Achieving Recommended Physical Activity Levels through Public Transportation Use: Unpacking Individual and Contextual Effects

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ABSTRACT

This paper estimates the amount of daily walking associated with using public transportation in a large metropolitan area and examines individual and contextual characteristics associated with walking distances. Total walking distance to and from transit was calculated from a travel diary survey for 6,913 individuals. Multilevel regression modelling was used to examine the underlying factors associated with walking to public transportation. The physical activity benefits of public transportation varied along gender and socio-economic lines. Recommended minutes of daily physical activity can be achieved for public transportation users, especially train users living in affluent suburbs.

KEYWORDS:

Public transportation, transit, commuting, walking, physical activity, health disparities

INTRODUCTION

The World Health Organization (WHO) identified transportation as one of the top ten social determinants of health (Wilkinson and Marmot, 2003, Commission on social determinants of health, 2008). Physical activity associated with the use of public transportation leads to a number of health benefits including reduced rates of obesity and many chronic diseases (Brown and Werner, 2007, Jakicic and Gallagher, 2003, Sallis et al., 2004, Transport Canada, 2005, Wilkinson and Marmot, 2003, Warburton et al., 2006, MacDonald et al., 2010). Previous research has shown that walking has the potential to have widespread public health impact, mainly due to its ease and low cost (Lee and Buchner, 2008).

Walking associated with daily commuting by public transportation can have a considerable impact on public health; however, the extent to which different groups of the population can benefit from this routine activity is rarely studied. Zhao et al. (2003) measured walking distances to transit stops to forecast transit accessibility and El-Geneidy et al. (2010) measured walking distances to transit stops to estimate bus service areas around stops. Another study has looked at the number of theoretical steps ‘in reserve’ if non-users were to start using public transportation (Morency et al., 2007). This study, however, did not incorporate characteristics of individuals, transportation service networks nor neighborhoods in their understanding of the public health potential of public transportation.

Two studies have measured overall walking to transit, the first by Besser and Dannenberg (2005) in the United States and the second by Morency et al. (2011), in Montréal, Canada. Besser and Dannenberg (2005) used the 2001 National Household Travel Survey to examine total walking to light rail and public buses in the United States; however, they did not incorporate transit service characteristics nor differentiated between trip purposes in their models. Previous research has pointed to the importance of modeling different trip purposes separately, as each trip purpose has different characteristics and interacts differently with the built environment (Saelens et al., 2003, Handy, 1996). Large variation in walking distances and durations by trip purpose were found in the 2009 National Household Travel Survey (Yang and Diez-Roux, 2012) as well as other studies in the Twin Cities (Iacono et al., 2010) and Montréal (Larsen et al., 2010).

Morency et al. (2011) used the same survey data (Origin Destination survey) that is used in our analysis to estimate total walking to public transportation. The study by Morency et al. (2011), however, had several major drawbacks. First of all, the study did not distinguish trip purposes. Their study, further, did not take into consideration important contextual factors of neighbourhood and transit service characteristics. Accordingly, their walking trips model was missing key variables that resulted in a poor explanatory power (R-squared value of 0.069). The utility of their results are further hindered in that they are not reproducible elsewhere with routinely available software.

This paper estimates the amount of daily walking that can be achieved when commuting by public transportation by way of analyses of a travel behavior survey (Origin-Destination Survey) in Montréal, Canada. Our analyses unpack the underlying individual (e.g. age, gender, income level) and contextual factors (e.g., transportation service characteristics, land use diversity, street design, neighbourhood social characteristics) associated with this type of routine physical activity. Our research improves the current knowledge on this subject by: (1) focusing exclusively on commuting trips (work and school) ; (2) incorporating the influence of contextual factors of neighbourhood and transit service characteristics on daily walking in a multilevel modelling framework; (3) providing a clear replicable methodology for use in other cities.

BACKGROUND

Our modern urban environments tend to promote sedentary lifestyles (Egger and Swinburn, 1997). The heavy dependence on single occupancy vehicles in North America and perceived lack of adequate time for physical activity can contribute to poor mental and physical health as well as the onset of chronic disease such as obesity, cardiovascular diseases, hypertension, osteoarthritis, some types of cancers and type 2 diabetes (Wei et al., 1999, Jakicic and Gallagher, 2003, Frank et al., 2004, Katzmarzyk, 2004). Physical inactivity is identified as the fourth leading risk factor for global mortality, estimated to contribute to 6% of deaths worldwide. It is clear that the overall burden of physical inactivity is a major public health concern and, from an economic perspective, a source of increasing health care utilization and expenditure (Sari, 2009, Finkelstein et al., 2003, Brown et al., 2008).

At least 60% of the global population fails to achieve the minimum recommendation of 30 minutes of daily moderate physical activity (WHO 2003). In Canada, two-thirds of the population are not meeting this level of physical activity (Public Health Agency of Canada, 2008, Sari, 2009, Katzmarzyk et al., 2000). Advising people to reduce sedentary time is one solution. It is notoriously difficult to change human behaviour, however, and so the general thinking is that advice must be combined with macro-scale policies that have the potential to affect entire populations. Substantial public health benefits are thought only to be possible through action directed at targets like structural modifications in the transport system and the built environment, marketing policies, and the education system (Ekelund, 2012)

The use of active transportation provides an opportunity to introduce routine, daily physical activity into the lives of large groups of people and thus can be thought of as an important population health intervention tool (Sallis et al., 2004, Transport Canada, 2005). Public transportation is considered an active mode of transportation since it involves walking to and from stations. In Canada around 15.2% of work trips are done using public transportation

(Hollingworth et al., 2010), and in Montréal the figure is approximately 13.7% (Agence métropolitaine de transport, 2003).

In this paper, total walking distances to and from transit stops for a variety of public transportation services (metro, commuter train, urban and suburban bus services) are estimated. Total distances walked to and from transit stations are further translated into minutes of physical activity in order to estimate the contribution of public transportation in achieving the public health goal of 30 minutes of daily physical activity. Our analyses are informed by the general hypothesis that both individual factors (age, sex, socioeconomic status) and factors related to neighbourhoods and transit systems influence the amounts of physical activity that can be achieved by using public transportation. Knowledge of these factors can help inform the potential public health impacts of investments in public transportation.

METHODS

Study area, selection and description of participants:

Montréal, Québec, is the second-highest populated metropolitan region in Canada with 3.7 million residents. Participants in this study were drawn from a travel behavior survey known as the Origin-Destination (OD) Survey (Agence métropolitaine de transport, 2003). The OD Survey is a phone survey conducted every five years in the Montréal metropolitan region by the Agence Métropolitaine de Transport (AMT) – the agency responsible for regional public transportation in Montréal. The OD Survey covers around 5% of the Montréal population (169,900 individuals). One person in every household contacted is asked to report all trips made by her/himself and every other member of the household in the previous day. Although this method might impose some error in the estimates of walking because of the proxy reporting, the Montréal OD survey has been extensively tested and several validation tools have been in place for several decades to ensure the quality of the collected data (Chapleau, 2003). For every trip, participants were asked to record the place where they started their trip (origin) and the place where they ended it (destination). Participants were also asked to record the mode of transportation used for each trip (i.e., bus, train, metro, car, cycling, walking, etc.). For participants using public transportation, additional questions were asked regarding which transit route they selected. All public transportation trips were tested against a database including all existing schedules in the region to ensure the accuracy of the reported trips.

Trips included in the analyses of this study were only trips that were made by public transportation (i.e. bus, metro and train), where participants walked to and from public transit stops or stations. They represent 13.7% of the total trips in the OD survey. Participants cycling to the train were excluded since they comprise a tiny proportion of total trips (less than 0.0001%). Additionally, participants were non-retired adults 18 years and older for whom their primary trip purpose (first trip in the day) was going to work or school (college/university) - around 45% of all reported trips in the survey. These are the main trips that people conduct on a daily basis and are the routine trips that have the potential to support frequent and enduring physical activity.

INSERT FIGURE 1 AROUND HERE

Calculation of variables used in the study:

For each respondent, total distance walked to and from transit stops was computed in a geographic information system (GIS) environment. In the OD survey, respondents were not asked to report the actual transit stop or station they used, but were asked to report the transit route (e.g., bus number, metro line, etc). Total distance walked was measured on the street network from participants' origin location to the nearest transit stop or station of the transit route they used. Transit stop locations were obtained from different transit agencies in the region as

XY locations, while origins and destinations were reported as XY coordinates in the OD Survey. The distance that participants walked at the end of their trip, from the nearest transit stop to their destination, was measured using the street network as well. Small paths and alleyways were included as part of the pedestrian network used while, freeways and any facility that did not allow pedestrians were excluded. For every transit trip, in-vehicle distance, which is the distance travelled inside the public transportation vehicle during the trip, was calculated using the transit network. Daily walking distances were calculated as:

$$\text{TDist} = \sum_{T=1}^{6} (\text{WDO} + \text{WDD}) \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:

TDist = Total distance walked for every person in the OD survey who used public transportation.

WDO = Walking distance measured from the trip origin to the nearest transit station or stop along the transit route.

WDD = Walking distance measured from the trip destination to the nearest transit station or stop along the transit route.

T = Number of transit trips made by a participant who walked to and from the transit stops.

INSERT FIGURE 2 AROUND HERE

Figure 2 shows a typical transit trip and its various components. Distances walked by respondents were then translated into walking minutes based on average walking speed. Observed average walking speed for adults varied from 4.8 to 5.7 km per hour (3 to 3.6 mile per hour) between different studies in North America and Australia (Bennett et al., 2001, Fruin, 1971, Knoblauch et al., 1996). The mid-range average speed observed by Knoblauch et al.

(1996) was 5.4 km per hour (3.4 miles per hour or 90.6 meter per minute) for individuals 14-64 years old. Since our simulation models (described below) are based on a typical 20 year old male and a typical 34 year- old male, walking minutes are calculated based on the mid-range average walking speed (5.47 km/hour (3.4 miles/hour)).

Multilevel analysis:

OD respondents were placed into census tracts (CTs). CTs are defined by Statistics Canada as “small, relatively stable geographic areas that usually have a population of 2,500 to 8,000 with homogenous characteristics” (Statistics Canada). Census tracts have been shown to be valid proxies of residential neighborhoods of individuals (Ross et al., 2004). A total of 547 CTs were included in the study; the median number of respondents included in each CT was 17 persons. A CT in Montréal covers an average area of 5.2 square km. Other data were collected as well at the CT level of analysis to control for neighborhood characteristics that might influence walking to transit service. These data included street center line files (street hierarchy, real length and speed limits) and enhanced points of interest files (e.g., retail, restaurants, recreation centers, etc.) obtained from Desktop Mapping Technologies Inc. (DMTI) (CanMap) datasets; land-use classifications obtained from the city of Montréal; and socioeconomic neighborhood characteristics obtained from the 2006 Census of Canada.

The level of attractiveness of a transit stop depends on individual, neighborhood and public transportation characteristics. Transit service characteristics that affect the amount of walking, include the type of service, its frequency and reliability (Fielding et al., 1978, El-Geneidy et al., 2010). A multi-level regression analysis was conducted to measure the effect of individual, neighborhood and transit service characteristics on walking. Key variables at the individual level included age, gender, income and individual travel behavior, including type of transit used, and trip distance. Key variables at the neighbourhood level included education level, population density, land use density, land use diversity, street connectivity and public transportation characteristics, including type of transit service, frequency and schedule of transit service (Table 1).

INSERT TABLE 1 AROUND HERE

Interpretation using simulation models:

Interpretation of the model under different scenarios (simulation models) was conducted to estimate overall walking distances achieved for each mode of public transportation. For simplicity, the simulation models highlighted walking minutes that can be achieved by males of average age going to work or school and coming back home by the end of the day (2 trips per day), who used a single mode of public transportation (no transfers) or two modes (2 transfers), with a transit service that runs all day, and holding transit characteristics (frequency of service and overall distance spent in transit vehicles) for each transit mode at their mean values.

RESULTS

Sample:

There were 37,411 public transportation trips reported in the 2003 OD survey. These trips were made by 18,445 individuals residing in the Montréal metropolitan region in 2003 (Agence métropolitaine de transport, 2003). The sample was limited to respondents who made a maximum of 6 transit trips per day, – representing 99.93% of the total sample (18,429 individuals) –, who were adults (workers and students) 18 years or older (3,089 individuals under 18 years old, and 1,267 retired individuals were excluded from the sample). Some outliers were deleted: individuals who resided in households owning more than 4 cars (22 observations); individuals who resided in households with more than 8 people (14 observations); and one individual whose age was more than 90 years. This left a sample of 14,057 people. From this total, 12,775 individuals started their first trip from their home, and of these, 29 individuals were excluded as they lived outside the Montréal metropolitan region. Respondents whose primary trip purpose (first trip in the day) was going to work (7,289 people) or going to school (college/ university (3,432 people)) were included (at total of 10,721 people). There were 1,894 individuals who did not report their income and 159 individuals had other missing data and these respondents were excluded. Finally, individuals doing complex 'trip chains' (1,755 people) were excluded from the study. A trip chain is a trip that incorporates various destinations. These were excluded due to our focus on the routine, daily, commuting-style trips, leaving a final sample of 6,913 respondents. All origins and destinations were then plotted in a GIS environment, and compared against all transit trips reported in the OD Survey, to ensure the filtering process did not lead to any systematic bias in the distribution of the subset of trips included in our analysis.

Descriptive Statistics

Respondent characteristics:

Just over half (57%) of the respondents were females, and the average age of the group was 33.6 years (SD 12.4 years). The majority of the sample (66%) was employed while 33% were students. Approximately 18% of the respondents lived in households earning less than $20K per year. For about 65% of respondents their household incomes were between $20K and $79K; and just over 16% lived in households with incomes greater than $80K per year.

Neighborhood characteristics:

There were 547 CTs in the Montréal metropolitan area in 2006. The percentage of university graduates across the CTs varied from 5.8% to 80% with an average of 31% (SD 15.3%); population density varied from approximately 67 to 44,078 individuals per square km with an average of 7,288 (SD 6,826); retail density had an average of 302.5 retail establishments per square km (SD494.1). Street connectivity had an average of 145 street intersections within a 500 meter buffer (SD 58.4).

Trip characteristics:

The Metro (subway) and city bus were used approximately in 57% of the trips; train was used in 39% of the trips; suburban buses in 15% and peripheral buses in 3% of the trips. The number of transfers made in a day during all trips ranged from none to a maximum of 8 transfers, with 2 transfers at the 75th percentile (SD 1.7). The average one way trip distance was 10.75 km leading to 21.5 km (SD 15.08km) of total distance traveled by transit in a day by individuals.

The average total walking distance per day was 1,480 meters (SD 950m). On average, across all ages, females walked 1.24 minutes fewer than males. Walking to and from public transit stops decreased with advancing age, with the average walking distance dropping by approximately 206 metres (2.3 minutes) between females aged 18 to 25 years old and 55 to 65 years old, and approximately 105.9 meters (1.2 minutes) between males aged 18 to 25 years old and 55 to 65 years old.

Multi-level regression findings:

We tested two types of statistical models. The first was a linear regression model and the second was a multi-level model. While the linear regression model had an r-squared value of 0.234, suggesting significant improvement in explanatory power over past models of walking to transit (e.g., Morency et al. (2011) had an r-squared value of 0.067), the likelihood ratio test that compares the multi-level regression model to the linear regression model was significant, which suggested that it is important to take into consideration that respondents of the OD survey were nested within neighborhoods.

INSERT TABLE 2 AROUND HERE

There was a statistically significant difference in walking distance between males and females, with males walking 59.44 meters (0.65 minutes) more than females when holding all other factors at their mean (Table 2). Walking distances decreased around 35.9 meters (0.39 minutes) with every decade increase in age. Walking distance differed significantly by household income level. Individuals with low household income (less than $20K) walked 201.51 metres (2.12 minutes) fewer per day than individuals with household incomes $80K or higher. Walking to transit for a school trip was slightly higher than walking to transit for a working trip by 78.5 meters (0.86 minutes).

Walking distances were associated with public transportation characteristics but not with neighborhood socio-economic (e.g., education) or physical characteristics (e.g., population density, land use mix and street connectivity). Each trip conducted by a commuter train contributed to daily walking distances of approximately 1319.29 meters (14.47 minutes). Trips made using buses serving the peripheral areas contributing to walking distances of approximately 899.53 meters (9.86 minutes) while Metro (subway) trips contributed 633.84 meters (6.9 minutes) of walking. Bus trips made the smallest contribution, with every trip made using suburban bus service adding 455.95 meters (6.95 minutes) and city buses adding 273.34 meters (2.99 minutes) to walking distances.

Trip length did not achieve statistical significance in the model, yet, it had a negative impact on the total walking distances. Frequency of service, which is a reflection of the waiting time, had a negative impact on the total walking distances. For example if the time difference between two consecutive buses (headway) was 10 minutes near the home origin, the total walking distance decreased by 70 meters (0.76 minutes). Meanwhile, if the headway is changed to 15 minutes, the average total walking distance decreases by 104 meters (1.14 minutes).

Interpretation of the random part of the model:

The random part of the model shows the standard deviations of the intercept and residuals (error term). In general, the idea of the random coefficient demonstrates that the overall error variance consists of two parts: the first results from the random variation of the intercept (standard deviation of the constant), and the second results from the variance of the error (standard deviation of the residual). The intra-class correlation coefficient showed that approximately 6.67% of the total variance in walking distance was explained from variation between the CTs. It was estimated that 95% of the random coefficient of the walking intercept varied between 180.85 meters and 239.15 meters, suggesting significant variability in walking to public transportation between CTs in Montréal.

Achieved minutes of walking

In order to show the impacts of total walking to transit on physical activity, walking minutes to transit stops were estimated for each mode of public transit based on the multi-level regression model. The simulation is derived from multiplying the coefficients obtained from the statistical model by the mean values of every variable. Each simulation was conducted for a work or school trip made by a typical male respondent of 20years and 34 years with a household income between $20K and $ 79K (Table 3).For dummy variables the value of 1 is multiplied by coefficients of the specific public transportation mode to derive the simulation results for certain modes. All multiplication outputs are then added to derive the expected walking time when certain trip characteristics are met. This method was used in previous research to highlight how different changes in the independent variables affect the dependent variable (El-Geneidy et al., 2010, Tétreault and El-Geneidy, 2010).

Approximately 11% of commuters achieved the 30 minutes of recommended physical activity, solely through walking to and from public transit stops to commute to work or school. Simulated trips that met the recommended 30 minutes of physical activity by walking to and from public transit stops during a daily commute are reported in bold. Italicized values indicate that the trip meets the above mentioned criteria through bouts of at least ten minutes of activity as recommended by the WHO (2010). Commuter train trips were associated with the maximum walking minutes (34.59 to 49.91 minutes), while trips made by bus serving the peripheral areas were the next highest (25.38 to 40.7 minutes). This was followed by walking to Metro (subway) (19.55 to 34.87 minutes). Average minutes achieved through walking to and from suburban bus stops were higher than those achieved through walking to bus stops on the island of Montréal (city buses). These findings can be linked to the distribution of service in the suburban areas and/or type of service (frequency and final destination location). On average, walking time achieved through walking to and from suburban bus stops was between 15.56 to 30.97 minutes compared to 11.65 to 26.96 for city bus stops.

INSERT TABLE 3 AROUND HERE

DISCUSSION AND CONCLUSIONS

This paper sought to estimate the extent to which daily physical activity requirements can be met by using public transportation in the daily commute to school or work, with the additional aim of identifying characteristics associated with this type of utilitarian walking. Females walked less than males (by 0.65 minutes per day), walking decreased with age and was higher for individuals with higher household incomes compared to the less affluent. Minutes walked to and from public transportation varied to a great extent with each mode of public transit used. The maximum minutes walked were by commuter train users (49.91 minutes per day with two transfers to a Metro).

Findings are consistent with previous research that identified guidelines for maximum walking distances to public transportation. Walking guidelines vary from 400 to 482 meters (0.25- 0.3 miles) for bus stops (Neilson and Fowler, 1972, O'Neill et al., 1992, Hsiao et al., 1997, Zhao et al., 2003, Murray and Wu, 2003, Kimpel et al., 2007, Gutiérrez and García-Palomares, 2008) and 800 meters (0.5 miles) for rail stations (Kuby et al., 2004, Schlossberg et al., 2007). Approximately 11% of commuters achieved the 30 minutes of recommended physical activity just through walking to and from public transit stops to commute to work and school. These results align with those of Besser and Dannenberg (2005) who suggested that public transit users can meet recommended minutes of physical activity and that commuter train users tend to have the most success in achieving public health recommendations. Morency et al. (2011) did not find that any commuter types met the 30 minutes of physical activity and these contradictory findings seemingly are related to differences in modeling techniques and variables included in their models.

One of the major reasons why walking distances to bus stops are lower than walking to other modes of public transportation has to do with the standards of bus stop spacing compared to other types of transit. In general, bus stop spacing is denser in North America compared to European cities. Bus spacing is also closer in the central areas of cities compared to suburbs (El-

Geneidy et al., 2006). Increasing bus stop spacing is currently being discussed in several North American regions with the goal of increasing the efficiency and reliability of service and this should also increase the potential for physical activity for these users. Other ideas include stop removals (stop consolidation) in areas where the spacing is too tight with the goal of increasing efficiency without harming accessibility for less mobile users

The type and characteristics of the public transportation service used by commuters was more important than the physical and socio-economic characteristics of neighborhoods for walking. We found that individuals with low household income (less than $20K) walked approximately 201.51 metres (2.21 minutes) less per day compared to individuals living in the most affluent households. These differences are related to the way the public transportation network is structured. Wealthy suburban neighborhoods are generally low density and harder to serve when compared to denser, lower income neighbourhoods closer to the city centre. Interestingly, viewed as a public health intervention, public transportation may produce unintended outcomes that could actually increase health disparities related to physical activity. Existing commuter trains in the Montreal area tend to service wealthy Montréal neighbourhoods and these commuters walk the most minutes compared to users of other modes of public transportation. A new commuter train line is currently proposed to serve low income suburbs in Montreal, which could, in turn, balance out these findings.

Access to public transportation service, which is the opportunity of having a reliable transit service within a reasonable walking distance, was positively associated with walking in this study as well as an earlier study (Schlossberg et al., 2007). Contrary to earlier studies that examined determinants of walking in neighborhoods, neighborhood physical characteristics (e.g. land use mix, street connectivity and land use density) (Ewing and Cervero, 2010, Owen et al., (2004). , Saelens and Handy, 2008) did not show any statistical association with walking to public transportation. Positive associations with walking distances found in earlier studies included population and dwelling density; land-use mix (Finkelstein et al., 2003, Hsiao et al., 1997, Loutzenheiser, 1997, Zhao et al., 2003) well connected streets (Hsiao et al., 1997, Loutzenheiser, 1997, Zhao et al., 2003); number of parking spaces at the stations (Loutzenheiser, 1997); and safety (Loutzenheiser, 1997, Zhao et al., 2003, Hsiao et al., 1997).

Our study confirms the role of public transportation in supporting active transportation and we demonstrate that suburban train users can meet recommended minutes of daily physical activity just by commuting to work or school. Although the recommended minutes of physical activity were not achieved by users of other modes of public transportation, we should not discount the smaller amounts of physical activity achieved by these different groups. In the words of the WHO (2010), *"Inactive people should start with small amounts of physical activity and gradually increase duration, frequency and intensity over time."* Public transportation can be used as a tool to start this process for many individuals. That said, being viewed as a public health intervention, public transportation planning must balance public service provision with an aim of increasing physical activity for all socioeconomic groups across the city, especially in areas where bus users walk less than other transit users.

STUDY LIMITATIONS:

The OD Survey provides a representative sample of Montréal travel behavior (5% of the population). However, it is a one day travel diary that does not take into account seasonal influences in travel behavior in a city with weather extremes. There could be some error associated with the fact that land use, and census data are from different years than the OD survey (2006, versus 2003). Walking between transfers could add to the total achieved minutes per day; however it was technically difficult to measure walking during transfers in this study. Also in the study we used the shortest distance to the nearest stop; however, if an individual chose to walk longer for safety or other reasons, these additional walking distances would not be captured. Presence of sidewalks, stop signs, and traffic signals were not included in this study mainly due to lack of available information.

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Achieving Recommended Daily Physical Activity Levels through Commuting by Public Transportation: Unpacking Individual and Contextual Influences

Table 1: Variable definitions

Variables	Definition
Total walking distance	Individuals' total walking distance during the day for all trips done to and from transit stops or station (see
Individual characteristics	
Individual socio-economic characteristics	
Gender (ref.=female)	Dummy variable for gender of the individual
Age	Age of the individual in years
Household income	High Household income ($80K>), Medium household income.($20K-79K). and low household ($<20K)
Individual travel behavior	
School	Dummy variable for school trips
Trip distance in (km)	Total trip distance travelled while sitting in transit
Type of transit service	
City bus	Number of times city bus is used in a day
Train	Number of times the commuter train is used in a day
Metro	Number of times the Metro (subway) is used in a day
Suburban bus	Number of times the suburban bus is used in a day
Peripheral bus	Number of times the peripheral bus is used in a day
Neighborhood characteristics	
Social characteristics	
Education	Percent of people with university degrees
Physical characteristics	
Built environment characteristics	
Population density/ km2	Population density at the home location of the
Retail density/ km2	Retail density at the home location of the individual
Street intersections/km2	Number of street intersections around trip origin
Transit service characteristics	
Time between every two consecutive transit vehicles (headway)	The headway of the transit route used at the beginning of the day in minutes
Time between every two consecutive transit vehicles squared (headway2)	The headway squared
Transit service runs only in the morning (ref. All day service)	A dummy variable that equals to 1 if the first trip started from (6AM to 9AM) and equals to 0 otherwise
Transit service runs only in the evening (ref. All day service)	A dummy variable that equals to one if the first trip started from (3:30 PM to 6:30 PM) and equals to 0 otherwise

Table 2: Multi level regression model, total walking distance /day in metres

Variable	Coefficient (meters)	Z	P>|Z|	95% confidence interval	
Individual level					
Individual socio-economic characteristics					
Sex (reference=female)	59.44**	3.03	0.00	20.99	97.88
Age	-3.60**	-3.83	0.00	-5.44	-1.75
Medium income ($20K - 79K)	-122.62**	-4.43	0.00	-176.90	-68.34
Low income (<$20K)	-201.51**	-5.69	0.00	-270.89	-132.14
Individual travel behaviour					
School Dummy	78.50**	3.10	0.00	28.79	128.20
Trip distance in (km)	-0.32	-0.38	0.70	-1.97	1.33
Number of times transit service used					
City bus	273.34*	2.29	0.02	39.12	507.56
Commuter train	1319.29**	10.57	0.00	1074.55	1564.02
Metro	633.84**	5.28	0.00	398.39	869.30
Suburban bus	455.95**	3.76	0.00	218.11	693.80
Peripheral bus	899.53**	6.99	0.00	647.48	1151.58
Neighborhood characteristics					
Social characteristics					
Percentage of people with university degree	-0.56	-0.59	0.56	-2.43	1.31
Physical characteristics					
Built environment characteristics					
Population density/ km2	0.001	-0.25	0.80	0.00	0.00
Retail density/ km2	0.02	0.82	0.41	-0.03	0.06
Street intersections/km2	0.07	0.36	0.72	-0.30	0.44
Transit service characteristics					
Schedule of service					
Time between every two consecutive transit vehicles	-7.10**	-6.07	0.00	-9.39	-4.81
(Time between every two consecutive transit vehicles) squared	0.01**	5.71	0.00	0.01	0.01
Transit service runs only in the morning (ref. All day service)	-234.60**	-3.64	0.00	-360.78	-108.43
Transit service runs only in the evening (ref. All day service)	389.53**	5.50	0.00	250.73	528.33
Constant	812.12**	3.26	0.00	323.83	1300.42

Random-effects parameters	Estimate	Std. Error	95% confidence interval	
Canadian census tract : Identity				
sd (Constant)	211.078	15.14133	183.393	242.9419
sd (Residual)	790.9704	6.98946	777.389	804.7888

** Statistically significant at the 99% confidence level

* Statistically significant at the 95% confidence level.

Table 3: Achieved walking minutes and distance to and from transit stops and stations for work and school trips

	School Trips			Work trips		
	No Transfers	2 Transfers to Metro	2 Transfers to City Bus	No Transfers	2 Transfers to Metro	2 Transfers to City Bus
City bus	1190.52 (13.06)	2458.21 (26.96)	1737.20 (19.06)	1061.68 (11.65)	2329.37 (25.55)	1608.36 (17.64)
Commuter train	3282.41 **(36.00)**	4550.10 ***(49.91)***	3829.09 ***(42.00)***	3153.57 **(34.59)**	4421.26 ***(48.50)***	3700.25 ***(40.59)***
Metro	1911.53 (20.97)	3179.21 **(34.87)**	2458.21 (26.96)	1782.69 (19.55)	3050.38 **(33.46)**	2329.37 (25.55)
Suburban bus	1555.74 (17.06)	2823.43 **(30.97)**	2102.42 (23.06)	1426.90 (15.65)	2694.59 (29.56)	1973.58 (21.65)
Peripheral bus	2442.90 (26.80)	3710.58 ***(40.70)***	2989.58 **(32.79)**	2314.06 (25.38)	3581.75 **(39.29)**	2860.74 **(31.38)**

Note: Distance reported in meters, while time reported between parentheses in minutes

Figure(s)

Achieving Recommended Daily Physical Activity Levels through Commuting by Public Transportation: Unpacking Individual and Contextual Influences

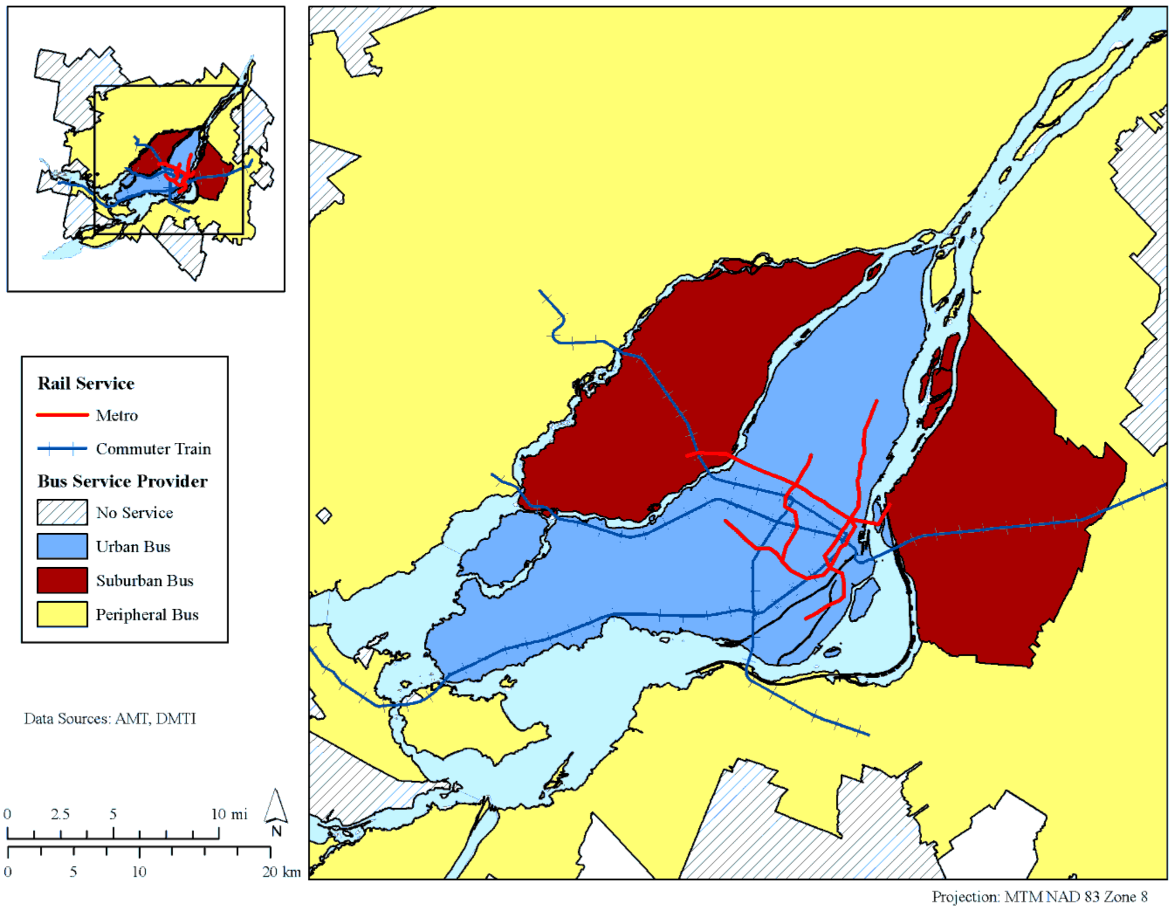

Figure 1: Transit services in the Montréal metropolitan region[1]

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[1] The Agence metropolitaine de transport (AMT) is an agency responsible for regional transit in Montréal. In this study, the region served by AMT will be used as the study region.

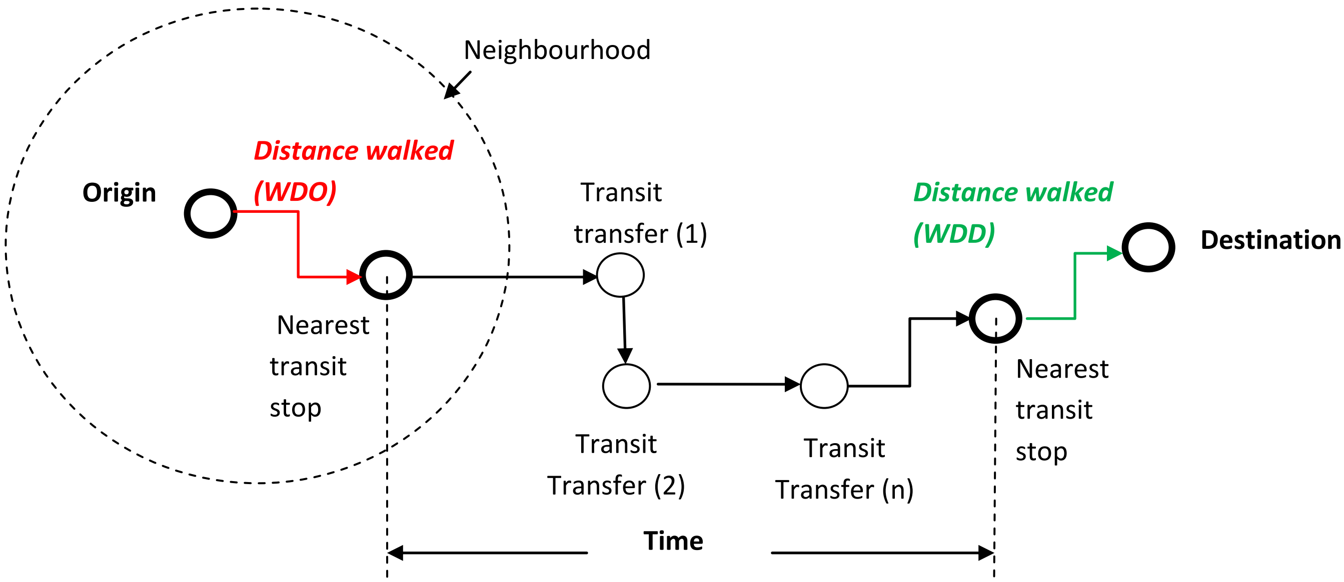

Figure 2: Hypothetical model of walking trips associated with transit use