Validating walkability indices: How do different households respond to the walkability of their neighbourhood?

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For Citation please use

Manaugh, K., & El-Geneidy, A. (2011). Validating walkability indices: How do different households respond to the walkability of their neighbourhood? *Transportation research Part D: Transport and Environment,* 16(4), 309-315.

Abstract:

Recent years have seen a continued shift in land use and transportation planning priorities towards issues of neighborhood walkability. An inviting pedestrian environment with access to commercial, leisure and school destinations is seen as a key component of walkability. Walkability indices have grown in popularity, due in part to their potential to measure qualities of livability. However, it is not clear how well these indices predict actual pedestrian behavior. Many studies have not been able to adequately analyze the effects of these walkability indices across trip purposes and for households with varying characteristics. This study analyzes 44,266 home-based trips obtained from the 2003 Montréal Origin-Destination survey. Several statistical models are built to examine the correlation of different walkability scores and household travel behavior while controlling for individual, household and trip characteristics. Further clustering of households allows the calculation of elasticities across household types. Our findings show that the examined walkability indices are highly correlated with walking trips for most non-work trip purposes; however, socio-demographic characteristics also play a key role. Most importantly, the results show that households with more mobility choices are more sensitive to their surroundings than those with less choice. Our findings highlight the fact that a walkability index will not have the same correlation with travel behavior for all individuals or households. Therefore, solutions to encourage non-walkers to start walking need to vary depending on the socioeconomic characteristics of the neighborhood.

Keywords : Walkability, equity, neighbourhood, shopping, school

Acknowledgments:

The authors would like to thank Mr. Daniel Bergeron of the AMT for providing the detailed Montréal OD survey used in the analysis. We would like to thank the two anonymous reviewers for their feedback on an earlier version of the manuscript. Also we would like to thank Aleisha Jacobson from walkscore.com for providing the walkscores used in the analysis. This work was partially funded through Le Fonds québécois de la recherche sur la nature et les technologies (FQRNT) the Fonds Québécois de la recherché sur la société et la culture (FQRSC) and the Natural Science and Engineering Research Council of Canada (NSERC).

Introduction

Recent years have seen a rise in popularity and use of walkability indices. By measuring both form and content of neighbourhoods, walkability indices are expected to measure the degree to which an area can provide opportunities to walk to various destinations. Many cities and regions include walkability goals in their land use and transportation plans. However, many of these goals are quite general and vague and difficult to quantify.

Walkability indices have been successful in describing the walking environment in many cities. However, due to small samples or lack of data, many previous studies have not been able to adequately analyze how different households with varying mobility needs and financial and time budgets might be affected by the walkability of their neighborhood. Few studies have compared differing measures of walkability on the same sample. Most studies used one measure across trip purposes and socio-demographic types. Our hypothesis is that walkability measures are not "one size fits all" and will vary by trip purpose and socio-economic characteristics of residents. In this view, walkability can be understood as a "match" between residents' desires and expectations for certain types of destinations, their willingness to walk a given distance and the quality of the required path. Neighbourhoods that find this match between built form and residents' needs will likely have more people walking in them. However, research that focuses solely on built environment and land use characteristics will miss this sense of neighbourhood/individual interaction. Furthermore, the equity implications of walkability are both important and delicate; it is vital to understand the difference between an individual who chooses to walk as a result of living in a "walkable" neighbourhood and someone who, for financial constraints or other reasons, has no choice but to walk in a neighbourhood that may or may not be conducive to walking.

This research article aims to address two main issues 1) how well do existing walkability indices explain observed walking behaviour? And 2) how do they vary across trip purposes and socio-demographic factors? To address these questions, the paper commences with a description of various walkability measurements and how they are calculated in this research. Then several statistical models are developed to explore the factors associated with the decision to make a particular trip by walking for shopping and school trips and to compare the various walkability indices that are commonly used in the transportation literature. This is followed by a modelling approach that takes into account socio-economic factors (instead of merely "controlling" for them) examining how different household types might respond to the walkability of their neighbourhood. Finally, policy relevance in Montréal and the wider North American context is presented.

Data Preparation

As the first objective of this research is to compare measures of walkability at different geographic scales, the initial step is generating the walkability indices. For the purpose of this study we have chosen four commonly used indices in the academic literature to compare. The walkability index developed by Frank, Schmid, et al (2005) is the first index tested in this study. This well-known index has been used at various geographical scales; census divisions, and network buffers around specific households or commercial centers (Cerin, Leslie, Owen, & Bauman, 2007; Saelens, Sallis, Black, & Chen, 2003). We generated this index at 4 scales: 400, 800 and 1200 meter network buffers, as well as at the census tract level. While we hypothesized that the buffer-based approach would perform better, previous research has looked at neighborhoods and census geography; therefore, we wanted to test this geographical level as well. Due to its ubiquity, this particular walkability index will be referred to as the "walkability index" (WI), in contrast to the approaches described below.

The second measure used was a simplified walk opportunities index that is similar to the measure used by Kuzmyack, Baber, and Savory (2005). Retail information was obtained from the Dun and Bradstreet business database. This was combined with a weighted intersection index. Possible destinations are weighted based on three key variables, distance, size and importance. The importance and desirability of a set of possible destinations was based on previous research (Banerjee & Baer, 1984) that ranked residents' views of given destinations. For example, "everyday" destinations such as post offices, pharmacies and food stores rank higher than sports arenas or night clubs. The sum of the weighted intersection z-score and "everyday" retail z-score represents the walk opportunities index. As the walk opportunities index takes into account different types of individual businesses as well as intersection types, it is hypothesized that it will explain more walking behavior than the WI.

The third measure uses the pedshed method (Porta & Renne, 2005), which is simply the area of the pedestrian network buffer over a straight-line buffer of the same distance. In order to generate the network buffers used in the measures, highways and highway entrance ramps were removed from the street centerline files and a GIS network was built. This measure was chosen as it differs from the methods used in the other indices.

For the fourth and final measure of walkability, the research team purchased a database of over 100,000 postal code points from Walkscore for use in the analysis (walkscore.com, 2010). In order to link this information to each household, a spatial join was performed in GIS to relate each household to the Walkscore of its postal code of residence. The process uses a simple gravity-based measure to weight nearby locations higher than those more distant.

The maps in Figure 1 show the scores of the four measures aggregated at the census tract level. All of the measures are standardized using the z-score value for ease of comparison. This allows visualizing the differences between the measures at the census tract level of analysis. The z-score is a unit-less measurement; the lighter areas are much lower than the mean, the darker areas are much higher (in this case, better) while areas shaded in the middle of the spectrum straddle the mean value. This is primarily for illustrative purposes as most of the measures used in the statistical models are at the household level not the census tract level. However, the maps clearly show patterns of the distribution of quality walking environments throughout the region. Interestingly, the four maps are remarkably similar. Only the WI map stands out, this could be due to the index's inclusion of general land use mixing instead of the more specific destination characteristics of the walk opportunity and walkscore measures.

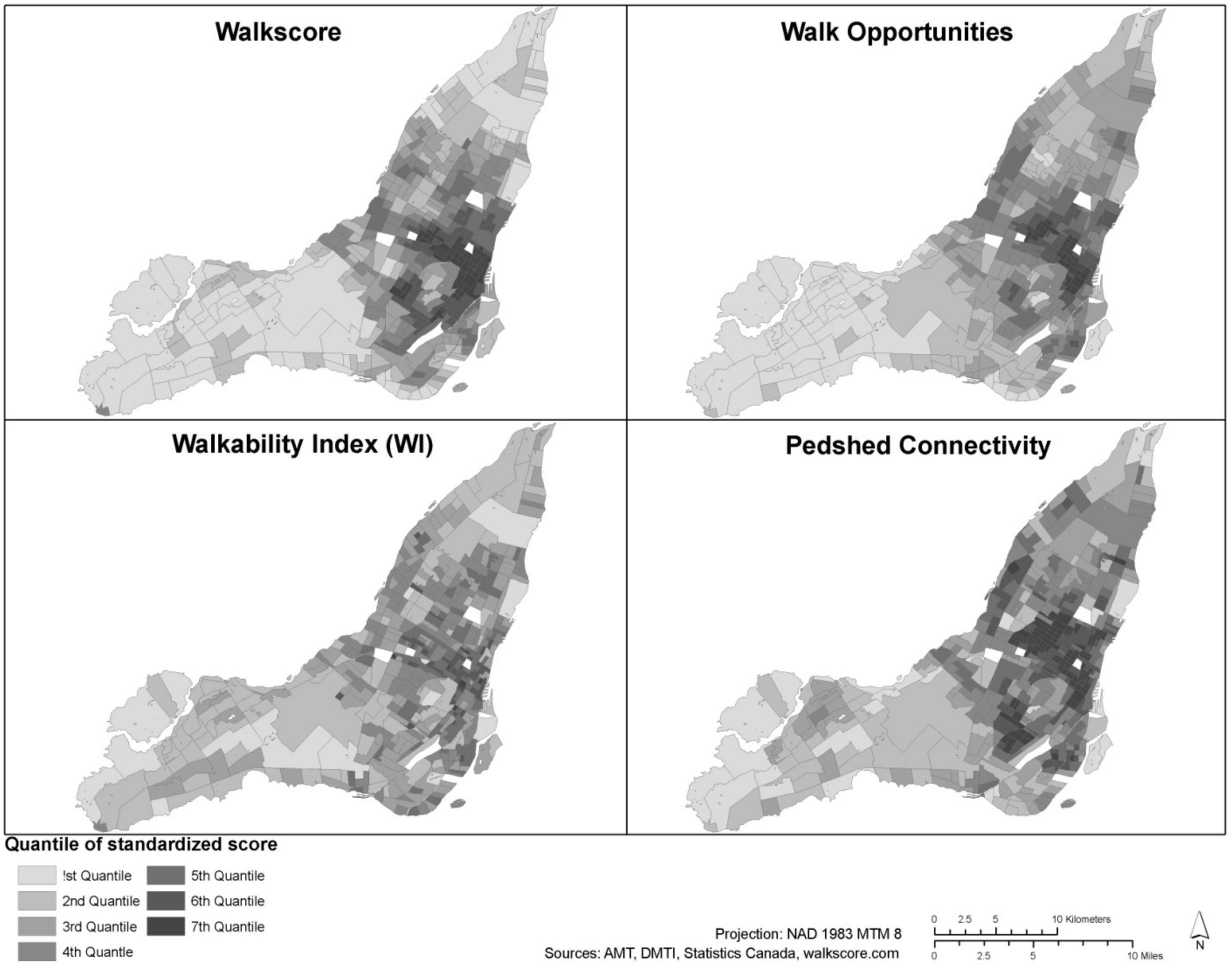


Figure 1: Visual comparison of walkability indices

Household level data and travel behavior characteristics are obtained from the 2003 Montréal Origin-Destination survey (AMT, 2003). The O-D survey collects detailed travel behavior data from 5% of the households residing in the Montréal region. The survey contains disaggregate data on each trip made in the respondent's household on the previous workday. The precise X and Y coordinates of each trip's origin and destination are collected, along with purpose, mode and time of each trip. In addition, several socio-economic characteristics of both the individual and household are recorded, including age, gender, work status, household income, number of household members and length of time at current residence. For the purposes of this research, a sample of 17,394 households on the island of Montréal was extracted; households with incomplete socio-demographic data were excluded from the analysis. After mapping the home location of each respondent household, the measures of walkability were generated using land use data and street centerline files from DMTI Inc. as well as census tract level demographic data from Statistics Canada. Circular and network buffers are generated around each household using 400, 800 and 1200 meter thresholds. From these households, 44,263 home-based trips were examined. Home based trips were chosen to better isolate walkability factors at the place of residence. Of these, 6,575 of the recorded trips were by foot for all purposes. Non-work trips are the focus of the research due to their likelihood to be more affected by local conditions than work trips.

In the following section the extent to which each walkability index increases the odds of walking to non-work destinations is examined. This section adds to the current state of knowledge by introducing a comparison of the various walkability indices that is not present in the current literature. It is important to note that, while we attempted to replicate the published indices as accurately as possible, studies in other cities or regions (or with different data sources) could, of course, show different results.

Statistical Comparison of Walkability Indices

Several discrete choice models were designed and tested. The decision to make a particular home-based trip was made by foot was modeled as a dichotomous variable in a binary logistic model. The independent variables included trip length, age, gender, income, car ownership and a single walkability measure. As we had access to a large sample of trips, we separated the models by trip purpose; each subsample had several thousand observations. This approach takes into account that not all individuals will evaluate a choice the same way; notably, the utility of a particular mode of transport will vary not only by the time, distance and convenience (or lack thereof), but also by the characteristics of the decision maker (Handy, 1996) and the type of trip. Accordingly, nine different statistical models were generated for each trip purpose using a different walkability measure in every run (walkscore, walk opportunities, the WI at four scales and three sizes for the pedshed connectivity measure), while keeping the other variables in the model specification constant. In other words, a different walkability measure was used for each of nine models. The findings from these models for shopping and school trips are reported in Table 1 showing the odds ratio associated with the walkability measure as well as the log-likelihood value to explain the model output. Log-likelihood values are used to compare model fit within trip purposes, the higher (closer to zero) value corresponds to better model fit. This value cannot be used to compare model fit amongst trip purposes, however. The base model includes only the control variables for comparison.

Table 1: Comparison of models

Shopping		
Index	**OR**	**LL**
Walkscore	2.132***	-1276.97
Walk Opportunities	1.713***	-1290.92
WI 400 buffer	1.910***	-1293.83
WI 800 buffer	1.912***	-1294.46
WI 1200 buffer	1.813***	-1303.9
WI Census Tract	1.645***	-1311.78
Pedshed 800	1.497***	-1335.53
Pedshed 400	1.464***	-1336.27
Pedshed 1200	1.488***	-1337.41
Base	--	-1359.88

School		
Index	**OR**	**LL**
Pedshed 400	1.321***	-1469.32
Pedshed 800	1.311***	-1470.53
Pedshed 1200	1.243***	-1475.32
WI 800 buffer	1.297***	-1473.13
WI 1200 buffer	1.104***	-1475.49
WI 400 buffer	1.196***	-1478.89
Walkscore	1.140*	-1480.69
WI Census Tract	1.115**	-1482.04
Walk Opportunities	1.113*	-1482.03
Base	--	-1484.08

Note: Each walkability measure was inputted into a separate model controlling for age, gender, income, car availability and length of trip. Minimum pseudo R square (McFadden) .418; max= 0.471. "Base" is model with no walkability measure included. * indicates significant at the 10% level, ** indicates significant at the 5% level and *** indicates significant at the 1% level

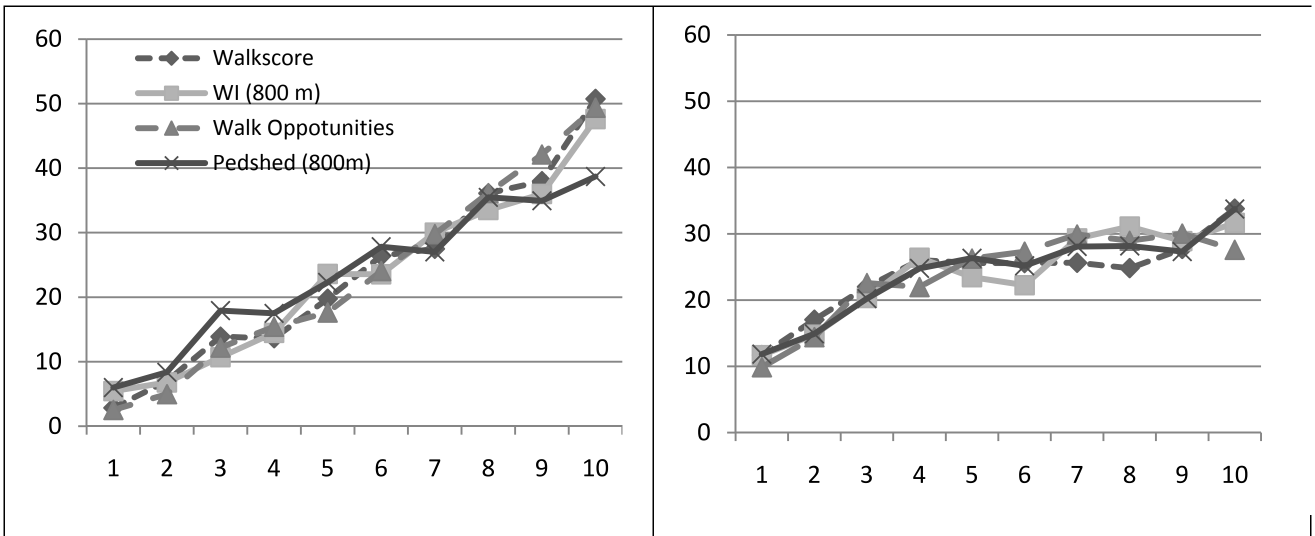
These nine models concentrating on shopping trips used a subsample of 5481 trips and control for age, gender, income, car availability (number of cars in household per licensed driver) and length of trip. Using a subsample of individuals who made home-based shopping trips, as opposed to using all of the observations, ensures that a fair comparison is being made. In this way, the model does not try to understand why a person did or did not make a shopping trip, but rather whether a particular home-based trip, that did in fact occur, was by foot. Furthermore, the approach deliberately excludes trip chains as an individual's decision to shop on her way home from work might have only a tenuous link to the walkability of her home neighbourhood. In addition, issues of work location and time budgets are beyond the scope of this paper.

Each model was consistent with regards to the control variables. Lower household income (defined as household income less than $40,000 is significantly ($p<.05$) and positively associated with walking trips. Vehicle availability is significantly ($p<.001$) and negatively associated with pedestrian behavior. Finally, age and being female have a respective negative and positive association with walking; however neither variable is statistically significant.

Examining, the results in Table 1, we see that Walkscore shows the best model fit. However, the differences amongst the indices are actually surprisingly small. The odds ratio here refers to the odds of a particular trip being by foot for each one-unit increase in the z-score of the given measure. Alternative model specifications, including quartile-based models yielded similar results and are not presented due to space constraints, however, this idea is explored further in the elasticities section. It should be noted that the WI is less data-intensive than the walk opportunities and is therefore perhaps preferable in some cases. Both the walkscore and walk opportunities index measure specific types of commercial and retail development as opposed to the WI that relies on more general land use categories. This could explain why these measures are seen to perform better in the shopping models. In addition, the WI uses an entropy measure of land use that has been criticized in the literature as being a somewhat arbitrary measure of land use mix (Hess, Moudon, & Logsdon, 2001). However, another strength of the WI is its malleability to be able to be measured at multiple scales; this is not the case for either walkscore or walk opportunities.

In order to test the factors leading to walking-to-school trips, a subsample of 6,433 home-based school trips was analyzed. This research concentrated on children walking to school and excluded adults (University, continuing education).The results show that the factors influencing school trips differ from shopping. We see that pedshed connectivity measure better explains variance in mode choice for elementary trips than the walkscore, walk opportunities, or the walkability index. This is not entirely surprising, given that these walkability measures examine factors that capture commercial and retail destinations. However, this does have important implications for understanding this important trip purpose. A high walkscore might not translate to more children walking to school. It is this subtlety that can be easily missed by focusing on only one measure of walkability. The model fit is almost entirely reversed from the shopping analysis. This suggests that these indices should be handled carefully depending on the type of trip being analyzed. One unexplored issue is the fact that the data does not record whether a parent accompanied their children; knowing what factors influence the frequency of unaccompanied school trips could deepen this analysis.

As a way to visualize these relationships, Figure 2 plots the percentage of actual shopping or school walking trips made on the y-axis and the decile of each walkability index on the x-axis. For example, in the shopping graph, in the lowest decile of households, as determined by the walkscore index, only 2.8% of all shopping trips are on foot, however, over 50% in the highest decile of the Walkscore are walking trips. This is instructive for several reasons, first the graphs show a clear trend between walkability and behavior, secondly, the four indices have very similar results, and third, the indices perform differently across trip purposes. While shopping trips seem to be more highly correlated with walkscore values, school trips have alternate findings; not only are different indices associated more strongly with school trips, but the overall fit seems slightly less obvious. For school trips made in locations with the highest decile walkscore or connectivity measures, only 33% are made by foot. The less conclusive findings for elementary school trips could be related to unobserved factors such as safety concerns, traffic levels or parental preferences. These two figures suggest that walkability indices explain the probability of walking for trip purposes quite differently.



Shopping	School

Figure 2: Percentage of home based shopping and school trips by deciles of walkscore

Household Characteristics

In order to understand how these various measures of walkability vary across different household types, a clustering analysis at the household level is performed. Our hypothesis was that the degree to which various households react could vary dramatically with household characteristics and mobility needs. The logistic regression models presented above, which control for socio-demographic factors at the individual level, were not able to measure the required nuances. By simply "controlling for" socio-economic factors, researchers can miss important distinctions (Adler, et al., 1994). Therefore, a two-step clustering analysis is undertaken; this is followed by generating a new set of statistical models, after which, elasticities are calculated to understand how different households differ in their response to increasing walkability levels in the area surrounding their home location.

Two-step clustering

Two step clustering is a well known method used when dealing with a large data-set with both categorical and continuous variables (Norusis, 2010). The goal of the clustering analysis performed here is to group household into distinct types with the maximum differences amongst groups and minimum variation within each group. A set of household-level variables were included in this analysis. These variables included income, number of people in household in various age categories, employment status, length of residence and vehicle ownership. These variables were chosen to capture factors that would explain preferences and demand for various trips purposes. The last step in the clustering analysis involves an analysis, and naming, of each cluster. Figure 3 shows the variation from the mean value for each cluster. Income is represented by ranges of $20,000, while all other variables are continuous. The large family cluster, for example, has 2.1 more members – on average, than the overall sample mean, while the wealthy no kids cluster has 0.7 less children and 0.4 more full time employed household members than the overall average.

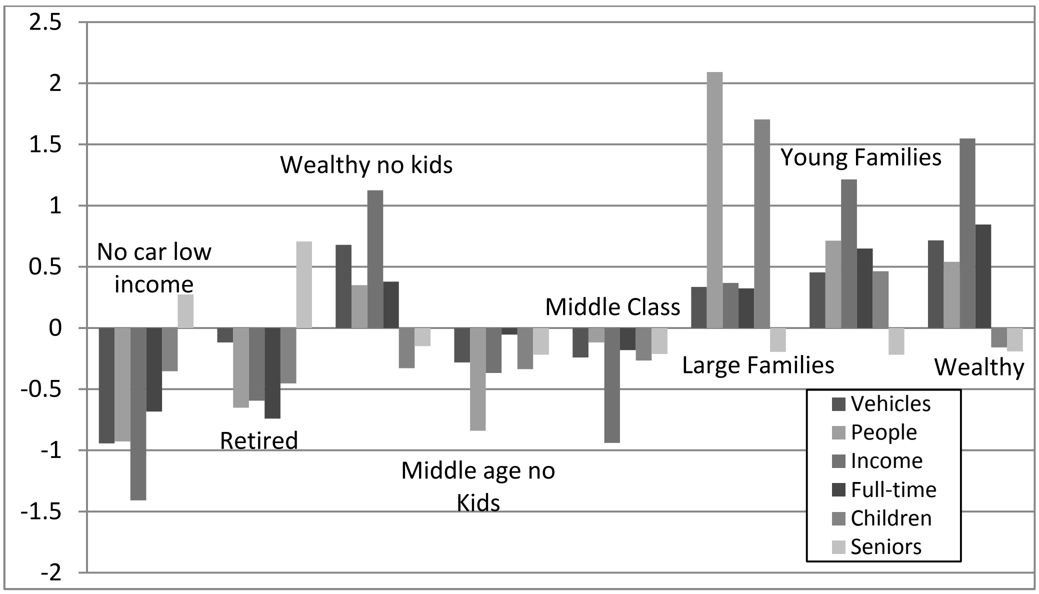


Figure 3. Variation of mean cluster values

In order to get a sense of how these clusters differed in their walking rates, a basic frequency analysis was performed based on the percentage of trips in each purpose that were by foot. Figure 4 shows, for example, that the “large families” cluster makes 20% more of their school trips on foot compared to the average, whereas “wealthy” households make almost 60% less school trips by walking. As no school trips were recorded in the retired seniors cluster, there are missing values in this category.

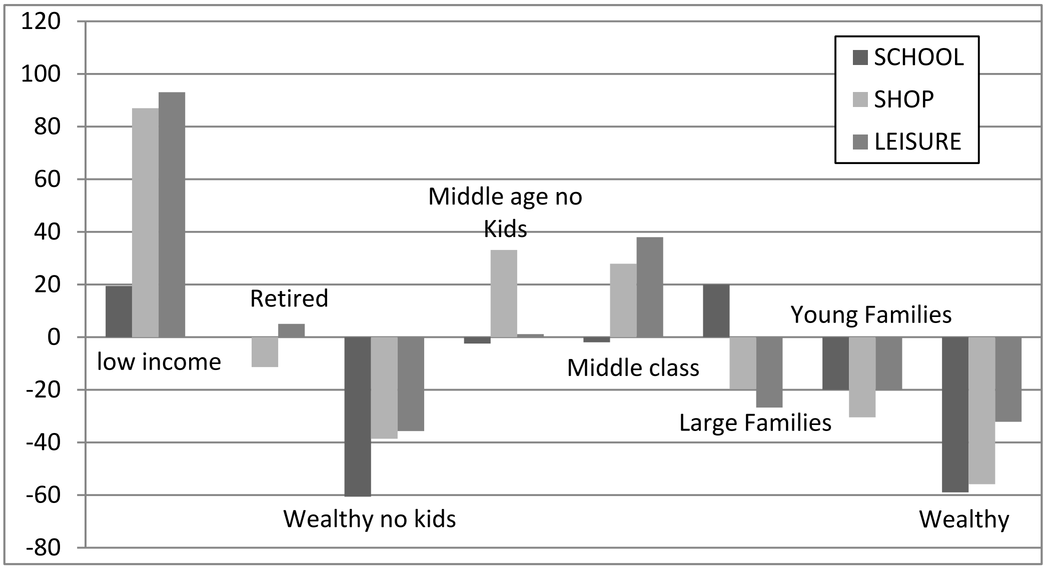


Figure 4: Variation from the mean frequency by mode and household type

However, to statistically validate this basic analysis, additional logistic regressions were specified. The decision whether or not to make a home-based shopping trip was modeled as a dichotomous variable in a binary logit model. A different walkability measure was inputted into each model. The definition of the sample depends on the household type identified in the two-step cluster. Based on the earlier findings (Table 1), only the Walkscore, WI at the 800 meter buffer, and the walk opportunities index is presented as these performed best for home-based shopping trips. We generated 24 different models with the same model specifications, with a different walkability measure as the independent variable of interest. Table 2 shows the odds ratio of the walkability indices, the pseudo R^2 and the sample size information.

Table 2: Comparisons of model outputs using samples identified in two-step cluster process

	WI 800 buffer		Walkscore		Opportunities		
Household Type	**OR**	**R^2**	**OR**	**R^2**	**OR**	**R^2**	**N**
No car low income	1.2	0.42	1.11	0.42	1.14	0.42	638
Retired	2.04***	0.44	2.41***	0.45	1.81***	0.45	1,329
Wealthy no kids	2.38***	0.40	2.68***	0.41	2.57***	0.42	581
Single	1.65***	0.45	1.93***	0.46	1.37***	0.45	732
Middle Class	1.21	0.47	1.21	0.47	1.17	0.47	373
Large Families	1.32**	0.42	1.62***	0.43	1.37*	0.42	714
Young Families	1.78***	0.43	1.54**	0.42	1.41***	0.42	583
Wealthy	2.79***	0.51	3.46***	0.53	4.22***	0.57	531

Note: Each walkability measure was inputted into a separate model controlling for age, gender, and length of trip. The reported pseudo r-square (McFadden) is for the fully specified model. * indicates significant at the 10% level, ** indicates significant at the 5% level and *** indicates significant at the 1% level

In the subsample of low income and "middle class" families, the three walkability indices are seen to not be statistically significant in regards to explaining the variation in walking behavior. However, in wealthy households and households with children the walkability indices play a major role as judged by both the odds ratio and p values. This supports the hypothesis that households differ in their response to the walkability levels in deciding to make a home-based shopping trip by foot or not. The fact that the walkability indices are not significantly correlated with walking trips in the low income cluster gives further credence to the idea that socio-economic factors play a vital role in explaining behavior.

In general, the control variables performed as expected; however, some interesting findings were discovered in regards to gender. In both the large family cluster and young family cluster, being female is significantly ($p<0.01$) and positively associated with walking (OR=2.03 and 1.79 respectively). Wealthy families however show a significant and negative correlation ($p< .10$; OR=.48). In the other clusters gender is not significant.

Elasticities

In order to simplify the findings from the above models a sensitivity analysis was performed to calculate the likelihood that a home-based shopping trip would be by foot. The goal was to determine the effect of moving to a higher decile in the walkability index for each of the identified household clusters. The mean values for age and trip length were inputted, the 'base case" for gender is female. Other socio-demographic data at the household level, such as income and vehicle ownership was not inputted as it is already imbedded in the clusters. The model predicts the likelihood that a 36 year female will make a home-based shopping trip at each decile of the Walkscore measure of walkability.

Of interest is the relative sensitivity of each group to changes in its surroundings. Examining Table 3, we see that a 36 year old female residing in a household in the low income cluster has a 72% chance of walking for a shopping trip of 734 meters (the average length of all home-based walking shop trips) in an area with poor walkability. This is contrasted by the likelihood of 3.3% in the wealthy cluster. However, what is arguably more instructive is the fact that the increase in likelihood from the lowest-to-highest decile varies greatly between groups. For the wealthy no kids cluster, the increase is almost fivefold compared to a mere 7.5% in the lower income cluster. Table 3 shows the probabilities at the first, fifth and tenth deciles. This analysis was also run for the other indices resulting in similar findings. This has implications for equity issues as people without a choice might be walking in areas with a low quality walking environment. In fact, the results suggest that a higher percentage of trips will be by foot in an area with a low-quality walking environment with a poor population than in the highest quality environment with predominantly wealthy residents. Given identical urban form factors a neighbourhood of predominantly poor car-less households and another with wealthy households would show drastically different behavior according to the model results. This also suggests the importance of accurately assessing the goals of pedestrian improvements in a neighbourhood as the results could vary by the population characteristics of the area.

Table 3: Sensitivity analysis*

	Low income	Retired	Wealthy no kids	Middle age no Kids	Middle Class	Large Families	Young Families	Wealthy Families
First Decile	72.1%	36.1%	12.6%	21.4%	30.6%	29.7%	18.5%	3.3%
Fifth Decile	74.8%	65.2%	38.4%	43.6%	43.6%	49.7%	35.8%	16.2%
Tenth Decile	78.0%	89.4%	79.5%	74.1%	61.0%	74.1%	63.1%	63.2%

*** Elasticities calculated at the mean (average length shopping trip)**

Conclusion

This study examined several existing walkability measures and indices at multiple geographic scales in order to understand how these measures are related to actual observed travel behavior. All examined walkability indices and individual measures perform quite well in describing pedestrian behavior on the island of Montréal. The highest level of correlation can be seen with home-based shopping trips. Our findings suggest that the online Walkscore index explains as much, if not more, of the variation in walking trips to shopping than other walkability indices used in the literature. However, it is important to note that the difference in the explanatory power amongst the examined indices is quite negligible. The simple pedshed (Porta & Renne, 2005) method was found to be the best walkability index when it comes to explaining the odds of walking to school. Accordingly, different walkability indices should be used when trying to understand the level to which the built environment encourages walking to various destinations.

Clear patterns were seen in both frequencies of trips across various household types and in how these households were affected by their environment. Wealthy, car owning households are much more sensitive to elements of walkability compared to retired or low-income households.

While it might be somewhat obvious that households without a car are more likely to walk, our findings suggest that improvements in walkability indicators of a given neighborhood will have drastically varying results in modal shift depending on the residents characteristics. Moreover, while wealthier households might be more responsive to improvements in the walkability of their neighbourhood, our results (Table 3) suggest that the number of people walking in more affluent neighbourhoods might never equal the number of people walking in neighbourhoods made up of individuals with less income and low car access, regardless of the quality of the pedestrian environment. These findings highlight the importance of differentiating the walkability intervention at the neighbourhood scale depending on the type of residents in the neighbourhood, their current travel behaviour, and not only the current built environment.

References

Adler, N., Boyce, T., Chesney, M., Cohen, S., Folkman, S., Kahn, R., et al. (1994). Socioeconomic status and health: The challenge of the gradient. *American Pyschologist, 49*(1), 15-24.

AMT. (2003). Fichier de déplacements des personnes dans la région de Montréal Enquête Origine Destination version 03.b période automne.

Banerjee, T., & Baer, W. (1984). *Beyond the neighbourhood unit; residential environments and public policy*. New York: Plenum Press.

Cerin, E., Leslie, E., Owen, N., & Bauman, A. (2007). Applying GIS in physical activity research: Community 'walkability' and walking behaviors *GIS for Health and Environment*.

Frank, L., Schmid, T., Sallis, J., Chapman, J., & Saelens, B. (2005). Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. *American Journal of Preventive Medicine, 28*, 117 - 125.

Handy, S. (1996). Understanding the link between urban form and nonwork travel behavior. *Journal of Planning Education and Research, 15*(3), 183-198.

Hess, P. M., Moudon, A. V., & Logsdon, M. G. (2001). Measuring Land Use Patterns for Transportation Research. *Transportation Research Record: Journal of the Transportation Research Board, 1780*, 17-24.

Kuzmyak, J. R., Baber, C., & Savory, D. (2005). Use of walk opportunities index to qunatify local accessibility. *Transportation Research Record: Journal of the Transportation Research Board, 1977*, 145-153.

Norusis, M. (2010). *PASW Statistics 18 Guide to Data Analysis*: Pearson SPSS Inc.

Porta, S., & Renne, J. L. (2005). Linking urban design to sustainability: formal indicators of social urban sustainability field research in Perth, Western Australia. *Urban Des International, 10*(1), 51-64.

Saelens, B. E., Sallis, J. F., Black, J. B., & Chen, D. (2003). Neighborhood-based differences in physical activity: an environment scale evaluation. *American Journal of Public Health, 93*, 1552 - 1558.

walkscore.com. (2010). from walkscore.com