Beyond the Quarter Mile: Examining Travel Distances by Walking and Cycling, Montréal, Canada

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ABSTRACT:

Interest in active transportation – especially walking and cycling – is growing within urban planning and transportation circles as a solution to many of the environmental and congestion issues plaguing many cities. This paper focuses on how far people are willing to walk or cycle for different trip purposes in Montréal, Canada and how travel distances vary spatially and by individuals' travel purpose and socio-economic characteristics. This research uses the 2003 Montréal Origin-Destination Survey (O-D Survey) to calculate the network distance traveled by pedestrians and cyclists and to obtain travel and socio-economic characteristics for each individual. Whereas much walking distance literature focuses on distance to transit, this paper is focused on walking and cycling trips where a second transit mode is not the intended destination. Primarily, the paper reveals that median walking distances recorded in the O-D survey (650 meters) are greater than the commonly-accepted distance or catchment area of 400 meters, and that there are a variety of personal built environment factors that influence these distances. While no widely-held standard exists for cycling, the analysis reveals a median distance of around two kilometers with a high degree of variation in distances. These findings will guide planners, designers, developers, and policy makers when promoting for greater levels of walking and cycling and suggests future research directions within this field.

Keywords: Cycling distance, walking distance, distance decay

Introduction

As cities face the challenges of traffic congestion and greenhouse gas emissions that have emerged from a half century of auto-oriented planning, cycling and walking are increasingly seen as alternatives that may come to bear a greater proportion of the transport burden. Indeed, the benefits of active transportation are manifold: while potentially reducing traffic congestion, human-powered transportation improves personal health, enhances quality of life, and has been linked to economic vitality in urban settings. Interest in promoting active transportation and better planning for this sustainable transportation mode is a shared preoccupation of urban planners, public health officials and community activists. The conventional wisdom related to active transportation – which generally refers to walking and cycling – is that trip origins and destinations should be brought closer together, facilitating easier access by these modes. Consequently, for integrated land use and transportation planning as well as promoting active transportation, revealing the distance travelled by pedestrians and cyclists for different purposes has become an important field of research.

There has been a great deal of academic attention on relationship between urban form and travel behavior in recent years (Cervero, 1994; Greenwald & Boarnet, 2007; Handy, Boarnet, Ewing, & Killingsworth, 2002; Saelens, Sallis, & Frank, 2003). This understanding has filtered into practice in many jurisdictions and has become policy in the planning of many transit-oriented developments. This has partly come about due to research from the public health field, which has become increasingly concerned with the health consequences of obesity due to inactivity. Recent studies have shown that increasing walkability is directly associated with reducing the health risks of obesity; notably, in areas where a doubling of walking trips to work occur, rates of obesity decline by almost 10 percent (Smith, et al., 2008). Thus, a bridge between the urban planning and transportation fields and public health, focused on the role that non-motorized transportation can play in improving the health and well-being of urban populations.

In recent years, the volume and level of detail of active transportation research has increased dramatically. However, very few of these studies have been concerned with the relationship between walking and cycling distances for a variety of trip purposes. Primarily, most walking distance studies have focused on determining an ideal access distance to a particular transit service, such as bus or light rail (Lam, Morrall, & Ho, 1995; Neilson & Fowler, 1972; Upchurch, Kuby, Zoldak, & Barranda, 2004; Zhao, Chow, Li, Ubaka, & Gan, 2003). The acceptable walking distance to transit is often been assumed to be 400 meters, despite a relative dearth of recent empirical evidence to support this (Alshalalfah & Shalaby, 2007; Iacono, Krizek, & El-Geneidy, 2008). Thus, in applied planning situations, 400 meters is often used to define service areas around transit stops. However, recent research has shown that commuters will walk farther reach certain types of transit than the general guidelines used in many North American cities (Alshalalfah & Shalaby, 2007; O'Sullivan & Morrall, 1996). A dated but particularly relevant study by Seneviratne (1985) considered walking distance to various destinations in Calgary, Canada, with special emphasis on defining "critical" walking distances to LRT and bus stops and other destinations in the Central Business District (CBD). Another study explores access/egress distances to transit as a function of total trip length (Krygsman, Dijst, & Arentze, 2004). However, reviewing the existing literature on walking distances, it is clear that there are many opportunities for further research, particularly with regards to trips where public transit is not part of the equation.

With regards to cycling research, a major focus of this field has been on safety issues associated with bicycle commuters (Aultman-Hall & Adams Jr, 1998; Epperson, 1995; Hunter, Pein, & Stutts, 1995; Kim, Kim, Ulfarsson, & Porrello, 2007; Sean, Lisa, & Jill, 2000), however, some researchers have emphasized travel behavior of cyclists more generally (Howard & Burns, 2001; Shafizadeh & Niemeier, 1997; Williams & Larson, 1996). Antonakos (1994) indicated that bicycle travel distance has a strong relationship with the trip likelihood and frequency, while others have examined the effect of dedicated cycling facilities on distance, and found that separated bicycle paths may influence significantly longer trips by bicycle (Krizek, El-Geneidy, & Thompson, 2007). However, as with walking trips, relatively little research has been directly concerned with travel distance of bicycle trips in the context of various trip purposes, with the notable exception of a study in the Twin Cities region looking at various modes (Iacono, et al., 2008). This study makes use of distance decay functions, which visualize individuals' willingness to travel a certain distance to reach a common destination. Distance decay curves provide a relatively simple way of understanding this subset of travel behavior, and can be useful when generating gravity-based measures of accessibility at the neighborhood level (Hansen, 1959; Iacono, Krizek, & El-Geneidy, 2010).

Researchers, planners and engineers regularly use the walking distances derived from the transit literature for a multitude of destinations (O'Sullivan & Morrall, 1996). This paper argues that walking distances for other purposes must be considered independently in order to derive walking distances for different trip purposes. As travel behavior studies deal with the complex interactions between individuals (or populations) and their environment, a multi-faceted approach should be taken to examining trip distances is advocated. For example, the analysis may be viewed from an economic perspective, highlighting both demand and supply factors that influence non-motorized trips. On the demand side, a comparison of the relative attractiveness of certain destinations is highlighted. Conversely, on the supply side, one might consider how walking and cycling distances reported reflects the local availability of a particular type destinations (supermarkets, for example). This paper is focused primarily on exploring the demand side in Montréal. The present research focuses on how far people are willing to travel to different destinations by walking and cycling and how travel distances vary by individuals' travel and socio-economic characteristics. However, we also touch on supply factors by exploring non-motorized trips originating in various geographic areas in the Montréal region.

The following section of the paper introduces the data sources and methodology employed in this research. The next section continues with an analysis of travel distance based on different purposes, which is followed by an analysis of walking and cycling distances by geographic location and an analysis of travel distance according to socio-economic characteristics of pedestrians and cyclists. Finally, the paper concludes with the summary of the findings from this research and policy recommendations.

Data and Research Methodology

The Montréal Metropolitan Region is used as our case study in this research. Montréal Metropolitan Region comprise of an area of 4,259 square km (1,644 square miles) and a population of 3,635,571 (Statistics Canada, 2006). The data required for the study was gathered from different secondary sources. First a source for a travel behavior data is needed. The Montréal O-D survey, which is conducted by the Metropolitan Transportation Agency (AMT) every five years surveying 5% of the region's population is used as the base data source in this analysis (Metropolitan Transportation Agency, 2003). The O-D survey is conducted between September and December, travel distances were investigated in light of temperature, however, no relationship was found. Montréal's 2003 O-D data contains 329,353 observations, where the modal share of walking is 9.3 percent and for cycling is 1.0 percent. In this paper, we consider origin-to-destination trips for pedestrians and cyclists, excluding walking trips to transit and return to home trips. The total number of walking and cycling trips considered in this paper are 12,831 and 1,421, respectively. Census boundaries and street networks of the Montréal region are obtained from the Desktop Mapping Technologies Inc. (DMTI). The street network is modified to exclude freeways and to include special bicycling and walking paths. Network distance linking every origin to every destination is then calculated using a Geographic Information System (GIS) by plotting individuals' origin and destinations and calculating distances based on shortest path along the modified street network. This may result in artificially long travel distances in peripheral areas, where low connectivity may prompt travel on non-geocoded paths. A set of distance decay functions for different purposes, namely, work, school, shopping, and leisure based on the network distances are estimated for walking and cycling trips. Spatial auto-correlation for walking and cycling trips is performed to examine the spatial patterns of clustering of long and short travel distances in different regions of Montréal. Travel and socio-economic characteristics of pedestrians and cyclists obtained from the O-D survey is used in analyzing travel distances according to these attributes, with the results tested for statistical significance using ANOVA and T-tests. The outcome for frequency distributions for both walking and cycling travel distances shows single-sided, long-tailed frequency curves, thus the median distance is considered rather than the mean to examine the relationships between travel distance and individuals' socio-economic characteristics.

Trip Purpose

A more nuanced understanding of trip distances for cyclists and pedestrians emerges when this analysis is placed in the context of trip purpose. Distinguishing between different types of trips provides an understanding of the demand for different types of destinations, and places emphasis on local accessibility to various services. A summary of walking and cycling distances based on the purpose of trips is shown in Table 1. Median cycling distance for all purposes (2,242 meters) is approximately three or more times higher than the median walking distance (653 meters), due to the higher speeds associated with bicycle travel. It is important to note that an individual has a limited amount of time during the day that constraints his amount of time he can dedicate towards travel (Marchetti, 1994). As Marchatti (1994) states people will travel further distances as speed of travel increases but the amount of time spent travelling will remain relatively constant. This notion is reflected in the higher distances associated to cycling and lower ones associated to walking. Four trip purposes, work, school, shopping, and leisure, are considered to examine the distances travelled by walking and cycling for different proposes. It should be noted that leisure trips are defined as trips with leisure activities as a destination, and not leisure as the inherent purpose of the trip.

Table 1. Attributes of walking and cycling to different purposes

	All		Purpose							
			Work		School		Shopping		Leisure	
	Walk	Cycle	Walk	Cycle	Walk	Cycle	Walk	Cycle	Walk	Cycle
Mean (m)	813	3,140	993	3,886	757	2,273	754	2,204	860	3,360
Median (m)	653	2,242	801	3,067	636	1,550	581	1,529	683	2,318
85^{th} percentile (m)	1,403	5,517	1,789	6,442	1,243	4,355	1,327	3,926	1,572	6,376
Standard Deviation	604	2,792	718	3,001	526	2,012	605	2,145	642	3,158
Number of cases	12,831	1,421	2,381	620	6,259	369	2,591	205	1,600	227
Percent of total sample (%)	100	100	18.6	43.6	48.4	26.0	20.2	14.4	12.5	16.0

Table 1 shows that median distance to work is the highest for both walking and cycling followed by median distances for leisure activities. Of the total walking trips, the percentage of school trips by walking is the highest (48.4%), although the median walking distance is 636 meters, which is lower than all but shopping trips. The highest percentage of cycling trips is 43.6% are for work and the median access distance is also high for work trips by cycling (3,067 meters). Overall, the 85th percentile of pedestrians travel is 1,403 meters and the 85th percentile of cyclists travel 5,517 meters in the Montréal Metropolitan Region. The 85th percentile values can be used in defining catchment areas around existing and new destinations. Catchment areas are generally used in land use and transportation planning to define location issues. They are used to understand existing demand as well as ensuring access to the population by a certain mode.

Distance Decay Function

As mentioned earlier, previous studies have suggested 400 meters as a general guideline for comfortable walking distance for the most destinations, empirical evidence to support this remains scarce. Applying a catchment area around a given land use based on the median or 85th percentile rule assumes that people walking or cycling to these destinations are equally distributed in this area; this assumption is not logically sound. The distribution of demand around land use generally follows a decay curve. The decay curves offers variation when trying to understand the level of demand in a catchment area. Accordingly people to reside near a location value it differently from the ones residing far. This follows a gravity theory and was used earlier in understanding the demand for transit (Kimpel, Dueker, & El-Geneidy, 2007). A set of distance decay functions for four different purposes are estimated for walking and cycling trips using a negative exponential curve. The statistical summaries including goodness-of-fit statistics (R^2 values) for each distance decay function are shown in Table 2. Distance decay curves for work and leisure for both walking and cycling are plotted in Figures 1 and 2, respectively. These figures are useful in understanding the distribution of demand for certain destinations and how close these activities should be located when trying to ensure accessibility by walking or cycling for all the population.

Table 2. Distance decay functions for different purposes for walk and bike trips

Purpose	Walking			Cycling		
	Distance (β)	Constant (α)	Model fit (R^2)	Distance (β)	Constant (α)	Model fit (R^2)
Work	-0.0009	8.4956	0.71	-0.0004	18.641	0.41
School	-0.001	11.392	0.74	-0.001	87.983	0.49
Shopping	-0.001	11.167	0.82	-0.001	184.13	0.50
Leisure	-0.001	11.835	0.76	-0.0006	19.877	0.26

Walking

Table 2 shows that distance decay functions are more similar in case of school, shopping, and leisure trips, while work trips show a more gradually decreasing curve, meaning that more people are willing to walk greater distances to work. Distance decay functions for work and leisure-walking trips are plotted in Figure 1. It is apparent from Figure 1 that walking trips extend up to approximately 3.5 kilometers for both work and leisure activities. For short distances, leisure activities comprise a larger share of walking trips, however for distances greater than 1 kilometer; work trips comprise a greater share. That more people are willing to walk longer distances for work than for leisure activities reveals the more specialized nature of work activities, whereas leisure destinations can be accessed closer to home. This contrasts with the past findings from Minnesota, where leisure and entertainment constitute the longest trips (Iacono, et al., 2008), however this may be due to the definition of leisure in the Montréal O-D survey mentioned earlier.

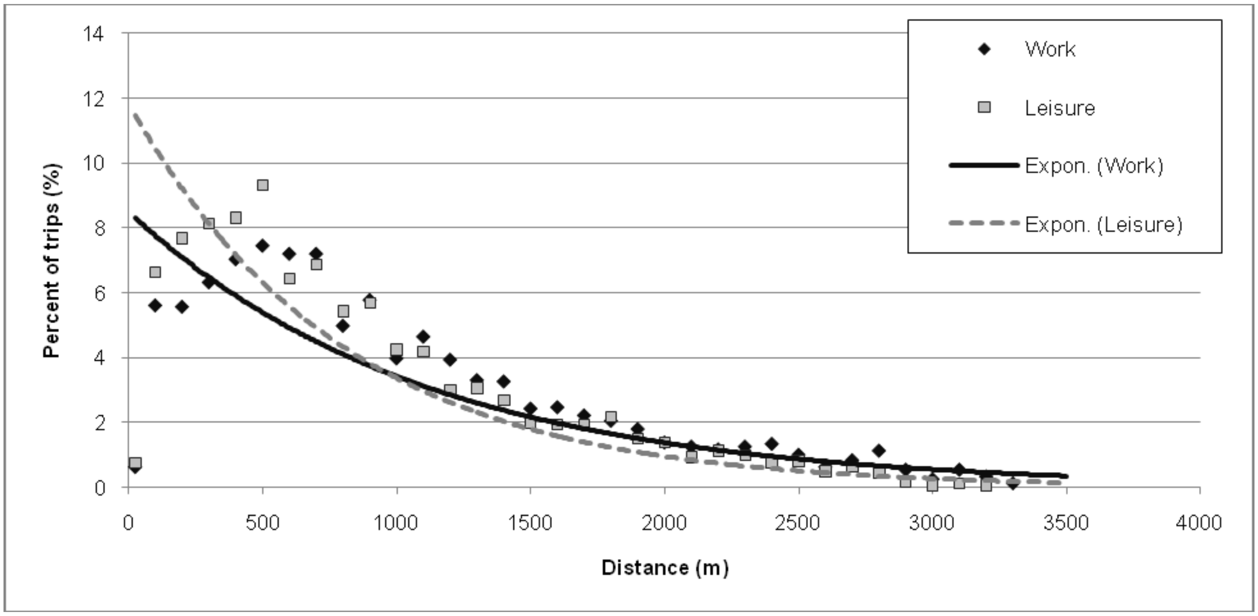


Figure 1. Distance decay curves for walking trips

Cycling

Distance decay curves for bicycle trips including work and leisure trips are presented in Figure 2. There is a greater variation in the distribution of cyclists than among pedestrians. As mentioned previously, median cycling distance are nearly four times greater than walking trips. This supports Marchetti's (1994) constant travel time theory mentioned earlier. The fitted curve indicates that the vast majority of bicycle trips for work purposes are less than 5 kilometers, while most leisure trips recorded are less than 3.5 kilometers. Notably, the curve for work trip distances decreases much more gradually than that for leisure trips, indicating that like pedestrians, cyclists are generally willing to travel greater distances for work than other purposes. This, too, contrasts with the Twin Cities study (Iacono, et al., 2008) which may be explained by inclusion of cycling trips for fitness purposes in the Twin Cities region, which tend to be longer than bicycle trips to leisure destinations. Unfortunately, it is not possible to contrast the questions asked in the two surveys.

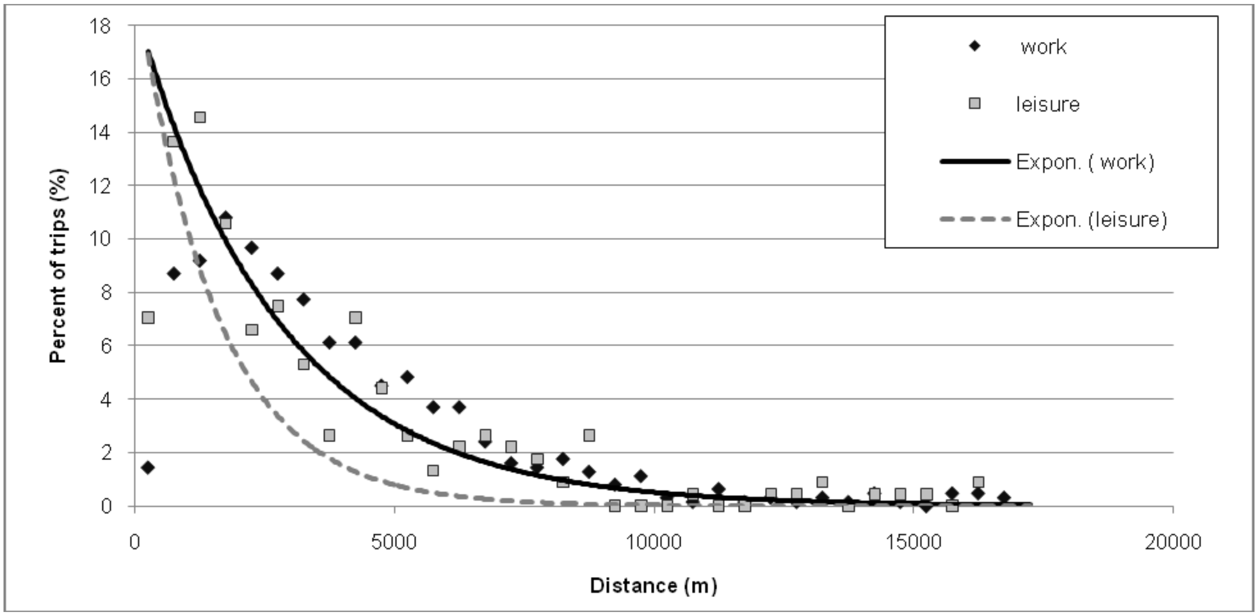


Figure 2. Distance decay curves for bicycle trips

Trip Origin

For the purpose of this research, the Montréal Metropolitan Region is divided into five regions using the city's borough and neighboring municipality boundaries as shown in Figure 3 and 4. Beginning in the city core, we identify these regions as: 1) Central business district (CBD); 2) Inner ring; 3) Middle ring; 4) Outer ring and 5) the Regional ring. Among five regions, the CBD has the highest median walking distance (813 meters), though the percentage of walking trips originated in this region is the lowest (6.6 percent), likely due to its relatively small area and thus population. The analysis shows that with the increase of distance from CBD, the median walking distance decreases up to middle rings; then increases in the outer and regional rings. The scenario is different in case of cycling trips; the highest median distance of 2,910 meters is found in the inner ring. It shows that trips originating in inner ring travel greater distances by cycling than other regions, though median cycling distances within middle ring and CBD are near to those observed in the inner ring. It is interesting to note that although the median walking distances of outer ring and regional ring are marginally higher than the middle ring, median cycling distances in outer and regional ring are much lower than in the other three regions.

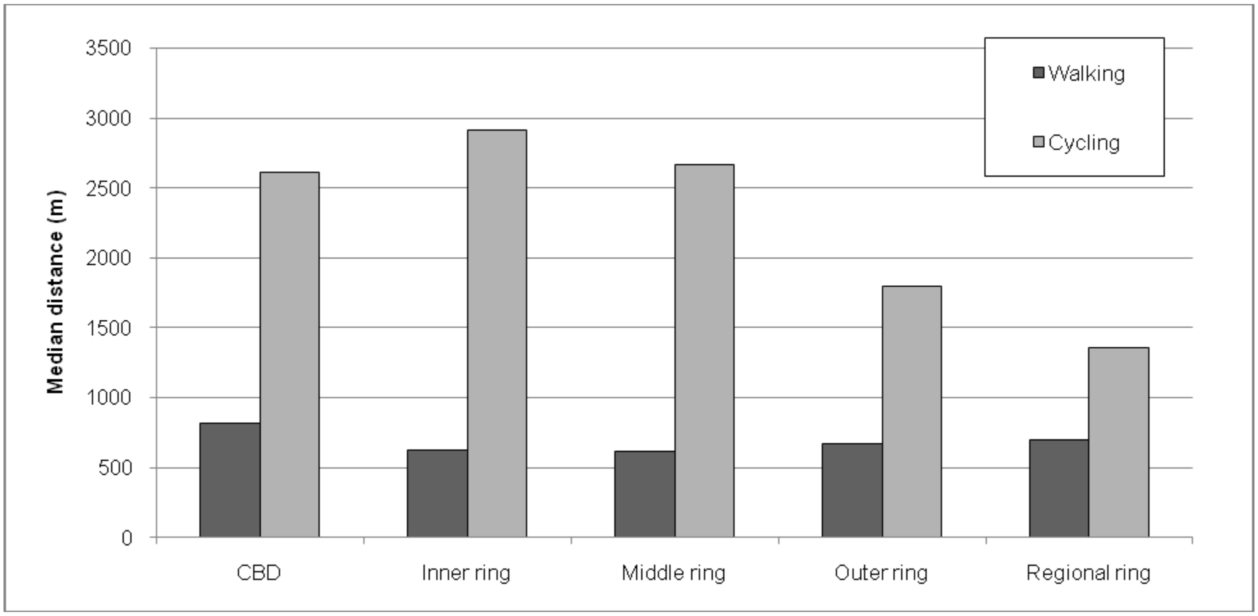


Figure 3. Median walking and cycling distances in different regions

Spatial auto-correlation for walking and cycling trips is performed to examine the spatial patterns of clustering of long and short distances originating in different regions. The results for walking trips shown in Figure 4 reveal that there is a clear pattern between clusters of long and short distance trips within the regions. Trips originating in the CBD and inner ring have longer walking distances than other areas, whereas an especially dense cluster of low distance walking trips is observed in the middle ring. Interestingly, this clustering of short distance walking trips occurs immediately adjacent to a cluster of long distance walking trips in the inner ring. Spatial auto-correlation was also performed for cycling trips to understand the spatial pattern within different regions. However, we do not include the results as the analysis does not reveal any general clustering patterns, possibly due to small sample size for cycling trips.

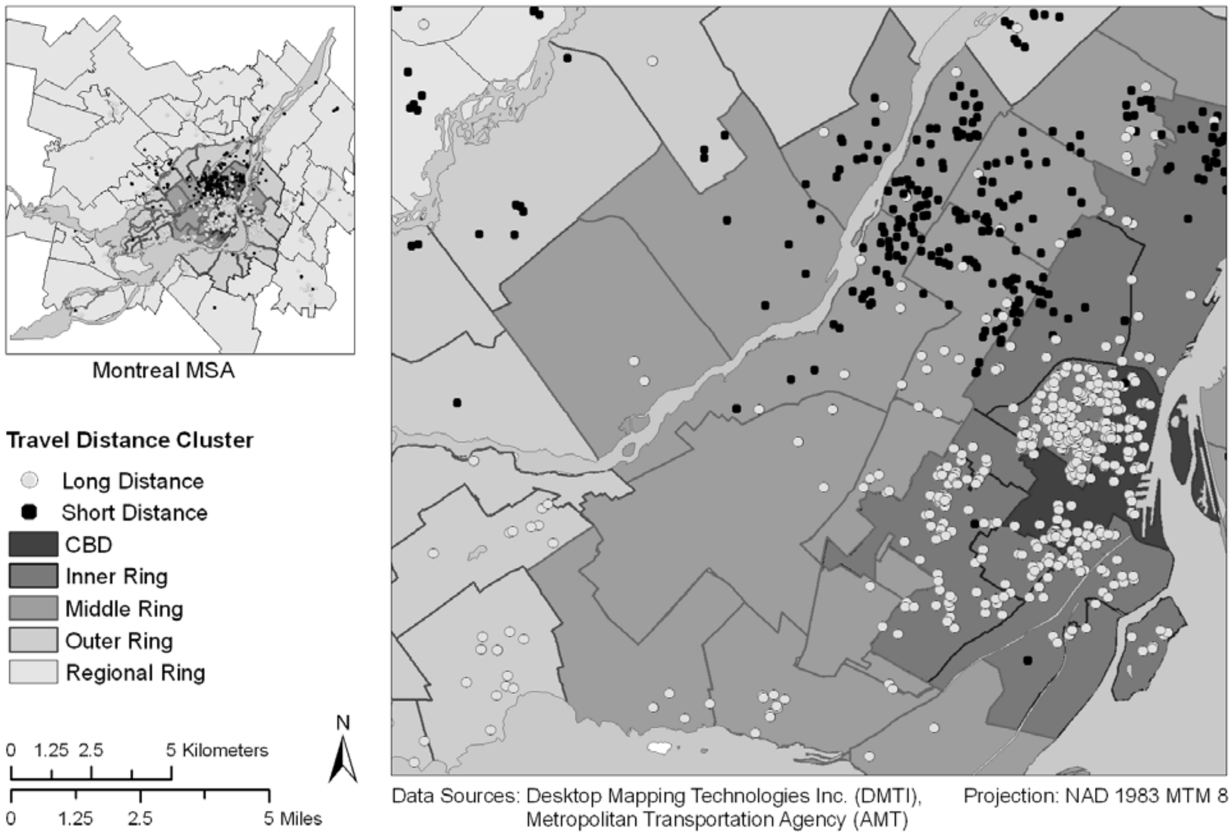


Figure 4. Long and short walking distances originating in different parts of the Montréal Region

In order to better understand the travel distances observed in the various geographic sub-regions, an examination of the built environment in these areas is performed. Figure 5 compares the share of walking and cycling trips in each region to the residential density (persons per square kilometer). This finding is consistent with other studies which have found close links between active modes of transportation and the built environment (Handy, et al., 2002; Saelens, et al., 2003). In this case we are using a simple density approach to help in generalizations for future studies. One notes a close relationship between density of inhabitants and walking and cycling, with a few notable exceptions. There is as great a share of walking trips originating in the CBD as in the inner ring, yet a lower residential density than the inner ring; this is likely due to the density of destinations, which contribute to a high walk share. As observed from Figure 3 the CBD and the inner ring had the highest distances traveled by walking and cycling in term of median distances. Likewise, at the periphery, while residential density decreases between outer ring suburbs and the regional ring, walking and cycling rates increase in this area. This study does not permit us to know whether this is due to aesthetic considerations, route conditions or a combination of aspatial factors which were beyond the scope of the research. However, this finding lends weight to research that suggests that other factors such as land use mix, urban form and residential self-selection may partly explain walking and cycling patterns (Forsyth, Oakes, Schmitz, & Hearst, 2007).

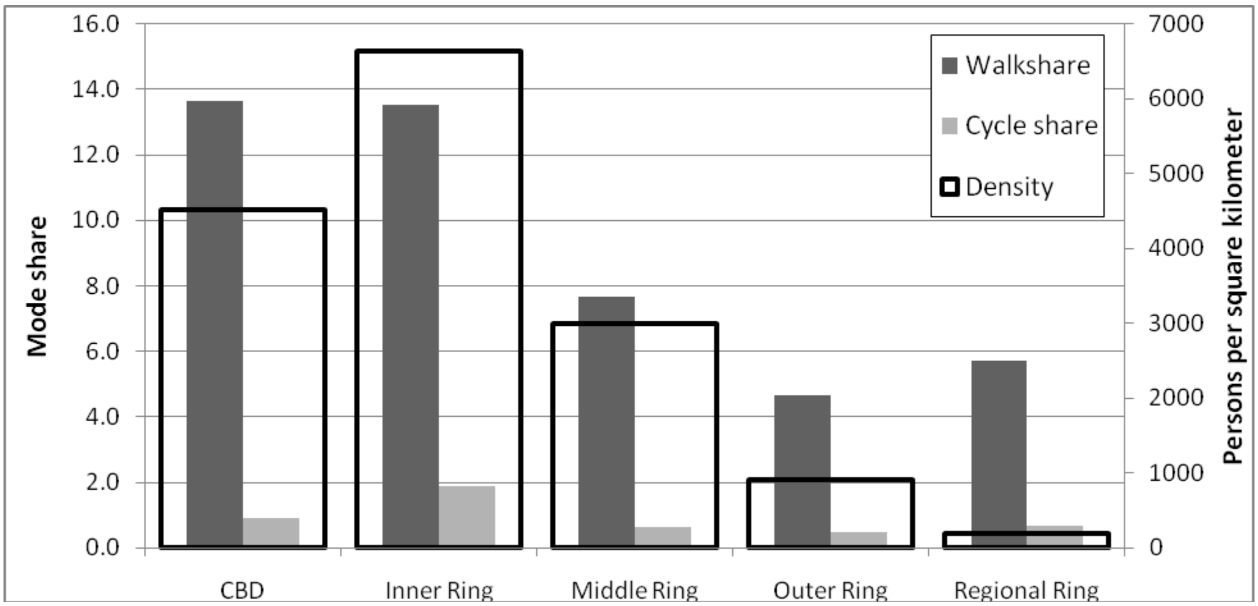
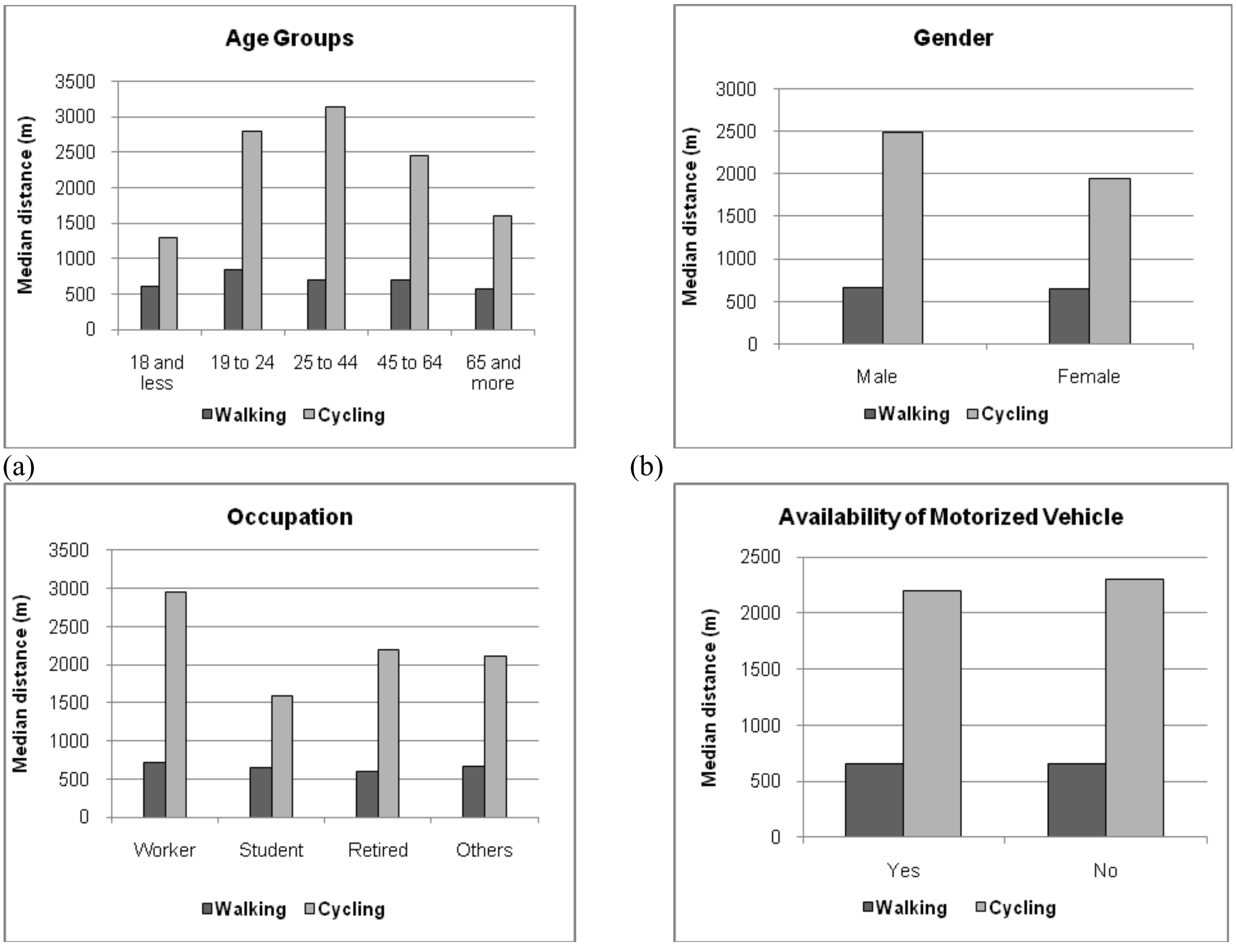


Figure 5. Population density and percentages of walking and cycling trips originating in different parts of the Montréal Region

Socio-economic Characteristics

This part of the analysis focuses on how travel distances vary with the individuals' socio-economic characteristics as well. It includes four different demographic and socio-economic attributes such as age, gender, occupation, motorized vehicle availability in order to understand their relationships with median distance travelled.



(a) (b) (c) (d)

Figure 6 Median distance based on socio-economic characteristics: (a) age groups; (b) gender; (c) occupation; and (d) availability of motorized vehicle

Age Groups

Figure 6(a) shows the relationship of age to walking and cycling distance. The median walking and cycling distances; these observations are different with a statistical significance at the 99 percent confidence level. The age groups comprising the greatest number of walking trips are below 18 and over 65 years old and represent 54.7 percent of the total walking trips, likely due to lower rates of motorization in these age groups. Figure 6(a) indicates that median walking distances for children and seniors are slightly shorter than other age groups. Not surprisingly, walking trips comprise a greater proportion of all trips by seniors (8.1 percent) than cycling trips within the same population (2.1 percent). Trip distances travelled by children (1,300 meters) and seniors (1,604 meters) are shorter than the distances travelled by cyclists observed within the age group of 18 to 65 years old. The highest median distance (3,142 meters) travelled by the cyclists is observed in the age group of 25 to 44 years. However, in terms of walking distances observed, there is a far lower level of variability. In general, one may conclude that there is an especially strong relationship between age of the individuals and the distance they are likely to bicycle. This finding points to the need for measures to improve the sense of security for these more vulnerable users of the road.

Gender

Figure 6(b) shows the relationship between median travel distance and gender of survey respondents, which is significant at the 95 percent confidence level. From previous studies, it is evident that men represent a larger percentage than women of all cycling trips (Cynecki, Perry, & Frangos, 1993; Moritz, 1998; Williams & Larson, 1996). This analysis also finds a similar result where 67 percent cyclists are male and 33 percent are female. Regarding walking trips this relationship is not present. Although the difference in median walking distance between men (657 meters) and women (648 meters) is low, it is significant at the 95 percent confidence level. However, the analysis shows a clear and strong difference of median cycling distances based on gender; male cyclists (2,493 meters) are willing to travel greater distances than the female cyclists (1,942 meters), an observation that supports previous findings (Howard & Burns, 2001) and is significant at the 99 percent confidence level. The differences observed in cycling rates and distances between women and men suggest that specific strategies targeting women may have beneficial results.

Occupation

Figure 6(c) shows the relationship between the occupation of pedestrians and cyclists and median travel distance by walking and cycling. The median walking and cycling distances for different occupations are significant at the 99 percent confidence level. Workers have the highest median walking distances, with student, seniors and others all slightly lower. This may be due the specialized nature of work locations, requiring workers travel greater distances. In terms of the overall proportion of walking trips, students are shown to make more trips (54.9 percent) than other occupations, such as workers (28.6 percent) and retired persons (11.2 percent). This is likely due the lower rates of vehicle ownership among students and minors. On the other hand, workers make more cycling trips (53.1 percent) than other groups such as students (37.9 percent) and retired persons (4.5 percent) and travel greater distances both for walking and cycling trips than other groups. Only 2.1 percent of cycling trips are made by seniors. The unexpected result is that retired persons travel greater distances than students; however, the percentage of retired person is very low.

Availability of Motorized Vehicle

In Figure 6(d), the availability of a motorized vehicle in the household is examined for its influence of this factor on median walking and cycling distances. In Montréal, pedestrians and cyclists have similar rates of motorized vehicle ownership in their household. About 70.5 percent pedestrians and 68.3 percent cyclists have at least one motorized vehicle in their household. In case of walking, though the median distances for these two groups are significant at the 99 percent confidence level, the difference between these groups in terms of median distances is not so high. Cyclists travel greater distances to reach different destinations when the household does not possess any motorized vehicle, with a significance level of 90 percent. The result may indicate that motorized vehicle availability has an influence on median travel distance, though less so in case of walking.

Conclusions

This paper has focused on how far people are willing to travel for different destinations by walking and cycling in the Montréal Metropolitan Region, with a view to promoting these sustainable modes of transport. Since walking and cycling provide significant health benefits, this research may be used by public health researchers to estimate caloric consumption or cardiovascular activity. It can be also used by land use and transportation planners and engineers to determine catchment areas and understand the level of access to services through walking and cycling in Montréal. This research examines how travel distances vary by geographic location and individuals' travel and socio-economic characteristics with an aim to filling some of the gaps in the growing fields of active transportation and travel behavior research. Primarily, this paper reveals that median walking distances recorded in the Montréal Origin-Destination survey are greater than the commonly-accepted distance of 400 meters, suggesting that people are willing to walk greater distance than the general guidelines of 400 meters and that walking distance is influenced by other factors, especially geographic location and trip purpose. In the Montréal region, the median walking distance is approximately 650 meters and is higher for work purposes (800 meters); however rather than suggesting a new standard for walking distances, this research points to the application of the distance decay function as a tool for accurately predicting walking distances. While no widely-held standard exists for cycling, the analysis reveals a median distance of around two kilometers with a high degree of variation in travel distance, particular by age, gender, and geographic area. These findings point to the need to target specific population and areas to increase both rates of cycling and distances cycled.

Distance decay functions for both walking and cycling reveals that work trips have the most gradually declining curve, meaning that people will cycle and walk farther for work than they will for other purposes in Montréal. This finding is coherent with the specialized nature of work, requiring individuals travel greater distances, however contrasts with past research, where walking and bicycle trips are longest for leisure and recreation purposes (Iacono, et al., 2008). If comparative analyses are to be performed between regions, variation between travel surveys will have to be addressed. With regard to different purposes, school trips and trips for children are relatively short distances yet comprise the largest percentage of walking trips, likely due to the age of majority required for a driver's license and the location of schools close to home locations. Seniors as a group represent the second highest proportion of walking trips. Gender analysis of travel distance reveals that the median cycling distances are higher in case of men than women, although walking distance appears not to be affected by gender. This suggests that greater attention needs to be given to understanding these groups' needs in terms of walkable and cyclable communities.

This paper is limited to the Montréal Metropolitan Region and caution should be made when making generalizations. Since our goal was to understand how far people are willing to walk or cycle to certain destination, we limited our analysis to generalized trip purposes. More detailed analysis to explain some of these findings is recommended where researchers can incorporate the effects of built environment, social attitudes, residential self-selection, the timing of the trip, or the availability and condition of walking and cycling facilities. Better information about precise routes would also improve the analysis, since pedestrians and cyclists generally use short cuts which could not be to modeled on the existing road network. It is recommended that future research aim towards this higher level of detail.

It is hoped that drawing on the findings of this paper will allow planners, designers, developers, and policy makers to create appropriate pedestrian and cycling facilities and urban environments that will help people reach different destinations by these active modes of transport.

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