Understanding the relationship between changes in accessibility to jobs, income and unemployment in Toronto, Canada

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ABSTRACT

In many cities, transport investments are being directed towards increasing access in socially deprived neighbourhoods in order to enhance quality of life and improve equity. However, little research has been conducted to assess the impacts of such targeted interventions on the well-being of these individuals and the resulting equity of outcome. This study aims to evaluate the impacts of accessibility improvements overtime on neighbourhood socio-economic status, by examining the relationship between changes in accessibility to employment opportunities by public transport and changes in income and unemployment in the Greater Toronto and Hamilton Area, Canada (GTHA). To investigate this relationship, two linear regression models are proposed in our study. The results show that accessibility to jobs by public transport is vertically equitable in the GTHA (i.e., low-income neighborhoods experience higher levels of accessibility), although vertical equity decreased during the study period. The regression models suggest that, for low and medium income census tracts, transit accessibility improvements are associated with increases in median household income and decreases in the unemployment rate, whilst controlling for local migration. For high-income census tracts, increases in accessibility by public transport are related to decreases in income, potentially due to the migration of high-income populations to less dense neighbourhoods, away from transit. The relationship uncovered in this study highlights the impacts of accessibility improvements on low and medium income areas. The findings from our study provide a case for transport engineers, planners, and policy makers regarding the importance of positive changes in accessibility as a tool to derive equity outcomes in low income areas.

Keywords: Accessibility, equity, public transport

2.1 INTRODUCTION

In many urban areas, transport agencies are trying to provide all citizens with greater access to opportunities as a means to improve residents' well-being (Boisjoly & El-Geneidy, 2017; Handy, 2008; Proffitt, Bartholomew, Ewing, & Miller, 2015). Several cities particularly intend to increase access to opportunities in socially deprived areas, in order to support social inclusion and enhance the quality of life of residents in these neighbourhoods (Mayor of London, 2018; NSW Government, 2012; San Diego Association of Governments, 2011). In this context, research suggests that improvements in access to opportunities by public transport can bring considerable benefits to vulnerable populations, as they are more likely to rely on this mode for accessing their destinations (Stanley & Lucas, 2008).

To quantify access to opportunities, accessibility, or the ease of reaching destinations, is increasingly being used in research and practice as a key land use and transportation performance measure. From a social equity perspective, accessibility has been used as a tool to assess the socio-spatial distribution of public transport services (Bocarejo & Oviedo, 2012; Delmelle & Casas, 2012; Golub & Martens, 2014; Kawabata & Shen, 2007), and to evaluate how changes in accessibility differ across socio-economic groups as a result of projected or new infrastructure projects (Foth, Manaugh, & El-Geneidy, 2013; Manaugh & El-Geneidy, 2012; North Central Texas Council of Governments, 2016; Paez, Mercado, Farber, Morency, & Roorda, 2010; Southern California Association of Governments, 2016). While a large body of literature has assessed accessibility levels for different socio-economic groups, or changes in these accessibility levels over time, little research has been conducted to assess the outcomes of such improvements in accessibility.

The goal of this study is, therefore, to assess the relationship between improvements in the levels of accessibility to jobs by public transport and the resulting socio-economic benefits, measured by changes in median household income and unemployment rate over time in the Greater Toronto and Hamilton Area, Canada. For this purpose, competitive accessibility levels to employment opportunities by transit and by car are calculated for all census tracts in 2001 and 2011. Competitive accessibility discounts the number of accessible jobs by the number of workers that can access them, thereby accounting for the demand potential for each job. The vertical equity of accessibility by transit is then assessed for both years by comparing competitive accessibility levels across median household income deciles. Vertical equity is used to measure the provision of service to vulnerable groups compared to the general population. Two linear regressions are subsequently performed to examine the relationship between accessibility changes and income and unemployment at the census tract level, while controlling for the movement of residents. This study contributes to the literature on accessibility and the equity of outcome resulting from these accessibility levels, and is of relevance to planning professionals and researchers wishing to investigate the effects of accessibility improvements across neighbourhoods, especially low income ones.

The rest of the chapter is organised as follows. Section 2 explains the concept of accessibility, examines how equity is incorporated in academic literature on this concept, and presents previous

literature on accessibility, employment and income. Section 3 considers the data and methodology used to investigate the relationship between improvements in transit accessibility and changes in income and unemployment, and section 4 presents and discusses the findings. Section 5 then concludes the paper and provides recommendations for further research.

2.2 EQUITY OF ACCESSIBILITY AND EQUITY OF OUTCOME

2.2.1 Accessibility

Accessibility was first defined by Hansen (1959) (p.73) as "the potential of opportunities for interaction". In contrast with mobility, accessibility also considers land use factors such as the variety and number of destinations that can be reached, instead of only examining an individual's ability to move through the transportation network (Handy & Niemeier, 1997). Geurs and van Wee (2004) posit that accessibility measures should comprise four interacting components: land use, transportation, time, and the individual. Accessibility thus tries to incorporate the spatial distribution of activities, the transport system connecting these activities, the time constraints of individuals and services, and personal needs and abilities to provide a more accurate picture of the performance of transport systems.

There are several commonly used measures of accessibility, most of which take into account only the land use and transportation component, as they can be more easily computed, interpreted, and communicated, increasing their chances to impact policy (Geurs & van Wee, 2004; Handy & Niemeier, 1997). Cumulative measures of accessibility count the number of opportunities that can be reached within a set time-frame, for example the number of jobs an individual can reach within 45 minutes of travel (Wickstrom, 1971). Gravity-based accessibility measures, on the other hand, take into account that people will not stop travelling at an arbitrary time-limit, and weigh opportunities by distance; the further an opportunity is, the less it contributes to accessibility (Hansen, 1959). While more realistic, gravity-based measures require the prediction of a distance decay function, rendering them more difficult to communicate, interpret and analyze across studies.

To account for competition effects, for example among workers competing for jobs, the concept of accessibility has also been extended to include measures of competitive accessibility (Shen, 1998). As cumulative and gravity-based accessibility only measure the 'supply side' of opportunities (Geurs & van Wee, 2004; Morris, Dumble, & Wigan, 1979), they assume that no capacity limitations exist. Therefore, when accessibility to jobs is examined through the lens of ordinary cumulative or gravity-based accessibility measures, it is assumed that one job can be filled by an infinite number of workers. To more accurately reflect reality, a demand potential is first computed by determining how many individuals can access each opportunity. Each opportunity is then discounted by this demand potential when calculating accessibility using the cumulative or gravity-based approach in what is known as a competitive measure of accessibility (Shen, 1998). For example, in a region with 10 jobs and 100 workers that can access these jobs, competitive accessibility would be 0.1.

2.2.2 Equity of accessibility

Measures of accessibility have often been used to consider the equity of the joint benefits provided by the land use and transportation system (see for example (Delmelle & Casas, 2012; Golub & Martens, 2014; Grengs, 2015; Guzman, Oviedo, & Rivera, 2017)). Two different interpretations of equity in accessibility research exist, both founded in the ethical concept of egalitarianism (Foth et al., 2013; van Wee & Geurs, 2011). Horizontal equity requires that all members of society have equal access to all resources. Vertical equity, on the other hand, implies that the more vulnerable groups should be granted more resources. From this point of view, it would be more beneficial to society to increase the accessibility of unemployed young individuals than to increase the accessibility of wealthier individuals (Lucas, van Wee, & Maat, 2016). Yet another approach defines an equitable system as having a minimal gap between transit and car accessibility (Golub & Martens, 2014; Karner & Niemeier, 2013), after which both the horizontal and vertical equity of the distribution of this gap can be measured.

Current literature mostly focuses on examining the vertical equity impacts of transportation projects. To examine this type of equity, socially vulnerable groups first need to be defined. Several studies identify socio-economic groups based solely on income (for example (Fan, Guthrie, & Levinson, 2012; Guzman et al., 2017)), whereas other studies also examine race, poverty status, minorities, and housing characteristics (Delmelle & Casas, 2012; Golub & Martens, 2014; Grengs, 2015), or create a social indicator combining several of these measures (Foth et al., 2013). The vertical equity of accessibility can then be investigated by comparing accessibility levels across different populations.

A distinction is often made between equity of opportunity and equity of outcome, the latter relating to the benefits gained from higher levels of opportunity (Delbosc & Currie, 2011; Litman, 2002; van Wee & Geurs, 2011). Transport-related outcomes (or benefits) include, among others, higher educational attendance, new employment opportunities and more frequent health visits . Studies discussing the horizontal and vertical equity of accessibility address equity of opportunity, but refrain from making judgements on the outcome of the process. This paper attempts to connect the two concepts by considering the link between equity of opportunity, measured by accessibility, and equity of outcome, measured by changes in unemployment and income over time.

2.2.3 Accessibility, unemployment and income

To determine the outcomes and subsequent benefits resulting from accessibility and accessibility changes, previous studies have focused on examining the relationship between accessibility to jobs and socio-economic status, mostly concentrating on unemployment duration. Korsu and Wenglenski (2010), using micro-data, demonstrate that low accessibility to jobs is related to high unemployment in Paris, and find that workers living in areas with very low accessibility have a 1.7% higher probability of being unemployed for longer than one year compared to workers living in neighbourhoods with medium accessibility. To this end, the authors use a measure of cumulative accessibility, by public transport or car depending on car ownership, specifically considering the employment opportunities of the same socio-professional status as the individuals in question. Andersson, Haltiwanger, Kutzbach, Pollakowski, and Weinberg (2014) investigate low-income workers who were subject to mass layoffs in several US cities, and find that high accessibility to

jobs is associated with a reduction in the time spent looking for work. A competitive measure of accessibility to low-income jobs is used for this purpose, taking into account the probability of using car or public transport, and explicitly considering competing job searchers to account for labour market tightness. Tyndall (2015) notes that after the closure of the R train in Brooklyn due to hurricane Sandy, unemployment rates along the line increased considerably, especially for those without a private vehicle, demonstrating that substantial changes in the public transport system affect unemployment. This study did not, however, examine the accessibility impacts of this endogenous shock to the transport system. Blumenberg and Pierce (2014) find that living close to a bus stop highly increases the chances of maintaining consistent employment, while having access to a private automobile has also been shown to be related to increased employment (Blumenberg & Pierce, 2017). Larson (2017) examines the relationship between access to jobs by public transport (broadly defined as the observed transit modal share) and economic opportunity over four decades in four US cities, and concludes that there is a positive relation between transit access and economic opportunity in predominantly white neighbourhoods in Orlando and Minneapolis, while a similar relationship is present in non-white areas in Birmingham.

This emerging body of literature suggests that accessibility to jobs is a potential determinant of unemployment duration. However, little is known about the relationship between unemployment rates and accessibility over time at a more aggregate, metropolitan scale; the literature presented above has not examined how accessibility changes impact longer term unemployment duration and more aggregated unemployment rates. Furthermore, no study has, to our knowledge, examined changes in accessibility and median household income over time. To provide a more holistic view on the relationship between accessibility changes and consequent changes in socio-economic status at an aggregate level, this study attempts to investigate the change in both the unemployment rate and median household income over a ten-year period. This paper therefore contributes to the literature by presenting a long-term study associating a robust accessibility measure with equity of outcome.

2.3 DATA AND METHODOLOGY

2.3.1 Study context

The Greater Toronto and Hamilton Area, the most populous metropolitan region in Canada, housing 5.6 million residents in 2001 and 6.6 million inhabitants in 2011, was chosen to examine the relationship between transit accessibility improvements and changes in income and unemployment. The region is well connected by public transport, and is home to a subway, commuter train system and bus network (Figure 1). While the subway only serves the City of Toronto, the bus and train network extend across the entire region. During the ten-year study period, several infrastructure projects altered the public transport network in the area. In 2002, a new subway line, the Sheppard line (the line shown in green in Figure 1), was opened, serving five new stations in the north of the City of Toronto. Additionally, several new train stations were constructed and new express bus services were introduced. At the same time, transit mode share increased from 20% in 2001 to 21% in 2011.

2.3.2 Data

Three different data sources were used for the analysis. Census and employment data for 2001 and 2011 were obtained from Statistics Canada. This data was enriched by a cumulative accessibility measure for a 45-minute trip by transit in 2011 at the census tract level, derived from GTFS data. The third data source, Metrolinx, provided travel time from 2001 at the traffic analysis zone (TAZ) level, calculated through the EMME travel demand modelling software, for both public transportation and automobile. Additionally, car travel time from 2011 during the AM peak was also supplied by Metrolinx.

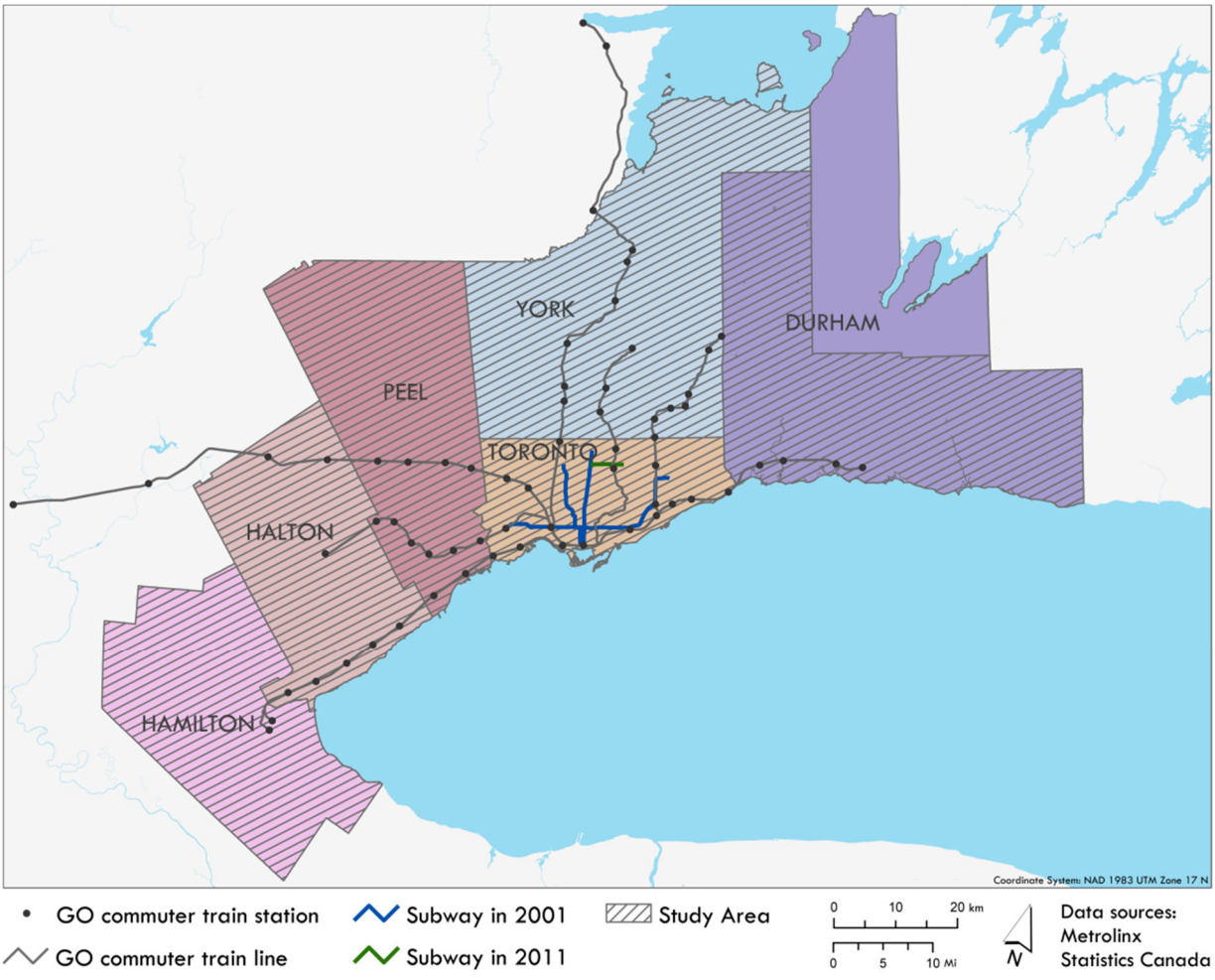

FIGURE 1 Context map

A competitive measure of accessibility for 2001 at the TAZ level was first calculated using 2001 travel times and employment. Competitive accessibility is given by:

$$A_m^i = \sum_j \frac{O_j f(t_{ij}^m)}{D_j^m}, \text{ where } D_j^m = \sum_j LF_j \, f(t_{ij}^m)$$

A_m^i reflects the accessibility at point i for transportation mode m, O_j is the number of opportunities at location j, and $f(t_{ij}^m)$ is 1 when the travel time between locations i and j (t_{ij}^m) is smaller than

the set-time limit, and 0 otherwise. D_j^m represents the demand for the opportunities at location j, and is given by the total labour force (LF_j) that can access those opportunities within the set time-limit. To ensure consistency with available data from 2011, and to allow for comparisons, the accessibility measure was calculated for a 45-minute trip limit for public transport, and a 30-minute limit for car, and then projected into 2011 census tract boundaries through a nearest neighbour interpolation (i.e., each 2011 census tract centroid was assigned the accessibility value of the nearest 2001 census tract centroid). These time limits reflect the average commute times in Toronto for both modes (49 and 29 minutes respectively (Statistics Canada, 2010)), in order to capture the opportunities an individual can access in an average trip, while accounting for competition from other residents trying to reach the same opportunities.

2.3.3 Methodology

To investigate the relationship between improvements in transit accessibility and changes in the unemployment rate and median household income, two linear regression models are employed. The first model predicts median household income in 2011, based on median household income in 2001 and changes in accessibility by car and transit between the two years. The second model is specified in a similar manner: the unemployment rate in 2011 is related to the unemployment rate in 2001 and changes in accessibility levels.

As changes in income, especially for low income census tracts, could be related to gentrification, i.e., the upgrading of the socio-economic status of a neighbourhood through local migration (Lyons, 1996), several additional variables are added to the model. Literature on the relation between transit and gentrification usually investigates land and housing values, changes in income, race, car ownership, the number of professionals, and educational attainment to identify gentrifying areas (Grube-Cavers & Patterson, 2015; Kahn, 2007; Pollack, Bluestone, & Billingham, 2011). A neighbourhood is said to be gentrifying if these variables change faster than the average in the metropolitan area. Such an approach, however, does not account for the movement of people. Some of the changes noted by the literature could, instead of being linked to gentrification, have resulted from an improvement in the conditions of the individuals living in a certain neighbourhood, without the presence of outside forces pushing these residents out; increases in income do not always imply that people were pushed out and wealthier individuals moved in (Freeman, 2005). Also incorporating the percentage of people moving mitigates these disadvantages and acknowledges that in-movers are the driving force behind gentrification (Freeman, 2005). Consequently, the change in the percentage of residents with a bachelor's degree or higher, and the percentage of residents that have moved between 2006 and 2011 are included in the regression model to control for the effects of gentrification, and, more broadly, migration. The summary statistics of the variables used in the two models are shown in table 1.

TABLE 1 Summary statistics

Variable	Mean	Standard dev.
Median Household Income in 2011 ($1,000)	75.664	26.536
Median Household Income in 2001 ($1,000)	64.534	21.558
Unemployment rate in 2011 (%)	8.7173	3.1598
Unemployment rate in 2001 (%)	5.7868	2.4814
Change in competitive accessibility by transit (jobs/worker)	-0.0897	1.1893
Change in competitive accessibility by car (jobs/worker)	0.2422	0.2917
Change in percentage of residents with a bachelor's degree or higher (%)	4.3710	4.9699
Percentage of residents that have moved between 2006 and 2011 (%)	35.131	11.480

2.4 RESULTS AND DISCUSSION

Figure 2 shows the spatial distribution of median household income and the unemployment rate in the GTHA in 2001 and 2011. In the top two maps, the darkest colour represents the census tracts with the lowest income, whereas the lightest color represents the least vulnerable neighbourhoods. In both years, the low-income census tracts are centred in a ring around downtown Toronto, although a suburbanization of low income areas has occurred; the neighbourhoods to the north and east of the City of Toronto have become more vulnerable in 2011. The outer suburbs, as well as the CBD of Toronto, house higher income populations in both years. In the bottom map, the lowest unemployment rate is presented in the lightest color, while the highest unemployment rate is shown in the darkest color. The financial crisis of 2007-2008 radically changed the pattern of unemployment across the region: the unemployment rate skyrocketed between 2001 and 2011 in almost every census tract, especially in the outer suburbs.

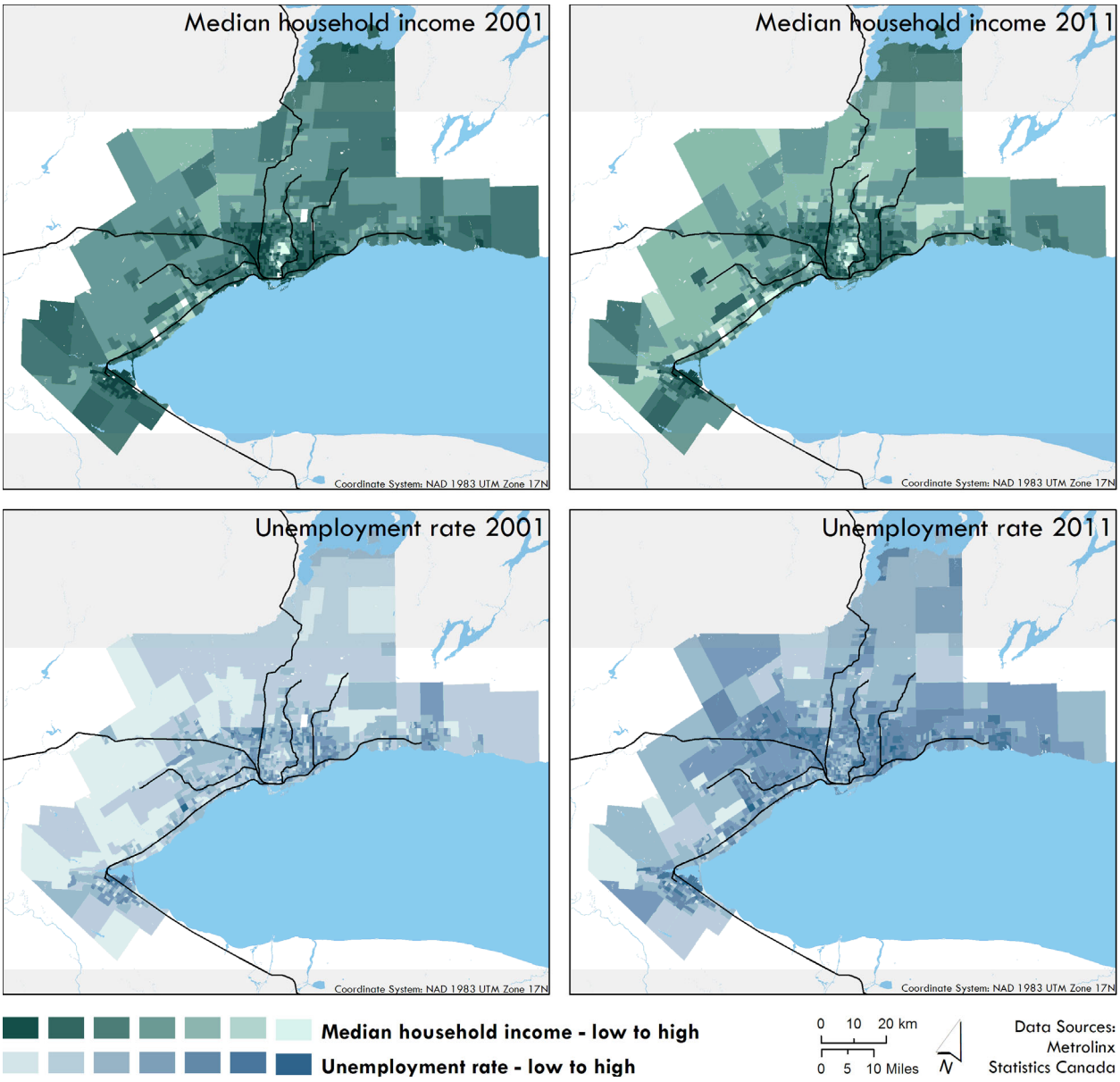

FIGURE 2 Median household income and unemployment rate in the GTHA in 2001 and 2011

The spatial distribution of competitive accessibility by public transport and car in both 2001 and 2011 are shown in figure 3. Transit accessibility was calculated for a maximum travel time of 45 minutes, whereas car accessibility was computed for a 30-minute trip. The two modes display profoundly different spatial patterns, due to significant directionality present in the public transport system. During the morning peak, the GO train network focuses on bringing residents into the Toronto CBD, while the service in the opposite direction is close to non-existent. Suburban job centers are therefore protected from competition by transit: only local residents can access these employment opportunities, resulting in high competitive accessibility levels. Suburban areas thus exhibit higher competitive accessibility levels than central areas, despite the high proportion of jobs in the CBD, as the potential demand for suburban jobs (number of workers having access to

each job) is lower than the potential demand for downtown jobs. Competitive accessibility by transit is thus largely determined by competition effects. In contrast, accessibility by car is mostly influenced by the presence of job opportunities, as directionality is less present in the highway and street networks. Car accessibility is thus highest in downtown Toronto, where the largest amount of job opportunities is present.

Between 2001 and 2011, accessibility by private automobile rose substantially in Toronto and in the western parts of the region, whereas a small decrease was observed in the eastern census tracts. This increase is likely due to the expansion of the highway 407, especially west of the CBD, allowing individuals residing in the western areas to access a considerably higher number of jobs located in and around the CBD. At the same time, competitive accessibility by transit increased in a few clusters of suburban job centers, and decreased in the rest of the Greater Toronto and Hamilton Area. This decrease is related to both a suburbanization of jobs and investments made in the GO train network between 2001 and 2011. As jobs moved away from the city centre, accessibility in Toronto's urban core decreased, as people could no longer access these jobs. In addition, the investments made in the GO train network ensured that more people could access jobs in the CBD. Thus, competition for this smaller number of downtown jobs increased, again lowering the competitive accessibility level.

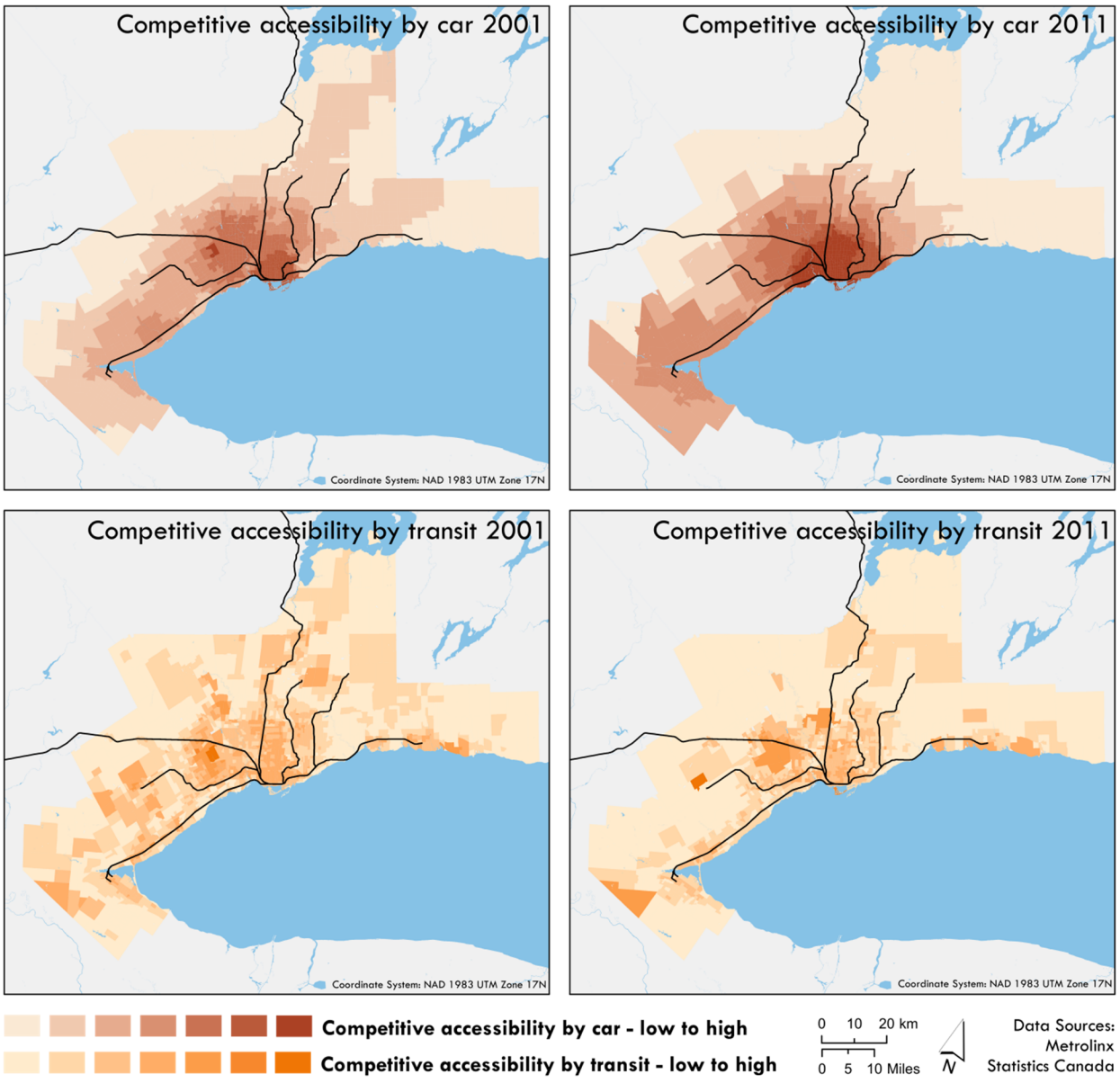

FIGURE 3 Transit accessibility in the GTHA in 2001 and 2011

2.4.1 Vertical equity

Figure 4 presents transit accessibility standardized values (z-scores – distance from the mean divided by the standard deviation) by income decile. In 2001, the four deciles with the lowest income in the region experience considerably higher competitive accessibility levels by transit than all other groups, highlighting that accessibility is vertically equitable in the GTHA, which is consistent with the findings of Foth et al. (2013) for the Greater Toronto and Hamilton Area. Competitive accessibility of the four groups with the lowest income decreased between the two years, however, although they continue to have a considerably higher accessibility than the other income deciles. The investments in commuter trains, connecting wealthier neighbourhoods to

downtown Toronto, have therefore succeeded in increasing accessibility to employment for high income census tracts, thereby reducing the relative accessibility of low income census tracts This suggests that, while the vertical equity of the transportation and land use system is still high in the GTHA, there is a trend towards decreasing vertical equity and increasing horizontal equity. Note that, as socially vulnerable groups have lower car ownership (Potoglou & Kanaroglou, 2008), this decrease in accessibility can result in substantial negative consequences for the region's most vulnerable populations. To quantify the effects of these accessibility changes on neighbourhood socio-economic status, results of the linear regression models are presented in the next section.

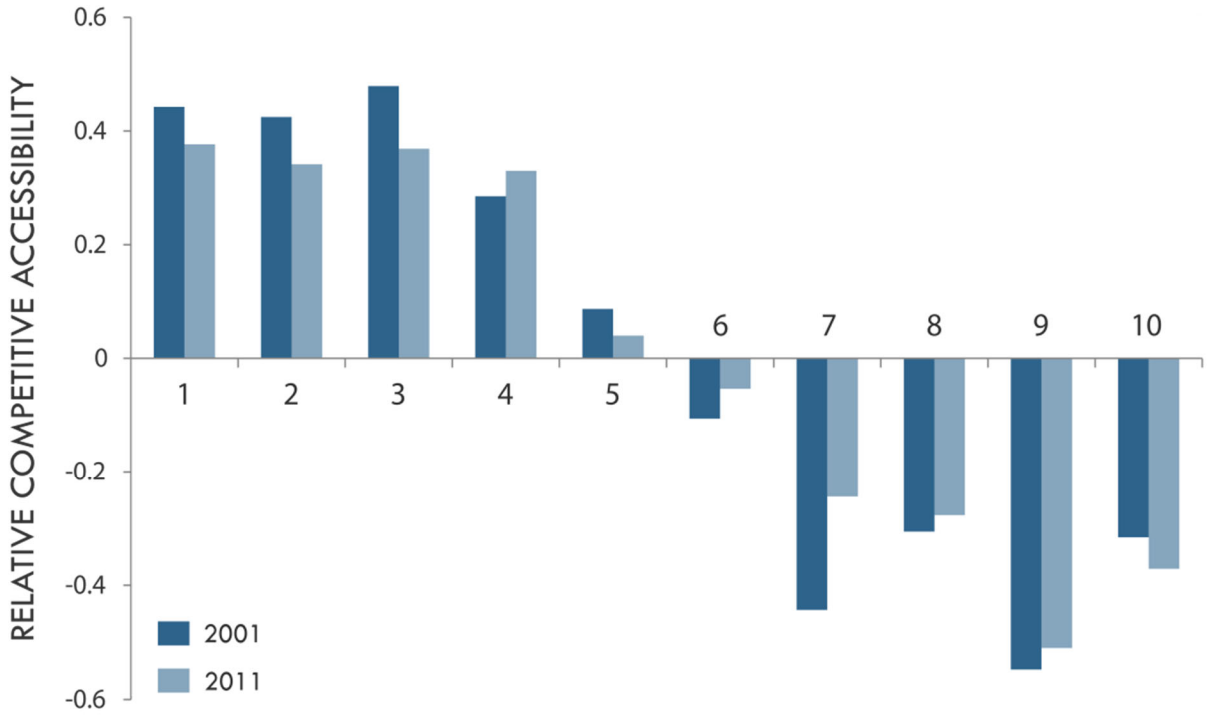

FIGURE 4 Relative competitive accessibility by transit, by income decile in the GTHA

2.4.2 Linear regression models

Table 2 shows the results of the two linear regression models, with both models showing similar patterns. Only the variables that are statistically significant will be described here. The model predicting median household income in 2011 demonstrates that higher median household income in 2001 is associated with higher median household income in 2011, while the coefficient of 1.12 for this variable suggests that overall income levels rose by 12% during the study period, while controlling for all other variables present in the model. Changes in competitive accessibility by transit, and the interaction term between this variable and median household income in 2001, are significantly related to income in 2011. For example, a census tract with a median household income of $40,000 in 2001 is predicted to have an extra increase in income of (7.67 – 0.099*40) = 3.71 ($3,710) in 2011 per extra unit in competitive accessibility (Table 2). A one unit increase in competitive accessibility occurs when a person can access an extra job that is not accessible to all other residents in the region. The effect of competitive accessibility reverses when income in 2001 is higher than $77,475 (when 7.67 – 0.099*Income = 0). As higher income populations are

more likely to move to less dense areas in search for open space, they tend to migrate to areas without public transport access. As a result, median income decreases in areas where these wealthy groups move out. Increases in competitive accessibility by car are also statistically significant and associated with higher incomes in 2011: a one unit increase in car accessibility is predicted to increase income by $3,370. An interaction term between car accessibility and baseline household income in 2001 was also analyzed, but was not significant, indicating that the effect of accessibility by car is income-independent.

The remaining statistically significant coefficients highlight that increases in the percentage of residents with a bachelor's degree or higher, and stable neighbourhoods (without many people moving) are related to higher median household incomes in 2011. The significant relationship between income and accessibility by both car and public transport thus highlight that changing equity of opportunity, measured by accessibility, is associated with a changing equity of outcome, measured by income. As the model controls for the migration of highly educated individuals and for percentage of households that moved between 2006 and 2011, the changes in median household income are not only related to gentrification, but also to changes in the income of the residing households.

The second model indicates that higher unemployment rates in 2001 are associated with higher unemployment rates in 2011, suggesting that census tracts with high unemployment rates in 2001 still have higher unemployment in 2011. An extra accessible job by transit that cannot be reached by any other individual (a one unit increase in transit accessibility) is related to a 2.5 percentage point decrease in unemployment rate for census tracts with a median household income of $0. If median household income in 2001 increases, the effects of changes in transit accessibility lessen and reverse at a median household income of $78,052. In contrast, the change in car accessibility has a uniform effect across income: one extra accessible job by car that cannot be reached by others is linked to a decrease of 0.54 percentage points in unemployment rate. As with the model predicting income, increases in the percentage of residents with a bachelor's degree or higher are significantly associated with lower increases in the unemployment rate. These results are consistent with the findings presented by Tyndall (2015), who found that a substantial change in the provision of public transport (and thus a considerable change in access by transit) was associated with changing unemployment. This suggests that the conclusions by Korsu and Wenglenski (2010) and Andersson et al. (2014) can be extended from unemployment duration at the individual level to aggregated unemployment rates at the neighbourhood scale.

Table 3 presents predicted values for median household income and the unemployment rate in 2011 for all income deciles in 2001. The values are predicted for a constant transit accessibility, and for a transit accessibility that increased by one unit during the study period. Median household income in 2011 is greater for all deciles except the two wealthiest groups if accessibility by public transport increased instead of remaining constant. The premium generated by transit accessibility ranges from $3,812 for the lowest income decile to -$13,744 for the highest income decile. One hypothesis for the negative premium observed in the highest income deciles is that wealthier individuals might decide to move away from areas with increased transit accessibility. This is in line with previous research conducted in New Jersey, which found that the construction of a new

rail was associated, although not significantly, with a depreciation in property value for houses in high income census tracts near the stations (Chatman, Tulach, & Kim, 2012). This suggests that locations with increased transit accessibility become less desirable for high income individuals. This is likely explained by differing neighborhood preferences; while low-income individuals might value transit accessibility, high-income individuals, which are more likely to have access to a private vehicle, might place a higher value on residing in a quiet, less dense neighborhood. A similar pattern is present in the predicted unemployment rates: the predicted effect of a unit increase in competitive accessibility by transit is -1.28 percentage points for the poorest census tracts, and 4.52 percentage points for the wealthiest decile. Based on these predictions, we can infer that the decreasing vertical equity of transit accessibility (as shown in Figure 4) is associated with a widening of the income gap among the census tracts of the GTHA.

TABLE 2 Regression results for census tract median household income and unemployment rate in 2011 in the Greater Toronto and Hamilton area

	Income				Unemployment rate			
Variable	**Coefficient**	**Sig.**	**Confidence interval†**		**Coefficient**	**Sig.**	**Confidence interval†**	
Constant	5.11	***	2.071	8.15	4.7788	***	4.2652	5.2925
Median household income in 2001	1.121	***	1.093	1.149	-	-	-	-
Unemployment rate in 2001	-	-	-	-	0.6986	***	0.6362	0.761
Change in accessibility by transit	7.67	*	1.276	14.065	-2.5523	**	-4.2517	-0.8529
Change in accessibility by transit • Median household income in 2001	-0.099	*	-0.181	-0.016	0.0327	*	0.0108	0.0546
Change in accessibility by car	3.37	***	1.49	5.249	-0.5402	**	-1.0368	-0.0436
Change in percentage of residents with a bachelor's degree or higher	0.664	***	0.554	0.775	-0.093	***	-0.1232	-0.0627
Percentage of residents that have moved between 2006 and 2011	-0.154	***	-0.206	-0.103	0.0116		-0.0020	0.0252
Adjusted R^2	0.8695				0.352			

Dependent Variables: Median household income in 2011 ($1,000), Unemployment rate in 2011 (%)
* 95% significance level | ** 99% significance level | *** 99.9% significance level
† 95% confidence interval

TABLE 3 Predicted 2011 income and unemployment rates for each income decile in 2001

			Change in transit accessibility = 0		Change in transit accessibility = 1	
Income decile	**Income 2001**	**Unemployment rate 2001**	**Predicted income 2011**	**Predicted unemployment rate 2011**	**Predicted income 2011**	**Predicted unemployment rate 2011**
1	38,967	9.7260	47,100	11.4435	50,913	10.1655
2	45,353	7.5418	54,260	9.9177	57,440	8.8484
3	50,835	6.5180	60,404	9.2024	63,042	8.3124
4	57,487	5.8651	67,860	8.7463	69,839	8.0738
5	63,125	5.6117	74,182	8.5693	75,603	8.0812
6	70,204	5.0530	82,117	8.1790	82,837	7.9223
7	75,605	4.6826	88,172	7.9202	88,357	7.8402
8	81,954	4.6638	95,289	7.9071	94,846	8.0347
9	89,749	4.1651	104,026	7.5587	102,811	7.9411
10	216,308	4.0577	245,900	7.4837	232,155	12.0046

2.5 CONCLUSION

Accessibility to jobs by public transport is a key factor explaining the quality of life of individuals. Results show that accessibility to jobs by public transport is relatively vertically equitable in the Greater Toronto and Hamilton Area, although vertical equity decreased between 2001 and 2011. The census tracts with the lowest income boast the highest accessibility to jobs thanks to their proximity to downtown Toronto and the public transport network, while wealthier groups experience lower accessibility levels.

This study suggests that, for low and medium income census tracts, increases in transit accessibility are related to higher increases in income. For wealthier census tracts, increases in transit accessibility are associated with decreases in income, potentially due to the migration of high-income populations to less dense neighbourhoods, away from transit. In other words, improvements in transit service, such as a new express bus or rail connection, might bring significant changes to a neighborhood's structure, namely densification and more mixed use, which might decrease the desirability of living in such areas for some populations. Further research is, however, needed to confirm and understand this relationship. The change in accessibility by car, on the other hand, has a uniform effect across income deciles and is associated with larger income increases. The equity of accessibility to employment opportunities thus plays a key role in determining resulting equity of outcome, stressing the need for methods that can incorporate equity considerations into the evaluation of new transportation projects.

It is important to note that the findings from this study are not conclusive, nor can they determine a causal relationship; more analysis is needed in multiple cities across the globe to further investigate the relationship between accessibility improvements and changes in income and unemployment. Different contexts might be associated with varying housing preferences, e.g. a preference for central mixed-use and dense neighborhoods, and accordingly yield different results.

While multiple variables related to migration were examined, this study does not fully capture the impacts of population movement between 2001 and 2011. The study controls for changes in the proportion of individuals with a university degree, but does not directly measure the movement of individuals according to their income level. The uncovered relationship could therefore partially be explained by transit accessibility attracting medium income populations, resulting in increases in income for low income areas, and decreases in income for the wealthiest neighbourhoods. This highlights the need for further research in order to disentangle the complex socio-spatial relationships uncovered in this study. Ideally, future research should employ micro-data to track individuals over time, and use surveys and interviews to shed more light on individual changes in accessibility and socio-economic status.

Future studies should also include the cost of transportation in their analysis and normalize the fares according to income. This would lower the accessibility of the entire population (El-Geneidy et al., 2016), and could reduce accessibility for socially vulnerable groups compared to wealthier groups.

Different types of jobs were not distinguished in the present study, although people cannot access all the different jobs that exist within a city; an individual without a high school diploma will not be able to access the high-wage service-sector jobs that cities offer, regardless of the transport and land use system. Future studies should therefore differentiate low, medium, and high income jobs when comparing accessibility across different groups and different years. The analysis should also take into account the time when different jobs start and incorporate the time aspect in the calculation of accessibility by public transport.

Nevertheless, the results of this study demonstrate a clear association between improvements in accessibility by transit and positive outcomes (measured by changes in income and unemployment) for neighbourhoods with low and medium income. The relationship observed in this study establishes new directions for future research in order to explore the equity of outcome resulting from changing accessibility levels.

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