travel times, people may be more willing to live further away (Graham 2013, Handy 2005). Secondly, by focusing transit development in certain corridors, the region may not see a net gain in the neighbourhood, but rather a redistribution. This is all to say that the impact of transit investment are hard to separate from the impacts of other policies (Handy 2005).

One thing that researchers can agree on is that there are other factors that contribute to the success of transit infrastructure on reshaping neighbourhoods[13] (Handy 2005, Knight and Trygg 1977). Some of these factors include local government land use policies, regional development trends and forces, availability of developable land, improvement in accessibility, positive social conditions, and the physical characteristics of the land (Knight and Trygg 1977, Higgins, Ferguson and Kanaroglou 2014)[14]. A study reviewing twelve cities with light rail transit (LRT) highlighted that although transit developments do have significant impact on the development and land use in regions, a "strong and growing regional economy is an important prerequisite" for station area development (Knight and Trygg 1977, Cervero, Light Rail Transit and Urban Development 1984). Furthermore, among ten TOD developments in Canada, all

> Proximity to transit and local amenities were the top two motivating factors for occupants in TODs, while developers saw access to local amenities as the major factor for investment decisions.

[12] Note that only one out of the ten Canadian case studies on TOD did not meet profit expectations.
[13] Similar to the conclusions reached regarding the impact of transit on land value in section **Error! Reference source not found.**.
[14] Another important factor brought up is that land use developments do not usually occur until several years after transit development and therefore transit operators need to take this into account when considering ridership.

but one were initiated by municipalities, further emphasizing the role of policy in development (CMHC 2009).

An example of this was the development of the Bayview and Don Mills Subway stations on the Line 4 subway in Toronto[15]. A study into the areas surrounding these stations between 1996 and 2006 found that, although they are only 3.4 KMs apart, the lands surrounding Bayview developed into a dense residential, mainly owner-occupied area, while the lands around Don Mills saw little, if any, change in neighbourhood composition. This was believed to be because the Sheppard Subway Corridor Secondary Plan (City of North York 1997) set out different guidelines for each area, envisioning Don Mills as a commercial and employment area, given the existing Fairview mall.

> Transit Investment does not guarantee that transit-oriented development will occur. Other factors such as local government land use policies, physical land characteristics, regional trends, and social conditions, are equally, if not more important than the transit investment itself.

Another unintended impact of transit development on neighbourhood characteristics is crime. As with other factors, theories speculate impacts in both directions. Improved transit could increase crime by allowing criminals to access new neighbourhoods and by creating new "activity hubs" that increase the probability of a crime occurring (Ihlanfeldt 2003, Zukerman 2013). On the other hand, TODs and new employment opportunities could increase the opportunity cost of crime (Ihlanfeldt 2003).

Studies from Atlanta and Chicago found that neighbourhood characteristics play a role in the directionality of transit's impact on crime. Crime decreased in suburban areas and increased in central areas (Zukerman 2013, Ihlanfeldt 2003). Another study on LRT stations in Charlotte found a decrease in crime following transit investment. After an initial modest increase in crime during the construction period, there was a sustained drop-off in crime, within a half mile of the LRT station, following the opening in 2007xvi (Billings, Leland and Swindell 2011).

1.2.2 ACCESSIBILITY: OPPORTUNITIES AND EQUITY

Land development and changing neighbourhood characteristics mean that new amenities and opportunities become available to not only the residents within the neighbourhood but those connected to the transit development. The ease of reaching these amenities define the accessibility of a region and its transit options[xvii] (T. Litman 2008, Handy 2005).

1.2.2.1 Employment Accessibility

[15] For more information on the impact of these two transit stations, please refer to Appendix B

A survey conducted in 2013 found that 76% of Canadians want a reasonable commute time, with 50% admitting that commute is the top factor in choosing one employer over another (Maurino 2013). People are even willing to work more or pay just to reduce their commute time (Harris 2013, Bialik 2016).

Steven Farber, an assistant professor of Geography and Planning at the University of Toronto, has created maps outlining the job opportunities available by different modes of transportation within a given time throughout Toronto[16]. He found that, obviously, having a car allows one to reach a large number of jobs throughout Toronto and surrounding regions like the Region of Peel. There is a magnitude drop in the jobs available for people who must use transit (Levine 2016). Those without cars in the city core and along the subway lines can access 30% of the jobs that those with cars can. As you move further away from the city core and subway lines, this drops to 5-10% of the jobs that people with cars can access[17] (Levine 2016). Farber took his analysis a step further and evaluated how future transit plans would impact this accessibility ratio. The Eglington Crosstown had the biggest impact of bringing areas above the 30% threshold, while the Scarborough subway extension only helped those who live along the transit line and does nothing for those just offsite of the extension (Levine 2016).

1.2.2.2 Equity

Accessibility benefits of transit investment also comes in the form of equity. This means that transit is accessible to vulnerable populations, in a way that allows them to access the amenities and opportunities that come with the investment (T. Litman 2016). Vulnerable populations[18] are increasingly living in suburban areas with less transit access and fewer public services (Hertel, Keil and Collens 2016). By providing accessible transit opportunities to these populations, their mobility barriers are removed and they are able to interact more freely with the economy (CUTA 2013).

> Outside of the downtown Toronto core and along the TTC subway lines, individuals without a car can only easily reach 5-10% of the jobs that those with a car can. Useful transit improves access to the largest population, not only to those along the new transit lines.

For example, accessible transit allows people with mobility issues (e.g., seniors) to visit friends and relatives, reach health care and social services, and participate in recreational and cultural activities. Transit is also more affordable than owning and operating a private car or taking taxis for daily trips, and leaves more disposable income to spend on other needs (CUTA 2013). Accessible transit also allows individuals with disabilities to be able to access job opportunities and education resources. In 2006, the unemployment rate for people with disabilities was 8.7% compared to 5.1% for other adults and an estimated 315,000 Canadians between 15 to 64 years of age with mobility disability

[16] Time limit was set to be 45 minutes

[17] This is based on a ratio (jobs accessible by transit/jobs accessible by car within 45 minutes). A value above 30% is considered desirable, which very few regions in the GTA hit.

[18] Include those with lower incomes living in spatially challenged areas (e.g. "in-between cities"), young and old people, and those who are disabled.

could work but don't participate in the labour force (CUTA 2013). Greater employment income means less affordability pressures and, if more equitably spread, less 'crowding out' in the shelter market.

Further, beyond employment, transit allows access to education, health services, and food. A GTA survey found that public transit was the most commonly used mode of transportation to employment, skills, and language training program services (City of Toronto 2013). Moreover, the survey found that distance, cost, and geographical inaccessibility and under-servicing of transit were barriers to accessing these services. Food is another necessity that has variable accessibility depending on modes of transportation available. If a car is available, food accessibility is not a problem. However, low-income families are less likely to own a car and therefore are highly reliant on other means of transportation, such as walking or transit to reach food stores (Milway 2010, City of Toronto 2013).

2.0 REGIONAL TRANSIT PLAN ANALYSIS

2.1 The Metrolinx Regional Express Rail (RER)

The Metrolinx Regional Express Rail (RER) plan focuses on transforming the current regional GO transit system into one that can address the growing transportation demands of the GTHA more efficiently. Since its inception in 1967, GO transit's rail network has grown from a single rail line into one that connects into 17 transit systems across the many communities in the region (Metrolinx 2015). Historically, the GO transit system has focused primarily on transporting commuters into the Toronto downtown core in the morning and shuttling them back in the evening, with a network of GO buses responsible for the off-peak and contra-direction transportation.

However, there is a growing need to update the current system into one that can accommodate growth in the region more broadly. In 2011, the region had a population of just under 9 million and it is estimated to grow to just under 12 million by 2031, accounting for roughly 80% of the population on Ontario (Statistics Canada 2015, Ontario Ministry of Infrastructure 2013). In addition, the current GO schedule limits options for residents travelling contra-directionally, such that the car still accounts for 70% of all trips around the GTHA and car ownership outside Toronto can be, on average, four to eight times more likely than in the city (James 2015). The resulting increase in car use has created congestion on major highways such as the 401, which is estimated to cost the GTHA between $6 billion and $11 billion per year (Metrolinx 2016, Dachis 2013). Therefore, an updated transit system is needed to accommodate the expanding regional population into one that is more frequent and accessible to accommodate the growing demand on transit.

The RER plan was created to do just that. Over the next decade, five of the seven GO rail corridors are expected to be transformed into services that operate all day, all week, and in both directions in a manner that does not require the consultation of a timetable. In addition to the improved accessibility and efficiency of transportation, the plan outlines the desire to add more tracks and stations, electrify the tracks, use electric locomotives, and add new control systems (Metrolinx 2015). In total, the RER is expected to cost approximately $13.5 billion to construct and $500 million each year to operate (Metrolinx 2015).

Currently, the GO Transit system has 64 stations. Under the RER plan, over 50 new locations[19] have been identified for future analysis and assessment as potential new stations, including 11 on the Lakeshore East line, 8 on the Lakeshore West line, and 10 on the Richmond Hill line (Woo 2015). Adding new stations would allow for an expansion of the current service area which could attract new riders through improved access to the transit system. Another change that would be implemented through the RER plan is the electrification of the rail system. The benefits of electrification include a faster service as electric trains can accelerate and decelerate more quickly and maintain a top speed for longer, which would make GO transit more attractive to commuters (Metrolinx 2016).[xviii]

[19] For more information on the identified locations for new GO stations and selection methodology, please see http://www.metrolinx.com/en/docs/pdf/board_agenda/20150922/20150922_BoardMtg_New_Station_Analysis_EN.pdf

2.2 Scope of the Analysis

Our study investigates Metrolinx' Regional Express Rail (RER) as it affects the SCAR index in the areas surrounding a GO train station. Using CANCEA's *Prosperity at Risk* (PaR), an agent-based 'big data' computer simulation platform, we simulate the connection between future potential housing cost increases and transportation cost decreases in 773 integrated communities across the GGH.

Much of the analysis around transportation costs is dynamic, such that it shows the potential savings depending on the proportion of people who shift from driving to taking the GO train. This provides a sense of which communities will see the largest affordability impacts stemming from the introduction of RER.

2.3 Prosperity at Risk (PaR)

Traditionally, a variety of economic models have been used to analyze the impact of infrastructure investment. These include cost functions, production functions, and growth accounting (Antunes, Beckman and Johnson 2010). Such approaches would suffice if only direct (i.e., construction), indirect (i.e., their suppliers), and the follow-on induced economic effects (i.e., workers go buy groceries) of building infrastructure were relevant. However, the economic impact of an infrastructure asset being *used* can go well beyond the economic impact of *building* it. Such effects are called 'system effects' (see Smetanin and Yusuf (2016)) which include variables not traditionally examined under the economic lens, such as 'productivity coupling' and consequent impacts upon asset values.

While such analysis is consistent with the more traditional approaches, it extends the scope of the impacts through the use of the infrastructure assets by considering:

- The direct consumption of public infrastructure by industry as an input to production of goods and services, as well as their transportation – as used in traditional economics (input/output matrices);
- The indirect consumption of public infrastructure by industry and governments in the movement of their employees; and
- The indirect consumption of public infrastructure by industry and governments in the health and skills development of their employees (current and future).

Metrolinx' Regional Express Rail will see five of the seven GO rail corridors transformed into services that operate all day, all week, and in both directions

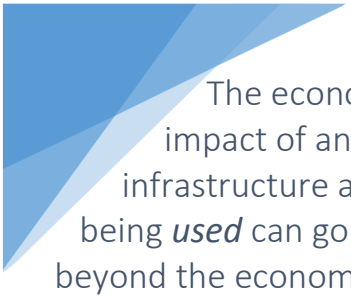
A broader coupling of public infrastructure with production activities exists when infrastructure is a constraint on production.[xix] That is, when public infrastructure is regionally insufficient, current and future production that can occur in that region is constrained. It is the indirect consumption of public infrastructure by industry, households, and governments that is a key component of the 'systems effects' alluded to earlier.

Additional systems effects occur as asset values may change with infrastructure investment, which can have impacts upon household, industry and government investment and debt, and private migration choices. For example, the value of homes near a new transit stop increase in many cases. This value proposition is particularly evident in the presence of existing public infrastructure deficits and a growing population.

Such systems effects require the identification and accounting of both financial (e.g., realized input and output, investment/debt decisions) and non-financial events (e.g., expected demand, expected supply, policy and planning choices, activity location choices). Additionally, the fact that households, industries and governments have to compete with each other under their own unique budget constraints (e.g., income, expenses, assets, ability to borrow) adds an additional layer of complexity which must all be reconciled in order to construct and simulate an internally-conserved, consistent, and cohesive system.

In order to simultaneously account for many of the economic impacts generated as a result of public infrastructure investment and the unique constraints on the economic players as they compete, agent-based modeling is employed. The ability to measure and understand such outcomes and manage the computational complexity required is at the heart of *Prosperity at Risk* (PaR). Appendix A includes a stepwise walk-through of the PaR approach.

PaR is a cutting-edge and powerful agent-based simulation platform for geo-spatial socioeconomic analysis. In slightly plainer language, it is a complex "big data" computer system that simulates the interactions of more than 40 million virtual agents (individuals and households, corporations, governments, and non-profit organizations) that are encoded with behavioural rules that enable them to make decisions, act based on those rules, and be influenced by the actions of others. Each agent has over 850 traits, and interacts with other agents across 235 industries and 440 commodities within 5,000+ census areas across Canada. Per step in time, this equates to over 19 billion interaction measurements, including the buying and selling of goods or an individual paying taxes. But it does so by scrubbing, linking, and testing masses of data and focusing precisely on the key drivers of behaviour. Further, agents' behavioural traits, such as their confidence in achieving outcomes or their tolerance towards risk (under normal and near-ruin circumstances) may change or evolve due to local circumstances or external stimuli, allowing unanticipated behaviors to emerge. These are only identified by way of experimental simulation.



The economic impact of an infrastructure asset being ***used*** can go well beyond the economic impact of ***building*** it. Such effects are called 'system effects', and include variables not traditionally examined, such as 'productivity coupling' and consequent impacts upon asset values.

This allows PaR to capture rare but significant events that result from unlikely synergies between risk factors. Such low-frequency, high-impact events constitute the so-called "long tail" of the risk distribution, which traditional methods to estimate risk fail to capture. Estimates are inaccurate because of the law of small numbers, that is, the tendency to draw broad conclusions from a

tiny number of events. PaR, with its ability to run millions of scenarios enables the long tail to be not only quantified, but distilled from either a single cause or from interconnected risk factors and cascading failures (e.g., herding or panic).

2.3.1 WHAT DOES 'AFFORDABILITY' MEAN?

In this evaluation, housing affordability will be quantified using CANCEA's SCAR index. The SCAR index more completely reflects both the consumption costs of satisfying shelter needs and households' actual disposable income after payments for things like taxes, food, clothing, and healthcare are made.

$$SCAR = \frac{\text{Shelter consumption costs}}{\text{Discretionary net income after other necessities}}$$

Shelter-related consumption costs: Unlike other affordability indices, the SCAR Index differentiates shelter consumption from ownership by considering rental costs for tenants, and imputed rent among homeowners who act as their own landlords[21]. Other shelter-related consumption costs in the SCAR index include utility expenses, maintenance and repair costs, and property taxes. In addition, as households must travel from their residence to reach necessary amenities and places of work, transportation expenses are also included.

Discretionary net income after other necessities: This represents income available to pay for the consumption costs of shelter. It is calculated as after-tax income less financial obligations (such as debt repayment) less other necessary expenses: food, clothing, private healthcare costs, and essential non-shelter employment costs.

In anticipation of developing state-of-the-art simulations that will quantitatively connect and reproduce all of the major affordability factors, the SCAR index was decomposed into factors that influence it. These factors all have a role in the complex interactions that affect the affordability of shelter. Please refer to Table 2 for information on the components and influencing factors of the SCAR Index.

For a more in-depth overview of the SCAR index and past evaluations using SCAR, please refer to CANCEA's research report, "Understanding Shelter Affordability Issues: Towards a better policy framework in Ontario" (Smetanin, Moca, et al. 2016), which introduced the SCAR index, as well as related CANCEA bulletins[22,23].

[21] This concept is already in use as a component of GDP measurement by Statistics Canada, although further CANCEA research is expected to suggest revisions to the methodology.
[22] CANCEA bulletin #5: Shelter Affordability Across Canadian Provinces – http://www.cancea.ca/?q=node/102
[23] CANCEA bulletin #4 – http://www.cancea.ca/?q=node/96

Table 2 Components of SCAR Index

SCAR Index	Components	Influencing Factors
Shelter consumption costs	• **Actual rent** • **Imputed rent** • **Maintenance, repair** • **Insurance** • **Utilities** • **Transportation costs**	• Population growth • Demographic change • Shelter stock, type, state of good repair • Shelter expectations (needs & wants) • Location, proximity, transportation • Shelter formation, type • Density • Rent formation – actual • Rent formation - imputed • Investment (local & foreign), return expectations • Factors of supply (land, materials, labour, private capital, public infrastructure) • Government agency policy (monetary, prudential) • Federal government policy (immigration, taxation) • Provincial government policy (factors of supply, planning, taxation) • Municipal government policy (factors of supply, planning, taxation) • Electricity, natural gas, water, sewage • Proximity costs (eg. transportation) • Insurance
Discretionary net income after other necessities	• **Income from all sources** **less** • **Taxation** • **Finance obligations** • **Food** • **Clothing** • **Private health care** • **Non-shelter essential employment costs**	• Population growth • Demographic change • Productivity trends • Labour demand • Production levels • Private capital attraction • Wage/income formation • Job quality • Non-shelter essential employment costs (eg. daycare) • Income and wealth inequality • Household operating costs and debt • Interest rates, inflation • Dividends, transfers • Capital gains/losses • Government agency policy (monetary, prudential) • Federal government policy (economic development, labour, immigration, taxation, re-distribution) • Provincial government policy (economic development, labour, taxation, re-distribution, health) • Municipal government policy (economic development & related taxation)

2.4 Data Sources

The advantage of using agent-based modelling, more specifically PaR, is that a larger amount of data from different sources can be used to "train" (i.e. parameterize) the agents in the platform. PaR uses available Statistics Canada data on demographics, national balance sheet accounts, current and capital accounts, financial flow accounts, income tables, input-output tables, labour force statistics, among many others.

Table 3 Relevant Statistics Canada Data used in PaR

Households	Economic	Capital
Demographics (e.g., population, birth, death, inter-national/provincial migration all by age/sex/location): 051-: 0001, 0002, 0011, 0012, 0013, 0019, 0062, 0063, 0064, 0065; 052-0005, 0006	**Business financial characteristics** (e.g., balance sheet and income statements, dynamics, employer businesses, contribution to employment): 187-: 0001, 0002; 527-: 0001, 0002, 0005, 0006	**Housing data** (e.g., CMHC housing starts/completions, lending rates, average rents): 027-: 0001, 0006, 0008, 0009, 0011, 0012, 0013, 0015, 0034-0053
Health & Mortality (e.g., health profiles by age/sex/region, death by cause, location, age/sex, income): 102-: 0521-0538, 0540, 0542, 0552, 4503; 105-: 0502 1200; 82-: 213, 228	**Labour force** (e.g., employment by age/sex, location, industry): 282-0002, 0008, 0076; 383-: 0030, 0031	**Capital and repair expenditures** (e.g., by province, asset type, and industry): 029-: 0005, 0035, 0039, 0040
Household financial characteristics (e.g., charitable donators, savers, investors, family characteristics by type, composition, income, and age of children, seniors' characteristics, RRSPs and capital gains, composition of assets): 111-: 0001, 0002, 0005, 0008-00014, 0022, 0030, 0032-0034, 0036-0039, 0042; 202-0407; 205-: 0002, 0003	**Economic accounts** (e.g., GDP, financial flow accounts, national balance sheets, current and capital accounts by type of organization, government revenue and transfers: 378-: 0119, 0121, 0126; 379-: 0023, 0028; 380-: 0063, 0071, 0072, 0075, 0076, 0079-0082, 0087; 384-: 0011, 0037, 0038, 0040, 0041, 0043, 0044; 385-0032	**Flows and stocks of fixed capital** (e.g., residential, non-residential by province, asset type, and industry, gross fixed capital formation): 030-0002; 031-: 0002, 0003, 0004, 0005, 0006, 0007, 0008, 0009; 380-0068
Household spending (e.g., by household type, tenure, size of residence, location, income quintile): 203-: 0001, 0021-0028, 0030, 0031; 380-: 0067, 0085	**Prices** (e.g., consumer price index, industrial product price indices): 326-0021; 329-: 0075, 077	
	Input-output (e.g., demand categories, supply-use, by industry, commodity, province): 381-0009, 0010-0016, 0022, 0023, 0028, 0029, 0030, 0031, 0033, 0035; 386-0003	

2.4.1 TORONTO REAL ESTATE BOARD (TREB) DATA

In addition, summary community-level data from the Toronto Real Estate Board (TREB) was provided to supplement the quantitative analysis of the impact of a regional transportation plan on housing affordability in the GGH. TREB provided multiple listing service (MLS) data for the region being analyzed at an aggregated and anonymized level. The summary metrics provided include, among others, counts of sales and listings, average selling price, average days on market, and average selling price-to-listing price ratio.

TREB data on monthly sales, aggregated to the community level[24] from 1986 to 2016 were used. A total of 1,015,004 records were provided. Of these, 15,897 were discarded because of incomplete data (such as a community location being 'Unknown') or were in a TREB 'municipality' with fewer than 500 sales over the 30 year dataset. Table 4 summarizes the characteristics of the data set used in this analysis. As detailed analysis of the qualitative aspects of the data set has been carried out frequently by TREB, such as in their monthly updates (Toronto Real Estate Board (TREB) 2016), this report will forgo such an analysis and focus on the impact of transit on shelter affordability.

Table 4 Characteristics of Data Set

Characteristic	Value
Total Number of Records	1,015,004
Number of Records Used	999,107
Number of Areas	12
Number of TREB 'Municipalities'	87
Number of TREB 'Communities'	773
Number of Home Types	6

It is important to note that TREB's primary market area covers more than just Toronto, and includes the Regions of Halton, Peel, York, and Durham, Town of Orangeville, and the five south Simcoe County municipalities of Adjala-Tosorontio, Bradford West Gwillimbury, Essa, Innisfil and New Tecumseth. Therefore, any listings and transactions outside of this primary market area may not provide a full accounting of market activity.

The data provided by TREB was broken down by other attributes, such as year/month of sale, number of bedrooms, and bathrooms.

[24] See http://trebhome.com/buying/district_map/index.htm for TREB community definitions

2.4.2 TRANSIT SCORES

In order to evaluate the impact of a regional transportation plan on housing affordability, the current availability of transportation options and their proximity to housing needed to be determined and matched to the current housing prices in TREB regions. Using TREB Area Maps[25] and MLS listings[26], transit scores were matched to TREB regions throughout the GGH. The MLS listings site was used to find listings in TREB regions and the transit score of the listings within a TREB region were averaged in order to determine the transit score of that area.

Transit scores were determined using 'Walk Score', a website that provides scores for a property, measuring how easy it is to walk to amenities, such as grocery stores (the "Walk Score") and how well a location is served by public transit (the "Transit Score"), on a scale of 0 to 100[27]. For the purpose of this evaluation, only the Transit Score® was used. The Transit Score® for a specific point is calculated using an algorithm that summarizes the usefulness of nearby routes, including distance to the nearest stop, frequency of routes, and type of routes (Walk Score 2016). These determining factors are then multiplied together and normalized onto a 0 to 100 scale. A general scale of the Transit Scores® are as follows:

Table 5 Transit Score® Range (Walk Score 2016)

Transit Score®	Description
90-100	World-class public transportation
70-89	Transit is convenient for most trips
50-69	Many nearby public transportation options
25-49	A few nearby public transportation options
0-24	Minimal transportation options

It should be noted that even within TREB regions, transit scores are highly variable and based on the location of the transit source, such as train stations or bus routes. For example, in the Lynde Creek region of Whitby, transit scores ranged from 0 to 43 with higher scores occurring closer to the GO station and lower scores occurring as you move further away from the station (i.e., as accessibility decreases).

For more information on the methodology of the transit score, please refer to their methodology section, available at https://www.walkscore.com/transit-score-methodology.shtml .

[25] Available at http://trebhome.com/buying/district_map/index.htm
[26] Available at https://www.realtor.ca/
[27] An overview of Walk Score is aavailable at https://www.walkscore.com/

2.4.3 OTHER DATA SOURCES

In order to calculate the cost savings associated with mode shifting caused by Metrolinx' RER, the following data sources were used:

Table 6 Other Data Sources

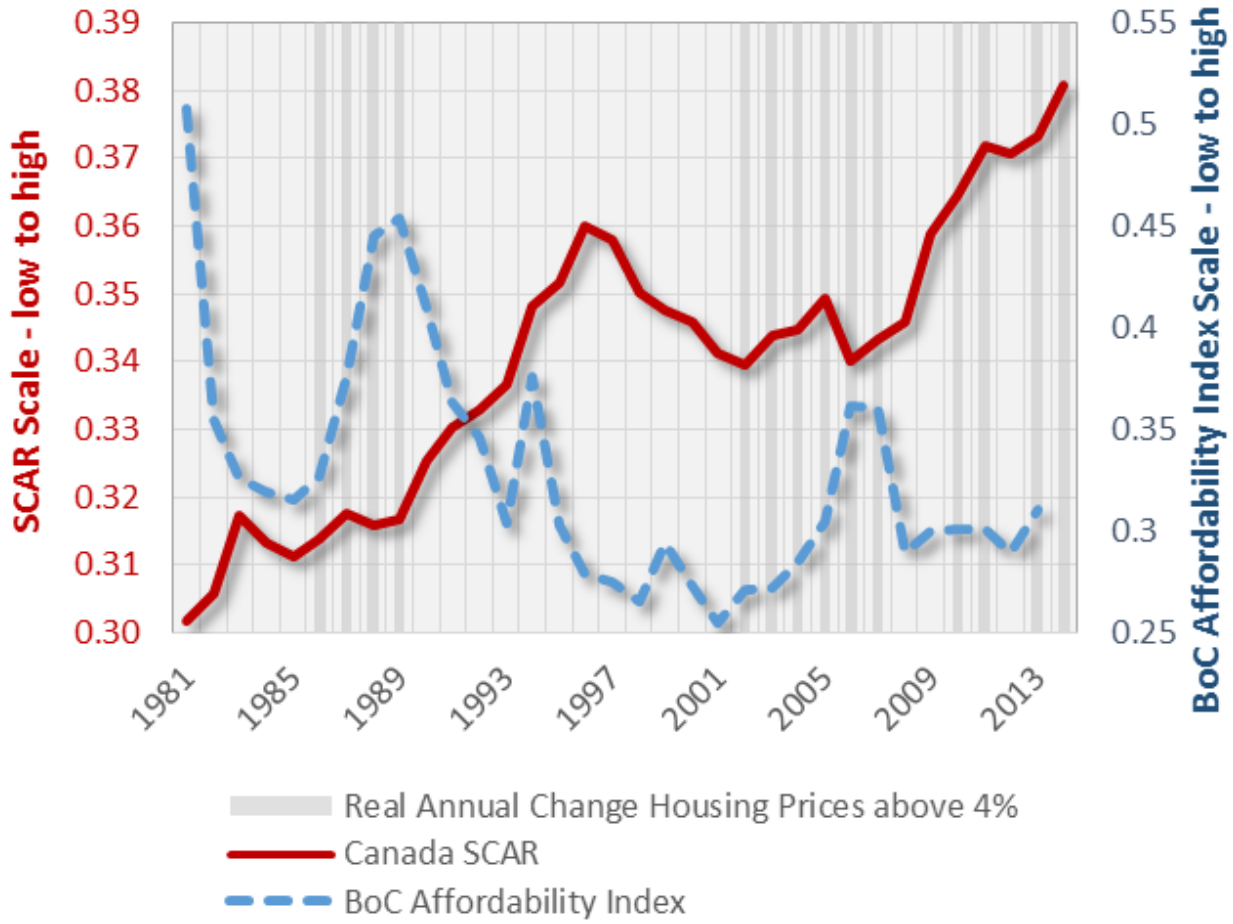
Data	Source
Monthly Cost on Presto	GO Fare calculator[28]
GO Train Ridership	(Metrolinx 2013)
Auto Mode Share	(Metrolinx 2013)
Actual Days Worked	Sick days (Nguyen 2013) and Vacation Days (Expedia 2015)
Cost of Car Ownership	CAA Cost calculator[29] and (CAA 2013)
Parking Costs	Average of monthly parking options around Union Station at "WhereiPark"[30]
RER service changes	GO RER business case (Metrolinx 2015)

[28] GO transit fare calculator aavailable at http://www.gotransit.com/publicroot/en/fares/farecalculator.aspx
[29] CAA driving cost calculator available at http://caa.ca/car_costs/
[30] WhereiPark calculators are available at https://www.whereipark.com/?lat=43.650507823374234&lon=-79.38012600000002&zoom=15

3.0 METHODOLOGY AND RESULTS

Many affordability indexes consider housing prices as the key determinant of housing affordability and do not capture the breadth of costs that households incur to make a structure a home (such as transportation). As evident by the dotted blue line in Figure 2, the Bank of Canada's housing affordability index shows that housing affordability is resting near its long-term average. The Bank of Canada's affordability index takes into consideration housing related costs such as mortgage payments plus utility fees (Bank of Canada 2016), and because interest rates are currently low, so are carrying costs for mortgages. Meanwhile, SCAR, which reveals affordability pressures to be at an all-time high, takes into consideration more than just housing costs (refer to Table 2 in Section 2.3.1) because affordability isn't just a matter of housing costs but rather the cost of making shelter useful.

Figure 2 Comparison of SCAR with Bank of Canada Affordability Index



In the sections below, we provide a quantitative analysis on how transportation costs, an equally important cost in the use of shelter, impacts housing affordability in the GGH.

3.1 Factors Affecting Prices

In order to estimate the effect of transit accessibility on affordability across the GTHA, a Bayesian generalized linear model is used. The idea behind a Bayesian approach is that rather than estimating specific values for parameters (i.e., a more static estimate of how much one factor influences another, all else being equal) as is done is many statistical analyses, probabilistic distributions are estimated (i.e., a *range* of likely impacts of one factor on another, all else being equal). This naturally captures a more realistic range of behaviour, where individual purchasers may value various housing characteristics differently to other purchasers (e.g., unmeasured factors that influence how a purchaser "feels" about a bedroom), and can also account for factors not explicitly included in the analysis. Technically, the Bayesian approach estimates the effect of various factors, with a probabilistic range, on the sale price. In particular,

$$P = exp\left(\sum_i \mathcal{N}(\beta_i X_i, \sigma) + \mathcal{N}(I, \sigma)\right)$$

where the sum is over the following factors (the X_i's in the formula):

- Time (to capture general market shifts)
- Housing Type (e.g., condo, detached, semi-detached, townhouse)
- # bedrooms
- # bathrooms
- Community
- Transit Score
- Previous sale prices

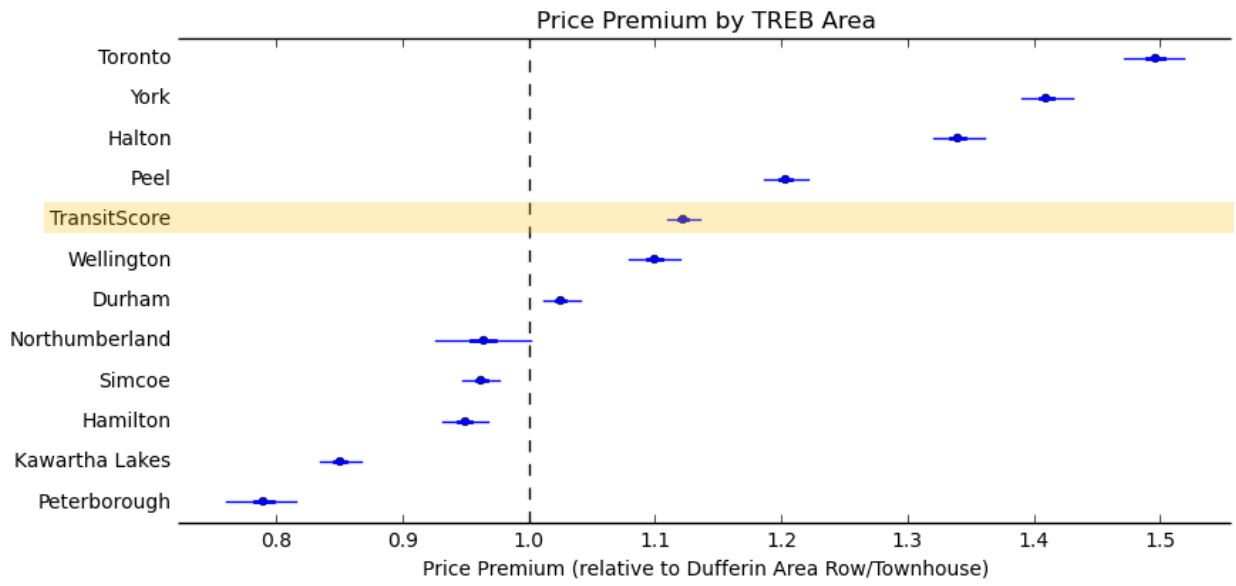
Note that since the model assumes that underlying prices have been growing exponentially with time, and are modified by housing characteristics, location, and transit access. In addition to transit accessibility, there are two categories of factors which were considered: housing type, and location. Figure 3 compares the impact of housing factors on prices. To interpret the figure, the peak of the distributions (roughly the mid-point) is proportional to the contribution to the house price relative to a reference regions (Dufferin) and housing type (attached row and townhouses), and a transit score of 0. The choice of reference factors is arbitrary and does not affect the conclusions but simply shifts the distributions. A value above 1 (i.e., to the rights of the dashed lines) indicates that the specified factor acts as a *premium* to increase the prices relative to the reference case, whereas a value below 1 indicates a *discount*.

3.2 Transit Housing Premium

More importantly for this analysis, when considering GGH housing prices only, the contribution of improved transit access is shown to be always positive (controlling for other factors), with transit scores of 100 resulting in a price premium of about 12% over the reference case (with a transit score of 0). However, it is important to note that this is an average indicator across the GGH. As indicated in Section 1.2, the specific local characteristics of the transit could locally affect prices to a greater or lesser extent.

Moreover, not surprisingly, the premiums for regions themselves have a strong effect on house prices with Toronto having the highest premium and Peterborough the largest discount. As is evident in Figure 3, while top-notch transit imparts a 12% premium on housing (compared to the reference region and housing type), it pales in comparison to the premium and discount in Toronto (just over 50%) and Peterborough (-20%), respectively. As discussed in sections 1.1 and 1.2, research highlights that transit does, generally, have a positive impact on affordability, but the cases where no impact or even a negative impact occurs highlights the fact that other factors contribute to the premiums placed on land value.

Figure 3 The historical average price premium of TREB areas compared to transit score. The reference point corresponds to Dufferin with a transit score of 0.



Such is the case with Toronto and Peterborough. These two areas exhibit a large premium and discount, respectively, which cannot be completely explained by the factors in our data. The regional factor in the analysis captures many characteristics of the neighbourhood not explicitly included in the model. For example, the geographic divisions implicitly capture the effects of factors such as schools, crime, and average house and lot sizes. The data set used in this analysis did not include such factors but the methodology does not preclude them. Therefore, upon further examination, it is important to highlight some differentiating factors that could be contributing to this large gap, such as walkability and employment.

Transit can impart up to a 12% premium on housing. However, it is overshadowed by premiums given based on region (i.e., Toronto, York, Halton, and Peel) and single-detached homes.

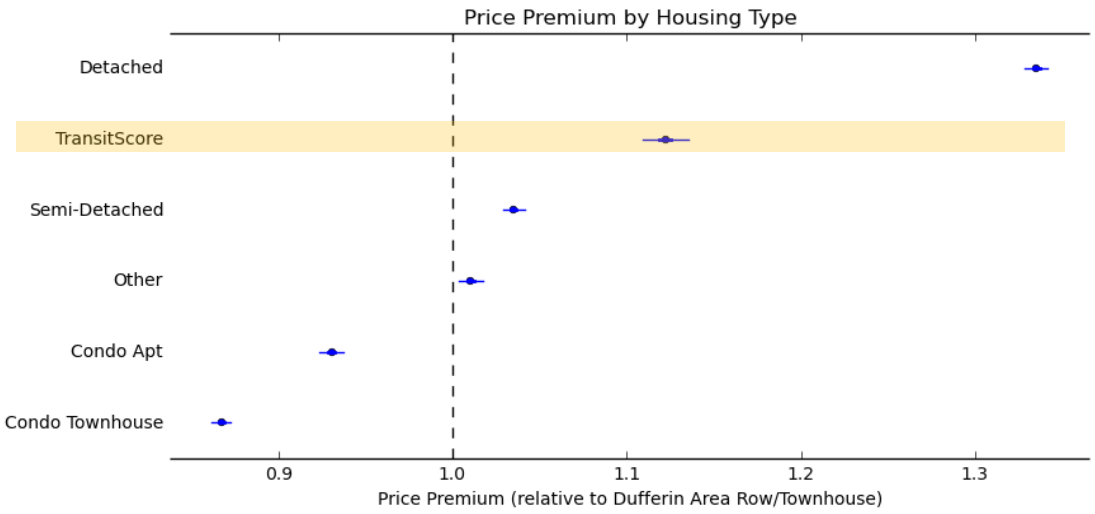
For example, Toronto has an average walk score of 71 (with some locations reaching as high as 99), while Peterborough has an average walk score of 47[31]. With an overwhelming number of people preferring to live in neighbourhoods with walkable designs, it is no surprise that Toronto carries such a premium (Burda and Singer 2015). A study in the U.S. found that a one point increase in walk score was associated with a $500-$3,000 increase in home values (Cortright 2009). In addition, areas with both good walkability and extensive transit see even higher premiums, something prevalent in many areas in Toronto (Cortright 2009).

Likewise, locations that are close to current and potential jobs are seen as more favorable to buyers and renters and therefore convey a premium due to their increased accessibility (Higgins and Kanaroglou 2016). In fact, people are willing to work three hours more per day to commute less (Harris 2013). One study done in New York City found that people were willing to pay an additional $56 a month just to trim a minute off their commute time each way (Harris 2013, Bialik 2016). This further illustrates why a large premium exists in Toronto, while Peterborough faces a discount. Toronto, in 2004, had an estimated 22.8 jobs per hectare compared, while Peterborough only has 8.8 jobs per hectare (Hess, Sorensen and Parizeau 2007).

This was similarly found in a study done by the Royal Bank of Canada and the Pembina Institute which found that residents of the GTA would prefer urban, highly connected shelter units. If housing costs were ignored, 83% of respondents would choose a modest house or condo in the city that allows for walkable access to amenities and rapid transit (Pembina 2012). When housing price is taken into consideration, 54% would still choose shelter that has walkability and access to transit (Pembina 2012).

Similarly, Figure 4 shows the impacts of housing type compared to transit. Single-detached homes demand a significant premium relative to the reference cases. However, transit more significantly affects price, relative to the reference types, than other house types.

Figure 4 **The historical average price premium of housing types compared to transit score. The reference point corresponds to row/town houses with a transit score of 0.**

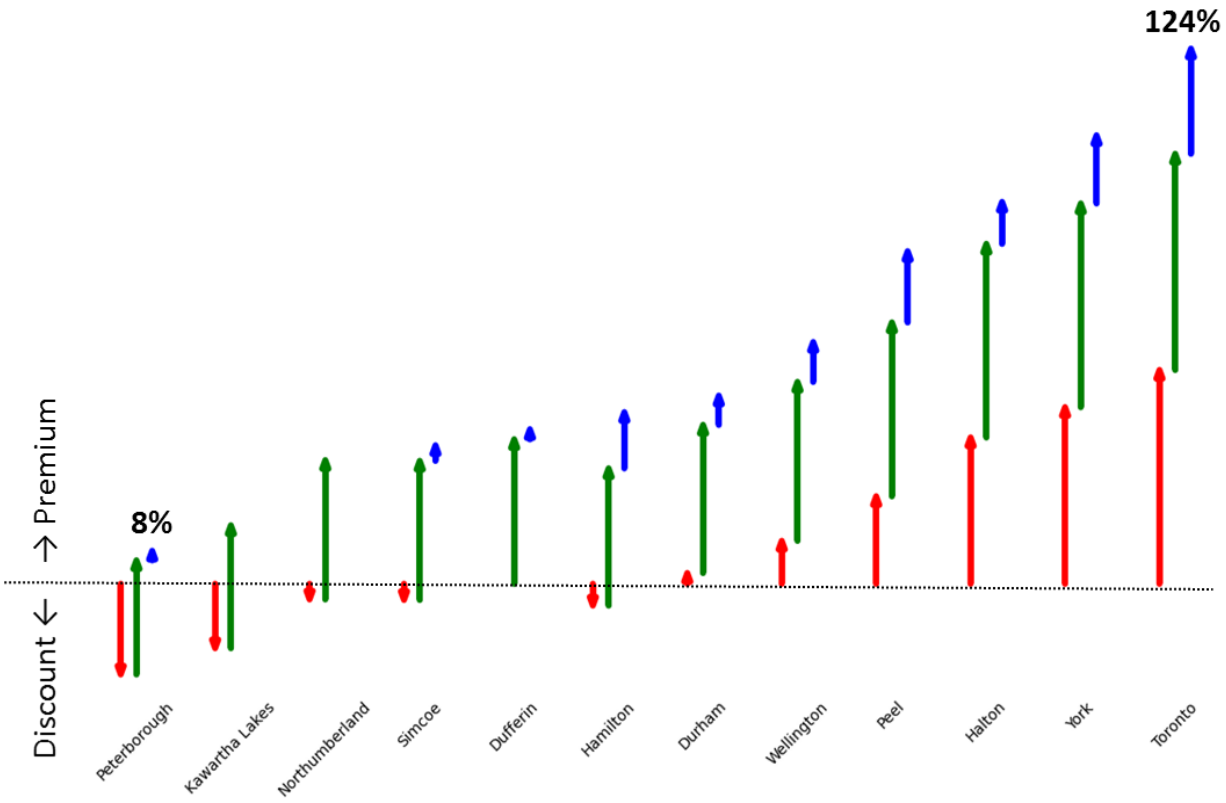


[31] Walk Scores are available at https://www.walkscore.com/

It is important to note that the net price premium is the product of the premiums for individual factors. For example, a single-detached home in Simcoe with a transit score of 25 would have a net premium of 36%, made up of the premium from the detached home (33%), the premium from transit score (6%), and the discount for Simcoe Area (-4%)[32], relative to the reference type of attached row/townhouses in Dufferin.

For example and comparison, Figure 5 illustrates the average premiums of detached homes with the best available transit in each region and shows how the premiums for various factors push and pull the *overall* housing premium (relative to the reference case). For example the premiums for some regions pull overall premiums down, whereas the premiums for detached homes and transit accessibility (where it exists) push it up. In the end, such homes in Peterborough have an overall premium of 8% vs 124% in Toronto.

Figure 5 Transit, Housing Type, and Region Premiums



Within the City of Toronto itself, transit scores have a much smaller impact due to the fact that most of the city already has relatively high transit scores compared to the broader GGH. Figure 6 and Figure 7 show the contributions to prices within Toronto by TREB municipality and house type. The large premiums associated with the C09 and C12 regions of the city likely reflect the larger houses generally found in those neighbourhoods. The general trend of the central regions to rank highly indicates a general preference to be centrally located even after transit is taken into account.

[32] 1.32 = 0.96 (Simcoe premium) x 1.33 (detached home premium) x 1.03 (25% of the transit premium)

Figure 6 The historical average price premium of TREB areas compared to transit score.

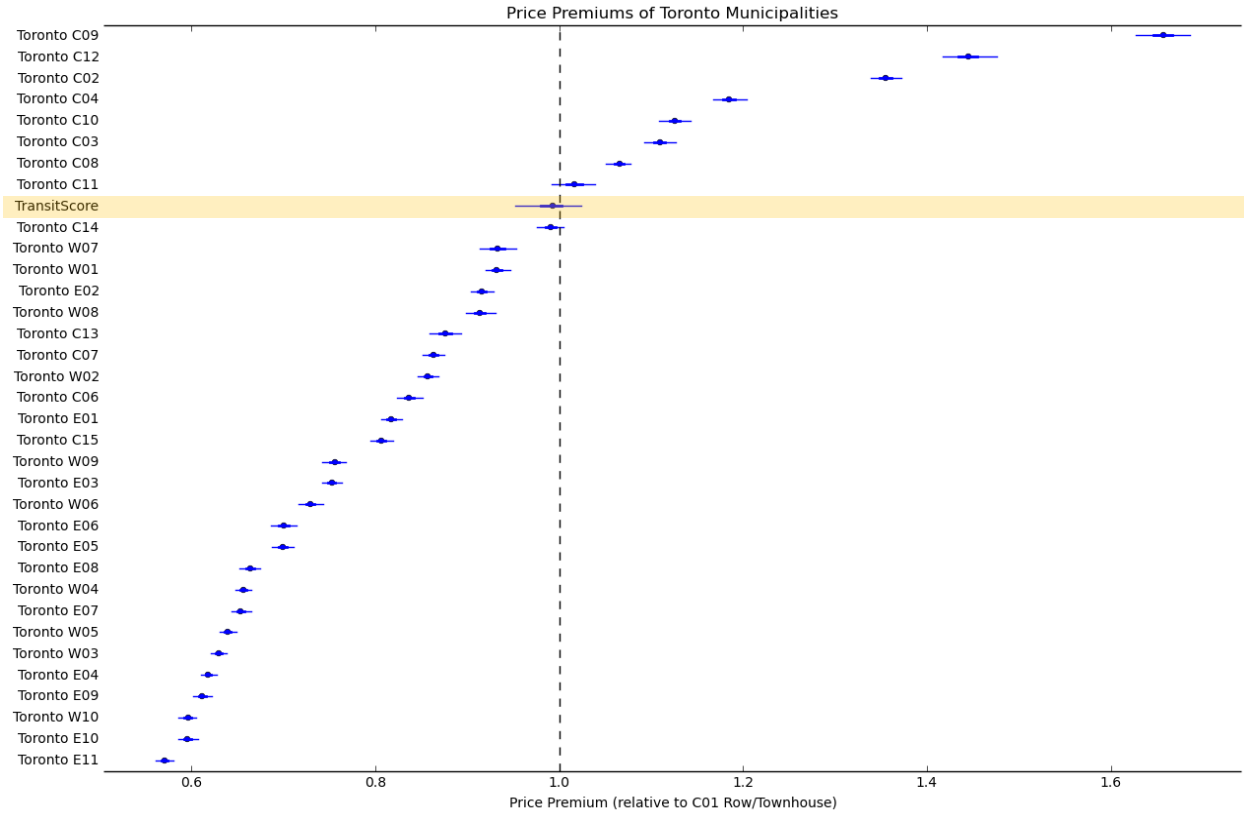
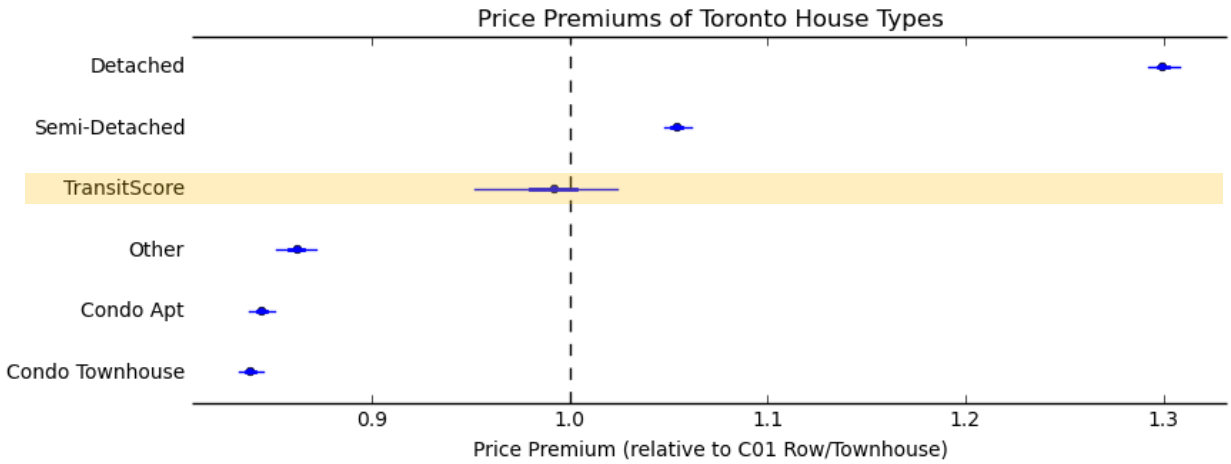


Figure 7 The historical average price premium of housing types compared to transit score



Overall, while transit accessibility is not the primary driver of prices in Toronto (given that within the city, transit scores are relatively high and there are other location factors driving premiums), it does contribute positively to the price that people are willing to pay for a property. A key question is then: does this increase in prices attributed to transit accessibility improve or hinder shelter affordability?

3.3 Impact of Regional Express Rail on Housing Affordability

At first glance, the conclusion that transit accessibility can act to increase house prices in the GGH seems like a detriment to affordability. However, as was mentioned previously, shelter affordability is not only about housing prices, but also the costs of factors that are needed to make shelter operational, such as the cost of transportation. If a GGH resident is able to switch from commuting by car, with an annual cost estimated to range from $3,000 to $18,000 per year depending on distance travelled (CAA 2013) to transit (with reduced car use) with an annual cost of $1,500 to $7,000, there is the opportunity for significant savings (see the case examples below).

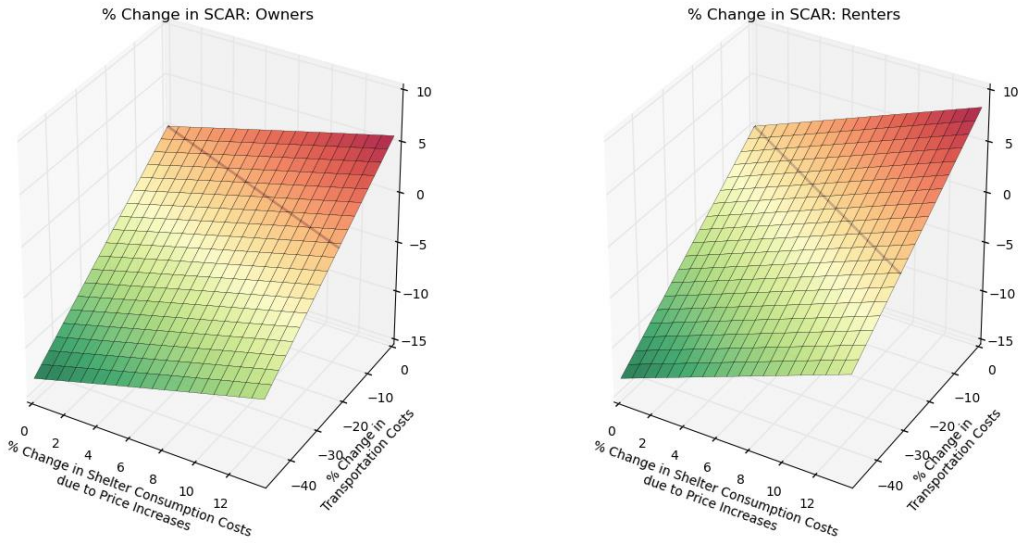
As it is unknown exactly how transportation costs will change (due to uncertainty as to who exactly will shift modes), a sensitivity analysis can be performed to investigate the conditions in which shelter affordability, characterised by the *SCAR* Index, improves given access to transit as the planned and potential RER is implemented. Note that in order to isolate the effects of transit, income and other factors involved in SCAR remain unchanged across the scenarios. For example, wages earned in the case with no RER are the same as with RER.

In addition to the uncertainty in transportation costs, the analysis in the previous section resulted in a distribution of possible values of housing prices to transit response. Figure 8 presents how average shelter affordability is affected by both transportation costs, and the estimated range of shelter-related consumption costs based on the transportation-induced premiums due to the presence of improved transit. The left panel shows the impact on owners while the right panel shows the impact on renters.

The estimated improvement in affordability (due to RER) is 1.5% in aggregate for households around GO stations outside Toronto, while similar households in Toronto see a slight worsening in affordability of 0.1% in aggregate.

Running sensitivity analysis for households, those that can be induced to shift from cars to transit see large improvements in their affordability (green) while those that don't see affordability pressures increase slightly (red). Some break even (line). If there is no mode shift (i.e., commuters still use their cars as opposed to using the GO train), owners will see their affordability worsen by 0.4% for every 1% increase in shelter costs, while renters will see their affordability worsen by 0.6% for every 1% increase in shelter costs. The difference between how renters and owners are impacted illustrates a difference in likely behaviour for owners and renters. If, for example, the change in shelter consumption costs increases by 12%: owners must reduce transportation costs by 19% to see overall affordability unchanged, while renters must reduce transportation costs by 27% to see overall affordability unchanged.

Figure 8 **% Change in SCAR depending on change in net transportation spending and shelter consumption costs. Recall that smaller SCAR values are better so a decrease in SCAR is an improvement in affordability.**



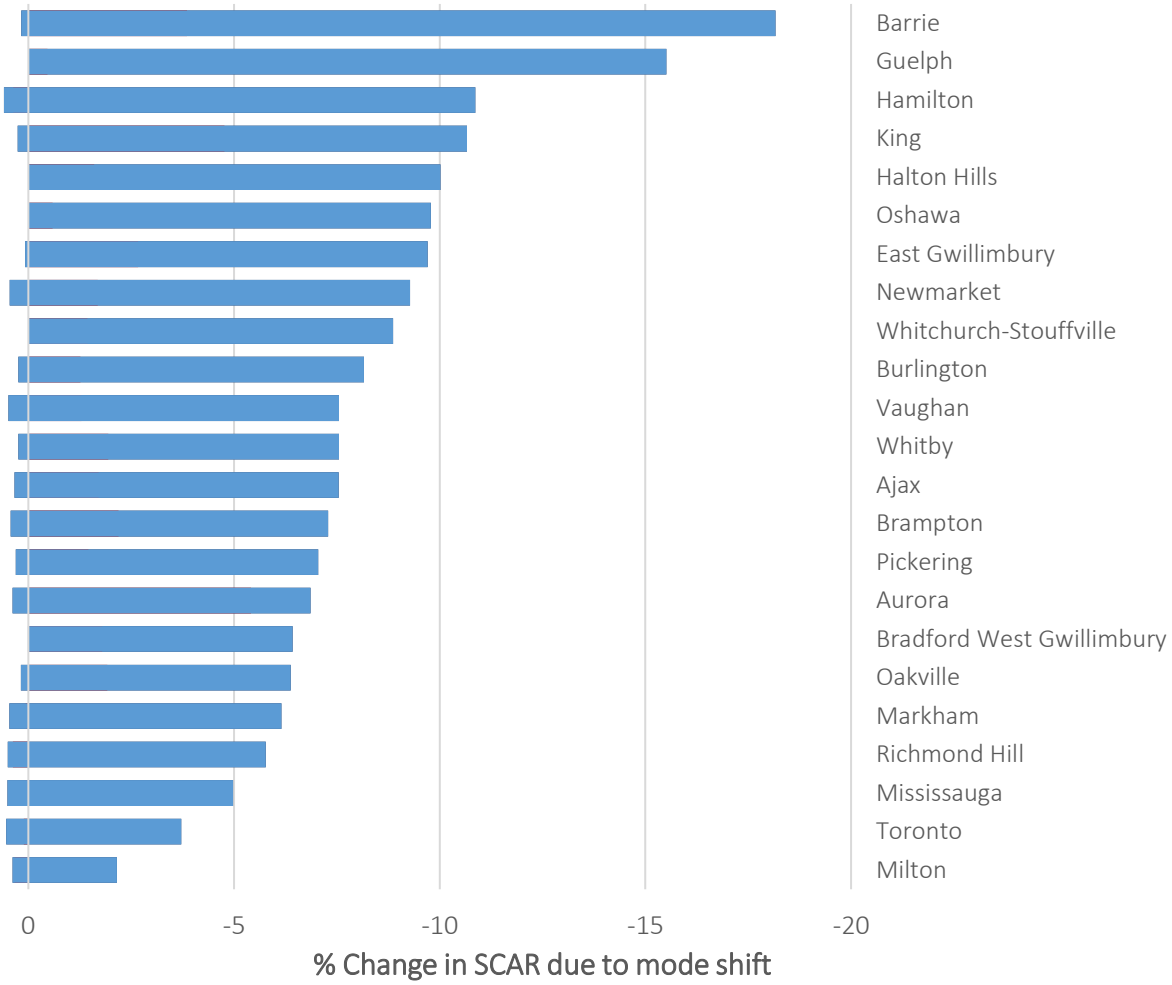
Since SCAR uses a measure of shelter consumption rather than investment, changes in house prices have a relatively minor impact on affordability for owners if there is no savings on transportation costs. However, for renters, if the cost of rent follows the changes in house prices, they would experience a more significant worsening in affordability if there were no transportation cost savings.

Each of the 773 TREB communities in the analysis is impacted differently through different transportation costs and changes in transit accessibility. People that currently drive larger distances have the largest opportunity to reduce transportation costs while regions that are currently poorly served by transit may have a larger impact upon prices. Based on Metrolinx' business case for RER, when taken as an aggregate, the RER is expected to entice about 10% of the population commuting to Toronto by car to use GO Train services (due to increased transit accessibility) but only 1% of car commuting residents of Toronto (because of relatively good existing transit). The importance of policy and local transit-oriented developments then becomes very clear. At the level of individuals who change their commute from a car to taking the GO train, the affordability benefits are significant (accounting for changes in the SCAR index such as changes in housing and transportation costs).

Unsurprisingly, individuals who live in areas much farther away from Toronto – such as Barrie, Guelph, and Hamilton – could see significant improvements in affordability (by shifting from driving to taking the GO train), whereas those largely served by good transit (e.g., Toronto itself) can only see slight improvements in affordability. However, this largely depends on the building up of these communities around the stations to maximize the likelihood of mode shift. (Note that it is assumed that people will still own cars but drive

much fewer kilometers.) In contrast, regions closest to the downtown core of Toronto see the smallest benefit (partly because, as discussed above, the city core is relatively well served by transit already).

Figure 9 **Variation of potential impact on individual affordability for each TREB municipality with a GO train station (lower values are better)**



Expanding RER could positively influence overall shelter affordability for those people who are able to more efficiently access transit. This could be either through local transit in the neighbourhoods around the stations, or through intensification at the stations themselves.

As discussed in the following sections, the improvement (or worsening) in affordability depends on how much mode shift occurs, both by location and by individual households.

Transportation Cost Savings: Case Examples

The following three people all work in the same office on the east side of downtown Toronto, about a 15 minute walk away from the central rail hub, Union Station.

Shari

Shari lives in eastern Toronto, near Highway 401, about half way between the Rouge Hill GO Station and the Toronto Zoo (about 3.5km, or a 6 minute drive/10 minute bike ride/45 minute walk to each). Given a lack of walkable amenities, plus the fact that many of her friends don't live nearby, she owns a small car. She has three options to get to work: drive, take local transit (the TTC), or take regional transit (GO train).

1. Drive: She drives 32km each way, at a cost of $0.30/km for gas, maintenance, and insurance, plus $200/month for parking, for an annual operating cost of around $7,000 a year. The trip takes her 35-55 minutes door-to-door each way in rush hour, depending on traffic.
2. Take local transit (the TTC): She waits for the 85 Bus, transfers to the 86 bus, transfers to the line 2 subway, before transferring again to the 75 bus. She only spends $1,700 a year on monthly passes (minus a few hundred dollars back at tax time). But the trip takes her 90-115 minutes door-to-door each way in rush hour, depending on the busses (scheduled every 11 minutes or so).
3. Take the GO train: She drives 3.5km each way, at a cost of $0.30/km, for an annual operating cost of around $500 a year. Her annual costs on the train are almost $2,700 (minus a few hundred dollars back at tax time), for total transportation cost of $3,200. The trip takes her about 60 minutes each way door-to-door, with scheduled trains leaving every 30 minutes or so.

The cost for convenience trade-offs are significant. Local transit is certainly the cheapest option, but adds around 2 hours to her commute each day and requires her to stand outside three times waiting for busses. She nearly doubles her transportation costs with regional transit, but saves on time (and can just sit on one train for most of the trip). Driving over double costs again, saves a little more time, but requires her to sit in Toronto traffic daily.

The introduction of more frequent service on the GO train, through RER, does not change any of these numbers, though it does make the train more convenient. However, the introduction of electrified service, which reduces her commute time on the train makes her choice much easier.

Giovanni

Giovanni lives in the Allandale area of Barrie, within walking distance of Allandale Waterfront GO station. He would prefer to work a little later given morning family responsibilities. He only has two options to commute to work: drive, or take regional transit (GO Transit).

1. Drive: he drives 107km each way, at a cost of $0.30/km for gas, maintenance, and insurance, plus $200/month for parking, for an annual operating cost of around $17,800 a year. The trip takes him 75-120 minutes door-to-door each way in rush hour, depending on traffic.
2. Take the GO train: He walks a few minutes, and hops on the train, which carries an annual cost of over $5,300 (minus hundreds of dollars at tax time). The trip takes him 130 minutes each way door-to-door.

Here the cost savings are significant, but the train takes slightly longer and currently only runs five times a day in each direction – which is hard for Giovanni given responsibilities at home.

Therefore, the introduction of more frequent service on the GO train helps Giovanni at home. More importantly, electrification speeds up the journey, making his choice much easier.

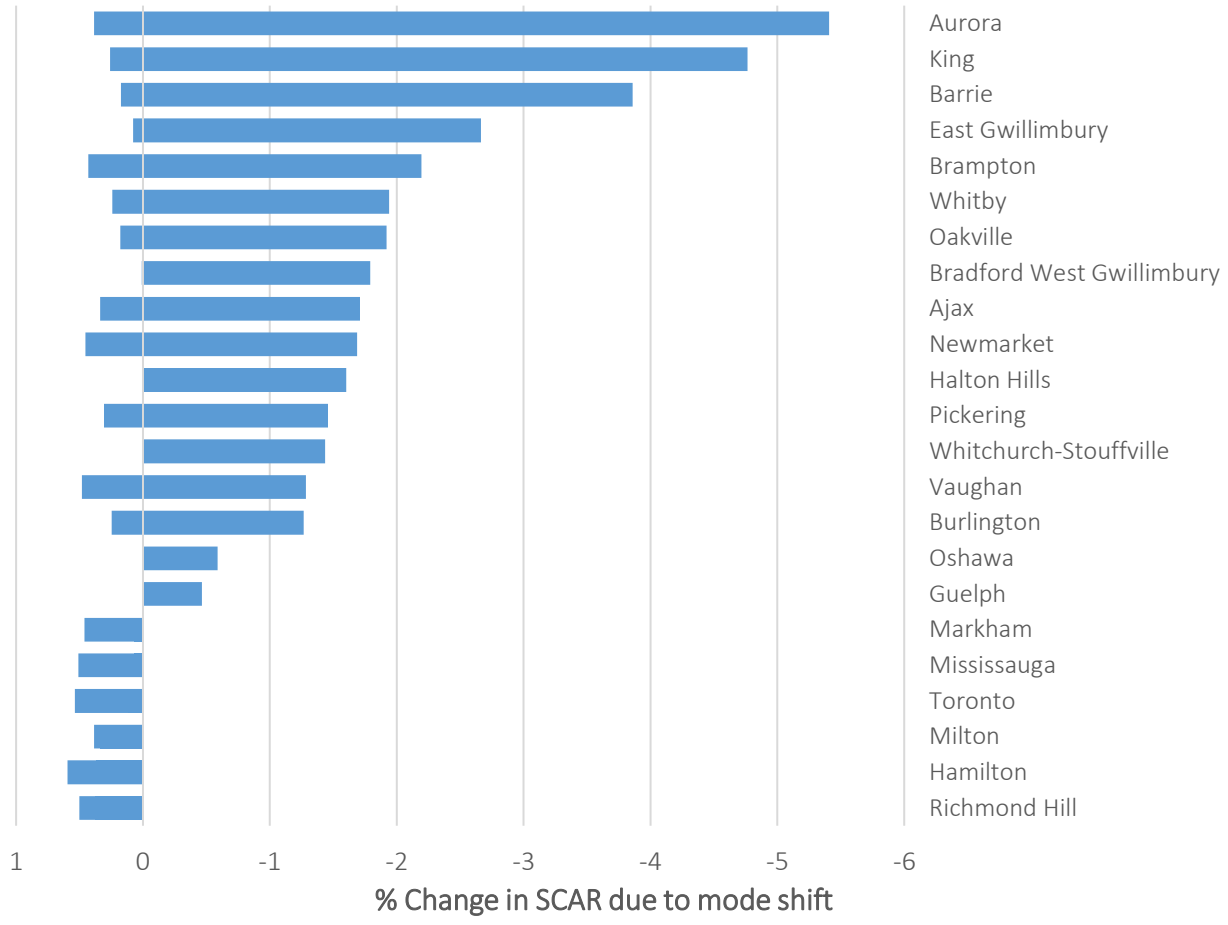
(Note: Giovanni's wife, brother, sister-in-law, and friends mostly all live and work in or around Barrie. The introduction of RER does not affect their commuting behaviour at all.)

Yasmin

Yasmin lives in Toronto, near Bloor and Lansdowne. She currently takes the TTC (line 2, transferring to the 75 bus), at an annual cost of $1,700 a year on monthly passes (minus a few hundred dollars back at tax time). Her trip takes her about 35 minutes door to door. If a new GO Train station gets built near her (as recommended) through RER, her commute time would not change significantly (though slightly less frequent) while her costs would increase slightly (likely to around $2,000 a year). The service is a little nicer, but she doesn't see a good enough reason to switch, especially given that her TTC pass allows her to travel outside of commuting, such as to see friends.

Once accounting for increases in housing costs and decreases in transportation costs, the average potential *aggregate* change in SCAR by region shows significant variation. In Figure 10, the left end of each bar is where no one shifts from driving to GO trains; the right end of each bar is where an estimated number of people shift to GO trains and reap the cost benefits of driving a lot less. As expected, areas outside the core see affordability improve, while those in the core see it worsen.

Figure 10 Variation of potential impact on aggregate affordability for each TREB municipality with a GO train station



Aggregating these community-level expectations, the average potential change in SCAR shows a noticeable difference inside and outside Toronto proper:

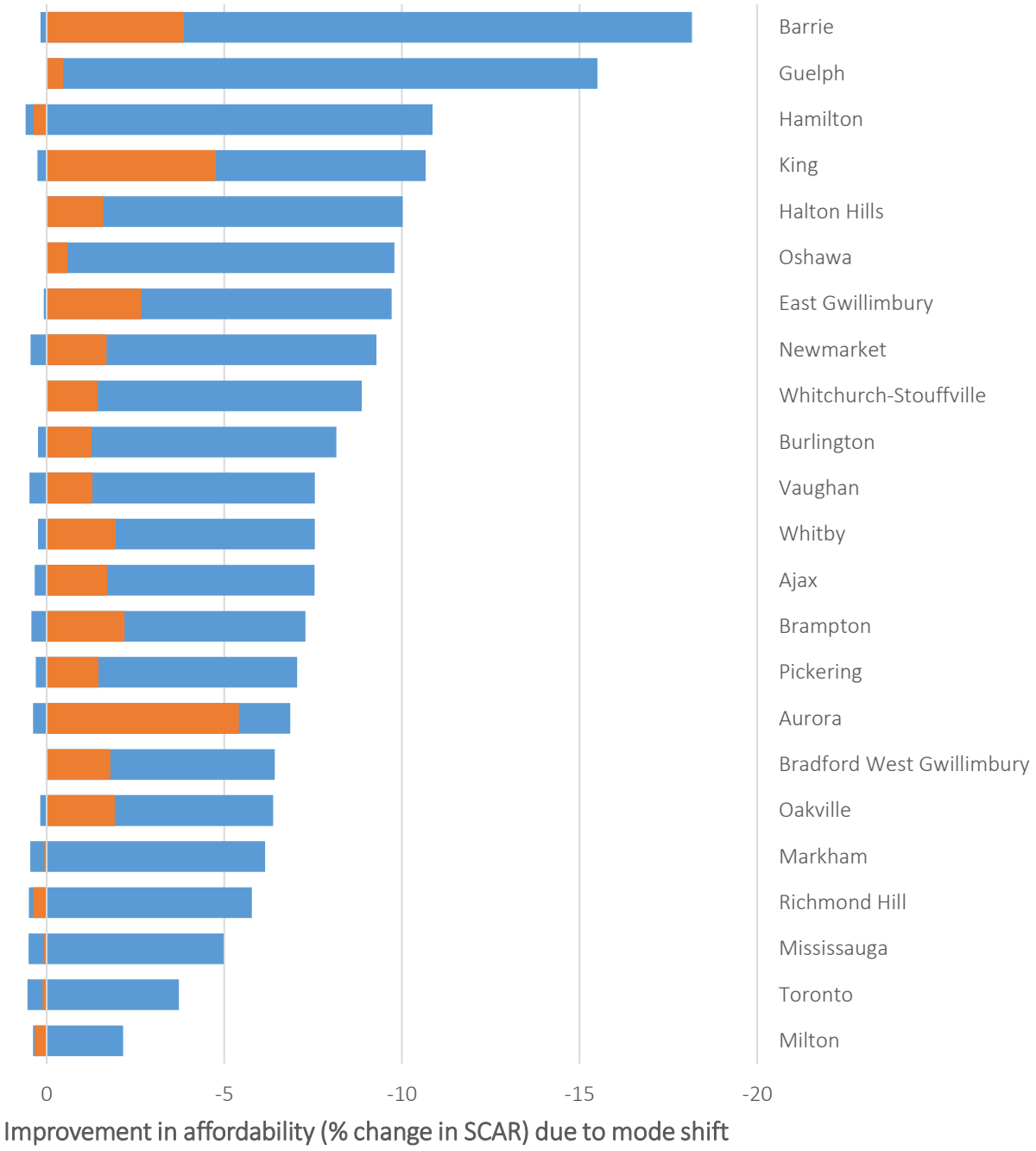
- **For households around GO stations outside Toronto:** Estimated improvement in affordability due to RER is 1.5% on average as housing cost increases are more than offset by lower transportation costs (for those who stop commuting by car).

- **For households in Toronto:** A slight *worsening* in affordability (characterized by an increase in SCAR) of 0.1% on average as housing cost increase are not offset by lowering already existing lower transportation costs.

More specifically, by comparing these community-level estimates (as in Figure 11), the significant difference between the overall average change in affordability (orange bars) and the potential for an individual to improve affordability (blue bars) is shown. This demonstrates a key policy metric to be considered by local and provincial governments, particularly in terms of local transit-oriented developments. For example:

- Hamilton/Guelph: large potential improvements in individual affordability are swamped by low estimated mode shift overall
- Aurora: while individual improvements are relatively small, large estimated mode shift sees largest improvements in affordability overall
- Toronto: few residents shift modes (so little savings overall), but local transit improvements are required to handle new GO riders coming in from outside the city

Figure 11 Variation of potential impact on aggregate (orange) and individual (blue) affordability for each TREB municipality with a GO train station



Person-level changes in affordability (blue bars) and potential *average* changes in affordability (orange bars) show that mode shift is the driving factor of how housing affordability is affected (where the right end of each line is full mode shift; left end is no mode shift).

3.3.1 AFFORDABILITY FOR TORONTO RESIDENTS

The current analysis shows very little affordability improvements for Toronto residents. In fact, it actually shows their aggregate affordability worsening slightly by 0.1% as changes in the cost of a home due to better transportation alternatives are not offset by lowering already existing lower transportation costs. This analysis focuses on the GO's RER and the mode shift from driving to becoming a GO train rider. Toronto, *on average*, is well serviced by transit and as such would not see a great change in mode choice. However, this is not to say that Toronto cannot benefit greatly from transit development. Although the average transit score for Toronto is 78, some areas score as low as 49 on average, on par with Hamilton and Markham. In addition, the 2011 Transportation Tomorrow Survey (2014) estimates that 58% of rush-hour trips made by residents of the city were made by car (including passengers)[34].

Moreover, many of the employment areas in Toronto have sub-par transit access and, as mentioned previously, for transit to be useful it must improve accessibility to job opportunities, among other amenities. The top 10 employment areas in the city of Toronto host about 20% of all employment in the city[35], yet they have below average transit scores. This is further supported by the fact that these areas report above average percentages of people who drive there[36] from the GTHA (76% compared to 57% to the city overall). Interestingly enough, the mode choice in some of these employment areas further supports the fact that proximity to transit does not mean accessibility. For example, Rexdale, which hosts over 40,000 jobs and an average transit score of 72 (not far off from the Toronto average of 78), sees 84% of GTHA residents commuting into the area by car and 69% of area residents themselves commuting by car, both well above average.

Furthermore, the large number of GTHA residents needing to drive into these employment areas not only highlights the importance of local transit in Toronto, but also emphasizes the need for such transit to be properly integrated with other regional transit systems. Take the case example of Giovanni above who drives in from Barrie. If he worked in South Etobicoke, which has an average transit score of 61, as opposed to Toronto's downtown core, the lack of integrated and accessible local transit would significantly lengthen his commute and discourage him from mode shifting, potentially worsening his affordability improvements.

Finally, while Toronto residents themselves could certainly use improved transit, local Toronto transit also needs to be improved to simply handle the expected increase over 100,000 new GO train riders due to RER, many of whom will not work within walking distance of Toronto-based GO stations.

[34] This proportion has not changed much since 2001 (60%) and 2006 (60%) (Data Management Group 2003, Data Management Group 2009)

[35] http://www1.toronto.ca/City%20Of%20Toronto/City%20Planning/SIPA/Files/pdf/T/2015-Employment-Bulletin%20FINAL-accessible.pdf

[36] Based on Toronto Wards

4.0 CONCLUSIONS

Many affordability indexes are focused upon housing prices, mortgage payments, and interest rates when evaluating affordability. As such, they are insensitive to the role and implementation of transportation alternatives. The affordability of a home is much more than just housing prices, which SCAR index is designed to accommodate.

Generally speaking, in the GGH, there is a transit-induced price premium up to 12% over the reference case. However, it is overshadowed as a factor by regional-premiums (i.e., Toronto, York, Peel, and Halton) and by the type of home, specifically single-detached homes. Within Toronto, improving transit does not have much of an impact on housing premiums given that the city is already relatively well serviced by transit, and is again overshadowed by central areas and detached homes (even semi-detached homes). With that being said, Toronto can still benefit from transit investment as the top employment areas outside the downtown core (which collectively host 20% of Toronto's employment) have below average transit scores and well above average proportion of individuals who drive to and from the areas.

Using SCAR index analysis combined with *Prosperity at Risk* simulation of 773 communities in the GGH region, we find that the value of households giving up their car for the GO train to get to work can have a significant effect upon the affordability of their shelter. Across the GGH, the impact of RER is generally positive, insofar as it improves affordability, but only for those who shift from driving to taking the GO train. Therefore, mode shift is the key driver of improved affordability.

The analysis highlights the value of RER combined with a focus upon local transit-oriented developments, and the communities in which this focus should be a high priority.

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APPENDIX A. AGENT-BASED MODELLING

A.1. Agent-Based Modeling for Evaluation of Infrastructure Investment

Traditionally, a variety of models have been used to analyze the impact of infrastructure investment. These include cost functions, production functions, and growth accounting (Antunes, Beckman and Johnson 2010). General equilibrium macroeconomic models would suffice if only direct, indirect, and the follow-on induced economic effects of infrastructure investment were relevant. However, there are 'system effects', which transcend these because they include variables that are not traditionally examined under the economic lens, such as productivity coupling and consequent impacts upon asset values.

Productivity coupling refers to:

- The direct consumption of public infrastructure by industry as an input to production of goods and services, as well as their transportation – as used in traditional economics (input/output matrices) – that is key to the calculation of direct, indirect and induced effects of infrastructure investment;
- The indirect consumption of public infrastructure by industry and governments in the movement of their employees;
- The indirect consumption of public infrastructure by industry and governments in the health and skills development of their employees (current and future).

A broader productivity coupling of public infrastructure with production activities exists when infrastructure is a constraint on production.[37] That is, when public infrastructure is regionally insufficient, current and future production that can occur in that region is constrained. It is the indirect consumption of public infrastructure by industry, households and governments that is a key component of the 'systems effects' alluded to.

Additional systems effects occur as asset values may change with public infrastructure investment, which can have consequent impacts upon investment, debt and private migration choices. For example, the value of homes near a new transit stop increase in many cases. This value proposition is particularly evident in the presence of existing public infrastructure deficits and a growing population.

Such systems effects require the identification and accounting of both financial (e.g., realized input and output, investment/debt decisions) and non-financial events (e.g., expected demand, expected supply, policy and planning choices, activity location choices). Additionally, the fact that households, industries and governments have to compete with each other under their own unique budget constraints (e.g., income,

[37] This conforms to the roots of stock-flow consistent economic models: see Macedo e Silva, A., Dos Santos, C. H., 2008. *The Keynesian Roots of Stock-flow Consistent Macroeconomic Models*. Levy Institute of Economics of Bard College, Working Paper no. 537.

expenses, assets, ability to borrow) adds an additional layer of complexity which must all be reconciled in order to construct and simulate an internally-conserved, consistent, and cohesive system.

In order to simultaneously account for many of the economic and productive impacts generated as a result of regional public infrastructure investment and the unique constraints on the economic players as they compete, agent-based modeling is employed. The ability to measure and understand such outcomes and manage the computational complexity required is at the heart of CANCEA's systems-based platform, *Prosperity at Risk* (PaR).

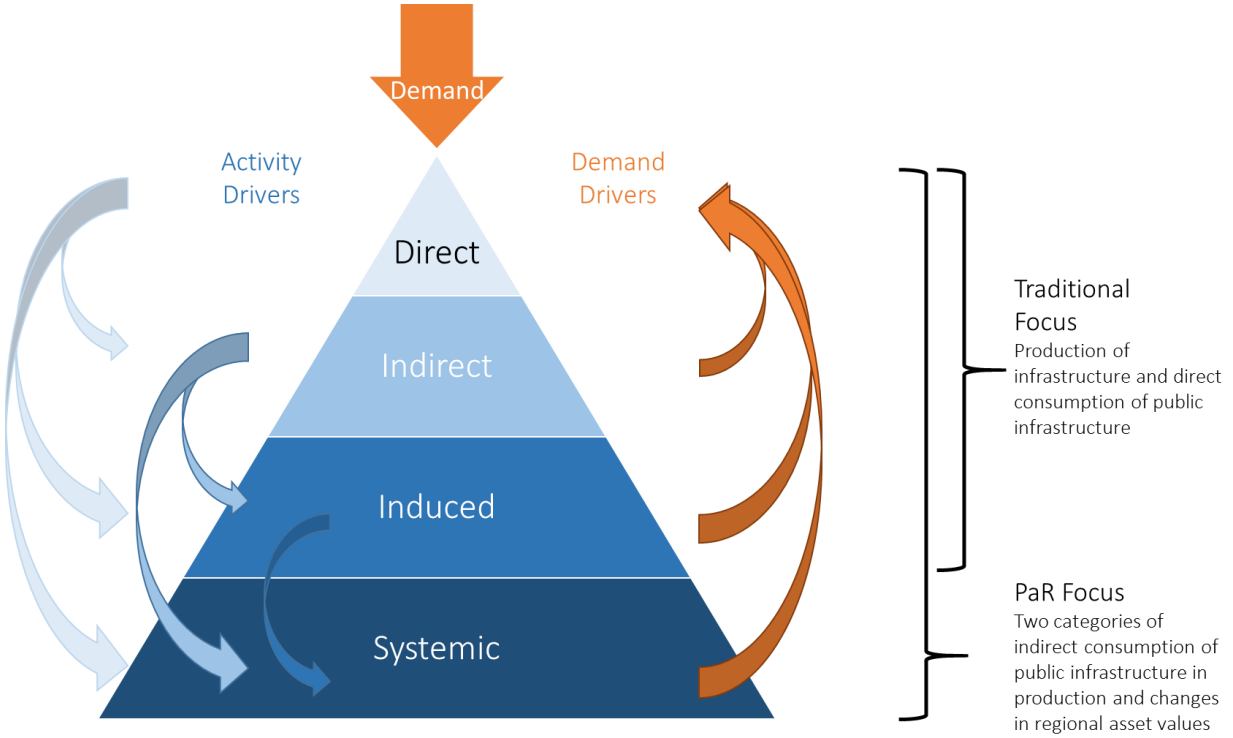
In a sentence: PaR is a more realistic and powerful agent-based simulation platform for geo-spatial socioeconomic analysis that is consistent with the principles of 'new economic geography'.[38] In slightly plainer language, it is a complex "big data" computer system that simulates the interactions of more than 40 million virtual agents (individuals, households, corporations, governments, and non-profit organizations) that are encoded with behavioural rules that enable them to make decisions, act based on those rules, and be influenced by the actions of others. Each agent can have over 850 features and interacts with other agents across 235 industries and 440 commodities within 5,000+ census areas across Canada. Per step in time, this equates to over 19 billion interaction measurements, including the buying and selling of goods or an individual paying taxes. But it does so by scrubbing, linking, and testing masses of data and focusing precisely on the key drivers of behaviour. Further, agents' behavioural features, such as their confidence in achieving outcomes or their tolerance towards risk (under normal and near-ruin circumstances) may change or evolve due to local circumstances or external stimuli, allowing unanticipated behaviors to emerge. These are only identified by way of experimental simulation.

Central to PaR's framework is agent-based modeling in the context of systems theory, the notion that all elements of an economy and society are connected to relevant others and influence one another both directly and indirectly. This occurs through a series of linkages between entities in the system, giving rise to impacts stemming from some catalytic investment, for example, that are not immediately obvious. Using PaR's interconnected modules (i.e., regional groups of processes/activities), the systemic impacts of an investment can be accurately ascertained through the linked analysis of health, social, and economic outcomes. The agent-based PaR framework has been cross-model validated through comparison with the baseline macro-economic outputs of third party demographic and economic models (to the extent that those models capture what PaR is measuring), as well as through back-testing of historical data.

Unlike traditional input/output models, PaR, is able to capture the systemic dependencies of infrastructure and industry by coupling infrastructure to private capital investment and productivity. In doing so, PaR is able to account for productivity constraints that will be encountered if infrastructure investment is not made, such as insufficient transportation investment leading to goods movement constraints. (It is also important to note that, unlike the traditional approach, agent-based modeling is able to identify the long-term productivity increase generated in the economy as a result of the investment.)

[38] See Tsekeris and Vogiatzoglou. 2010. *Multi-Regional Agent-Based Economic Model of Household and Firm Location and Transport Decisions.* European Regional Science Association conference papers.

Figure 12 Systemic dependencies in infrastructure evaluation



A.2. Simplified Walk-through of PaR Approach

To aid in the conceptual understand of PaR's approach to infrastructure evaluation modelling, this section provides a simplified walk-through of the various processes at work to show how an investment in public infrastructure propagates through the system. A staged approach of process representation is used for convenience only and does not reflect actual PaR processing. PaR processes as events occur, simultaneously where relevant.

Process 1: Demand for public infrastructure:

- Various orders of government have an expected demand for infrastructure from industry and households.

Process 2: Government decision to supply public infrastructure: the relevant government makes the decision to supply expected infrastructure demand which results in:

- Government tendering for the production of the infrastructure with a successful bidder;
- Governments and industries revise their output targets, investment and debt needs.

Process 3: Project financing:

- Government competes in credit markets and borrows money when needed to fund infrastructure project.

Process 4: Direct and indirect competition for factors of production:

- Construction (direct) and intermediate industries (indirect, i.e., suppliers) under their own expectations compete in markets for factors of production (e.g., goods, services, labour, capital).
- Ongoing, industry (along with households and governments) compete in credit/investment markets for credit, equity capital, and investment sales.
- Ongoing, households regionally seek employment and payment of wages.

Process 5: Regional production of public infrastructure by industry: Direct and indirect industries fulfil in-part or full their required factors of production and produce target output (or a fraction of target output if limited by insufficient factors of production):

- Government pays for work in progress;
- Industries receive revenue, pay for intermediate goods and services, pay taxes and receive subsidies (respective governments);
- Households produce labour regionally (labour retention, new hires, released), receive wages, and pay taxes to respective governments;
- Other government transfers are received or paid (dependent on income and household characteristics);
- Investment incomes and debt expenses are paid.

Process 6: Induced impacts of production of infrastructure by industry:

- Household income is spent on consumption of goods and services or saved via investments;
- Industry expected consumer demand responds to additional income (under budget constraints and spending vs saving preferences);
- Target industry outputs respond to changes of consumer expected demand resulting in additional direct demand for goods and services (with responses described in the previous step) under budget constraints.

Process 7: Systems impacts of use of public infrastructure by agents:

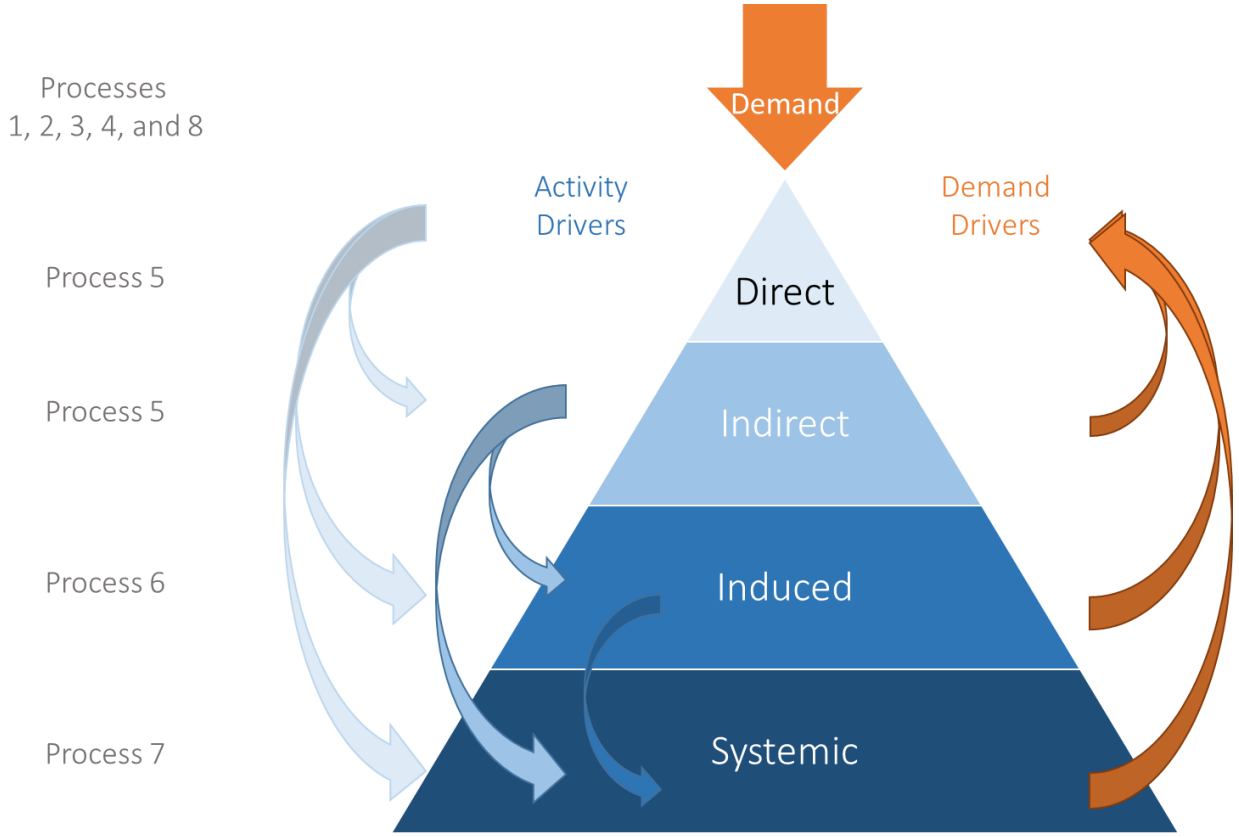
- Supply of public infrastructure impact on government, industry, and households:
    - is a direct and indirect factor of production to industry, government and households (described above);
    - changes the regional utility/valuation of capital assets.
- Government responds to change in supply of factor of production. Government operation/maintenance of infrastructure changes expectations and government production going forward.
- Industry responds to change in supply of factor of production in different locations (e.g., expectations, productivity, profit margins change, and firm location).

    - Now able to meet unmet demand where infrastructure was a limiting factor of production.
    - Sees increased profit/wage share of output value.
    - May relocate where profit/wage share can be increased (with restrictions on labour and availability of other factors of production).
- Households respond through demands on public infrastructure use in different locations (relocation, municipal housing investment intentions, location change of consumption).
- Increased incomes result in increased consumer demand and capital investment expectations leading to increasing target industry output and direct demand (return to step 5).

Process 8: Other ongoing demographic considerations that can influence the above processes:

- Endogenous demographic and labour force changes: change in number of people (age, sex, skills) through births, deaths, inter-regional migration (already mentioned), international emigration, or retirements.
- Exogenous policy changes: federal government may or may not be adding to the population through international immigration throughout the simulated time period.
- Change in number of people changes household numbers and structure.
- Change in supply of labour, consumers, consumer demand expectations, government services requirements, utilization of public infrastructure (factor of production for industry & households), and demand for infrastructure.

Figure 13 Systemic dependencies in infrastructure evaluation as processes in PaR



A.3. Systemic Dependencies Drive Results Away from Traditional Analysis

With the inclusion of the system dependencies discussed, the results of the analysis tend to diverge away from what is usually reported in the literature. That is, for those with economic analysis inclinations, there is likely to be an inherent 'sticker shock' reaction to the agent-based results presented in this report. Traditional economic input/output analysis will typically associate a $1 billion investment in public infrastructure with job creation of around 9,000 to 17,000 job-years and GDP growth of around $0.8B to $1.6B (Haider, Crowley and DiFrancesco 2013). Results that emerge from agent-based modeling of the same phenomena is likely to raise the interest of proponents of traditional input/output analysis.

As discussed, system effects are defined by a complex range of interdependencies between agents and the economy in which they interact. In doing so, agent-based results capture not only the stimulus impact that would result from an investment, but the range of indirect consumption impacts (productivity coupling) and asset revaluations (and consequent choices) that occur. That is to say, relevant public infrastructure investment changes the status quo. As such, we do not assume that the economy will continue to look like the current status quo into the future if a necessary investment is not made, like many cost/benefit analyses do.

The results of traditional input/output analysis usually pick up the stimulus effects of infrastructure spending and these results are almost always positive. In contrast, systems effects can be either positive, neutral or negative which allows analysis to determine if the spending is either an investment or a cost. It is this feature of the system impacts that make it a key measure of economic risk, as when:

- Systems impacts are positive: The infrastructure created provides an economic function that is:
  - a measure of benefit if done appropriately (implementation of form) which can be viewed as an investment by the system
  - a measure of what economic activity is at risk if not done
- Systems impacts are zero: The infrastructure created provides no economic benefits beyond the usual stimulus impacts
- Systems impacts are negative: The infrastructure created appears to be functionally inappropriate and a cost from an economic perspective. Justification would require non-economic arguments.

The nature of positive systems effects must be recognized as not an independent measure of the value of public infrastructure, but as a contribution by the many factors that combine to create value (a point often misunderstood). That is, to yield such an impact, it is necessary for additional events to occur in order for the infrastructure investment to be productive (which then become a measure of the risk to the productivity of infrastructure investments). This includes growth in private residential and non-residential private capital investment, additional public infrastructure investment at federal and municipal levels of government, wage growth, increased consumer and government consumption, and growth in taxation revenues.

The nature of interdependencies inherent to agent-based modeling imply that while this portfolio of events occur in tandem, they are each necessary in order for the other results to manifest as they do in the set. It is also important to note that these effects are not linear, and therefore cannot be assumed to occur as the sum of their parts (e.g., changes in asset values, new employment opportunities) or within the same year of the public infrastructure investment.

Systems modeling is akin to solving a multidimensional problem (much like a Rubik's cube). Inherently, these problems cannot be solved one dimension at a time, being at their very essence non-linear. Instead, a combination of relationships must be recognized in order to allow for the identification of value creation, as well as the underlying interdependencies and risks. Thus it becomes clear that there are a number of additional impacts that combine with job creation and GDP growth to generate value as a result of each $1 billion invested in infrastructure. Identification of these events (additional impacts) then becomes a measure of the risks to the productivity of public infrastructure investment; if they were not to occur, investment in public infrastructure would become unsustainable. Hence the need for such activities as economic development, planning and stakeholder co-ordination to mitigate such risks.

APPENDIX B. A TALE OF TWO STATIONS

A Tale of Two Stations: The Short-Term Impacts of Bayview and Don Mills Subway Stations (Graham 2013)

As was highlighted in sections **Error! Reference source not found.** and 1.2.1, the impact of transit investment is variable. Some areas may see increases in land value, while others may see negative changes in land value. Some station areas see increased density and TODs, while others may not. The impact of the Bayview and Don Mills subway stations (on Toronto's line 3 subway) on their surrounding areas highlight this heterogeneity. Highlighted below are the impact on areas such as neighbourhood characteristics, such as housing type, and demographics of the two subway stations between 1996 and 2006.

Bayview Subway Station

Occupied Dwellings: Owner-occupied dwellings, as a percent of housing, increased from 7% to 64%
Shift from a renter-occupied dominant neighbourhood to an owner-occupied area due, in part, to the combined benefits of accessibility and affordability provided by the line 3 subway.

Occupied Dwelling Density: Apartments more than 5 storeys, as a percent of housing, increased from 53% to 78%
Comparatively, the City of Toronto experienced almost no change (28% to 27%) in dwelling type.

Dominant ethnicity shifted away from English to Chinese.
Across Toronto, there was an increase in immigrants and visible minorities, but not as substantial as in the Bayview neighbourhood. Macroeconomic forces were also believed to have contributed to the shift in demographics.

Don Mills Subway Station

Occupied Dwellings: Owner-occupied dwellings, as a percent of housing, increased from 4% to 15%
Remained a mainly renter-occupied dominant neighbourhood.

Occupied Dwelling Density: No change in dwelling type and density.
Due to the emphasis on the Don Mills neighbourhood being a commercial-centric area, dwelling types and density did not change.

Dominant ethnicity shifted away from English to Chinese, in addition to increased immigrants and visible minorities.
The shift towards immigrants and visible minorities was believed to be prompted by the employment opportunities and affordable housing in the area. Macroeconomic forces were also believed to play a role.

- Even though the two stations are only 3.4 kms apart, the Bayview subway area developed into a dense residential, mainly owner-occupied area, while the Don Mills station saw little, if any, change in neighbourhood composition.
- **Role of policy**: the Sheppard Subway Corridor Secondary Plan (City of North York 1997) set out different guidelines for each area, envisioning Don Mills as a commercial and employment area, given the existing Fairview mall.
- However, three condominiums towers were completed in 2014, with a total of just under 1,200 units between them (Urban Toronto n.d.).

APPENDIX C. GLOSSARY

Accessibility	**The ease of reaching amenities**
Agent	An autonomous individual, firm or organization that responds to cues from other agents and their environment using a set of evidence-based behavioural rules in response to those cues.
Agent-based modeling (ABM)	A framework for modeling a dynamic system, such as an economy, by means of individual agents, their mutual interaction with each other, and their mutual interaction with their environment(s).
Amenities	Goods, services, activities, and destinations that people value.
Business case	An evidence-based argument in favour of a given choice.
Discount	The reduction in the value of shelter due to external factors making the shelter less appealing
GTHA	Greater Toronto and Hamilton Area
Heavy-Rail Transit (HRT)	The prototypical transit when people think of a subway. They generally run underground and carry a large passenger load at faster speeds.
Light-Rail Transit (LRT)	Form public transit that is faster than buses and streetcars, but slower than HRT, and focuses on smaller volume of passengers. They are run on separate tracks (from cars) and can be run aboveground at street level or underground like HRT.
Mobility	Movement of people or goods, where improvement is achieved through increased distance travelled or faster speeds.
Premium	The added value on the shelter due to some external factor
***Prosperity at Risk* (PaR)**	An event-driven, agent-based, microsimulation platform that tracks over 50 million agents for all of Canada by the end of a simulation. It simulates the economy's processes, including consumption, production, labour force dynamics, as well as evolving financial statements of agents. It conserves the flows of people, money and goods.
Metrolinx Regional Express Rail (RER) Plan	A regional plan to improve and extend the current GO transit line into a more frequent, efficient, and integrate system.

SCAR Index	Measure of housing affordability based on the consumption cost of satisfying shelter needs and households' discretionary income after payments for necessities.
System effects	Impacts that transcend direct, indirect and induced effects, which are not traditionally measured by economics. These impacts arise from the relationship between every economic agent and the environment in which they operate, as they influence one another's states and behaviours.
Systems approach	The belief that in complex systems, the whole is not equal to the sum of its parts. Such an approach requires the understanding that different combinations of assets can have different values for agents and that agents have different constraints and desires, and cannot be treated as aggregates.
Transit-Oriented Development (TOD)	TODs are developments within 10 minutes or 800 meters of a transit station and are characterized by high density housing, in addition to employment opportunities, retail, and services along the transit system.
Transit Score®	A measure of the level of public transit that services a given property on a scale of 0-100
Walk Score®	A measure of the ease of walking to amenities from one's property on a scale of 0-100

ENDNOTES

[i] http://www.fin.gov.on.ca/en/budget/ontariobudgets/2016/ch3b.html#t3-24

[ii] http://www.fin.gov.on.ca/en/budget/ontariobudgets/2010/ch2h.html#c2_secH_table30

[iv] This could occur because transportation networks would enhance the overall value of shelter units in non-core areas by reducing the cost of their distance. Another reason for this effect is that transportation facilitates business creation and a more diffuse economic development process, which could attract some households to live in these newly-growing areas and generate affordability pressures in those regions.

[v] There is an extensive literature around the "fundamental law of highway congestion" which states that increases in highway capacity result in an equal increase in vehicle usage along that same highway (Duranton and Turner 2009) . Therefore, increasing capacity does not alleviate congestion because of the notion of 'induced demand' – that is, that building additional roads (especially in metropolitan areas) reduces the cost (typically opportunity cost) of travel, which leads to increased driving since it is now "cheaper" to drive. The opposite is also true. In San Francisco, a freeway that once carried close to 100,000 cars per day was demolished and replaced with a reduced lane boulevard, which carries 45,000 cars per day (Syracuse Metropolitan Transportation Council 2010).

[vi] The differentiation of shelter itself is what allows for the process of households looking to satisfy their "wants" to crowd households looking to satisfy their "needs" out of the market. Because public infrastructure is a scarce resource that is laid in discrete quantities, certain households are able and willing to bid higher for these properties in order to make use of the adjacent transportation network and infrastructure (Real Estate Investment Network 2010). In this way, less affluent households would tend to be priced out of such well-serviced areas, exacerbating the affordability issue.

[vii] The carrying costs factored into CMHC's 30% cut-off include shelter expenses such as electricity, oil, gas, coal, wood or other fuels, water and municipal services, monthly mortgage payments, property taxes, condominium fees, and rent (Housing Affordability 2012).

[viii] Metro Vancouver operates under provincial legislation as a regional district and three greater boards to deliver regional services, policy, and political leadership on behalf of 23 local authorities, which comprise of 21 municipalities, one treaty First Nation, and one electoral area (Metro Vancouver 2015).

[ix] The regions considered were: Vancouver/UEL, Richmond, North Shore, Burnaby/New Westminster, Surrey/White Rock, Northeast Sector, Langley City and Township, Pitt Meadows/Maple Ridge, and Delta. Affordability was ranked from 1 to 9, 1 being the highest cost burden (least affordable) and 9 being the lowest cost burden (most affordable).

[x] Some literature identifies that land and property values increase the closer a shelter unit is to urban amenities up to a certain proximity, after which negative externalities (such as congestion and noise) could begin to reduce property values (Real Estate Investment Network 2010). In fact, when considering that shelter close to amenities imposes relatively small transportation expenses on one hand but high proximity-induced property value premiums on the other, the trade-off between transportation expenses and property value premiums begins to emerge.

[xi] Studies that evaluate the impact of transit on land and property value have found that home values and rents are higher and maintain their value (during downturns) surrounding new transit systems (Center for Housing Policy 2011, Becker, Bernstein and Young 2013). The introduction of new transit in London, Charlotte, and Sydney increased property values in nearby stations[xi] (usually defined as those within a 10 minute walk of the station or 1 KM distance). A report found that the London Crossrail (a high-speed commuter and suburban passenger service that links parts of Berkshire and Buckinghamshire to Essex and south-east London through central London) caused nearby property (those within a 10 minute walk of the stations) prices to increase 30% between 2008 and 2012 (Knight Frank 2013). Furthermore, a study of the Charlotte area found that single-family home prices decreased then increased when the

transit became operational (Yan, Delmelle and Duncan 2012). And another study in North-West Sydney found that prices increased before and after construction of a rail station (Ge, MacDonald and Ghosh 2012).

[xii] Evaluation of similar studies on single detached homes in New York, San Francisco, Washington, D.C., and Atlanta found a positive land value uplift between around 25-60% (Higgins and Kanaroglou 2016). For studies within Atlanta, the value of single detached homes increased by around 25% in one study, yet decreased by 20% in another[xii] (Higgins and Kanaroglou 2016).

[xiii] Transit impact studies usually focus on light-rail transit (LRT) and heavy-rail transit (HRT) for the transit investment and single-detached homes followed by commercial properties for the housing/land type. Light-rail transit refers to a form of public transit that is faster than buses and streetcars, but slower than heavy rail transit (HRT, e.g., subways). They are run on separated tracks (from cars) and can be run aboveground at street level or underground like HRT. HRT can also carry a larger passenger capacity.

[xiv] A common assumption made is that transit increases land value if it improves "accessibility". Accessibility in transit studies, however, focuses only on the commute trip to existing jobs. A broader definition should consider *potential* job opportunities as well as other amenities (Paez, Scott and Morency 2012, Higgins and Kanaroglou 2016).

[xv] When considering the Sacramento LRT, the service consistently had low ridership because the highway network available was still easier to use and provided better access, and therefore the land saw insignificant appreciation due to the transit line. However, studies using proximity as a proxy for accessibility found positive land value uplifts associated with the transit system (Landis, et al. 1995, Cervero and Duncan 2002a, Cervero and Duncan 2002b, Weinberger 2001).

[xvi] The study followed the monthly crime trends from 1998 (before the line existed), through its announcement in 2000, completion in 2007, and all the way up to 2009. The study also looked into two areas where stations were proposed to be built but never were and also crime in the city at large. They found that larceny dropped by 25%, burglaries fell by 26%, and robbery dropped by 32% (Billings, Leland and Swindell 2011).

[xvii] This should not be confused with mobility, a term that gets thrown around on par with accessibility. Mobility is defined as the movement of people or goods, where any increase in distance travelled or speed benefits society (T. Litman 2008). This doesn't measure how readily individuals got to where they were going, rather it measures how far they have moved. Given that most trips are not motivated by a desire to see the odometer increase but rather to achieve some goal, it is important to keep these definitions separate. That is not to say that mobility does not play a role in accessibility, especially when it comes to public transit: a fast trip is certainly preferable to a slower one.

[xviii] Moreover, electrification comes with a lower maintenance and operating costs (Metrolinx 2016). Considering current GO transit recovers 80% of direct operating costs through revenues, reducing operating costs would help improve this recovery rate (Metrolinx 2015).

[xix] This conforms to the roots of 'stock-flow consistent' economic models: see Macedo e Silva, A., Dos Santos, C. H., 2008. *The Keynesian Roots of Stock-flow Consistent Macroeconomic Models*. Levy Institute of Economics of Bard College, Working Paper no. 537.