

I only get some satisfaction: Introducing satisfaction into measures of accessibility

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ABSTRACT

Improving accessibility is a goal pursued by many metropolitan regions to address a variety of objectives. Accessibility, or the ease of reaching destinations, is traditionally measured using observed travel time and has of yet not accounted for user satisfaction with these travel times. As trip satisfaction is a major component of the underlying psychology of travel, we introduce satisfaction into accessibility measures and demonstrate its viability for future use. To do so, we generate a new satisfaction-based measure of accessibility where the impedance functions are determined from the travel time data of satisfying trips gathered from the 2017/2018 McGill Transport Survey. This satisfaction-based measure is used to calculate accessibility to jobs by four modes (public transport, car, walking, and cycling) in the Montreal metropolitan region, with the results then compared to a standard gravity-based measure of accessibility. This comparison reveals a discrepancy between both measures of accessibility, particularly for public transport users. By combining this discrepancy with mode share data, we identify areas that may be targets for future investigations to better understand the causes for discrepancy. The study demonstrates the importance of including satisfaction in accessibility measures and allows for a more nuanced interpretation of the ease of access by practitioners, researchers, planners, and policy-makers.

Keywords: Gravity-based accessibility, Commuting, Trip Satisfaction, Equity, Vulnerable

INTRODUCTION

An increasing number of cities and transport authorities are developing accessibility measures to assess the performance of land use and transport systems (Boston Region Metropolitan Planning Organization, 2015; NSW Government, 2012; Transport for London, 2006). In gravity-based accessibility measures, professionals discount destinations with decay functions using travel times obtained from local travel surveys (Geurs and Van Wee, 2004; Krizek, 2010). While this approach is effective in counting all possible destinations and adequately reflects traveler behavior, it does not capture the underlying psychology of travelers, namely potential dissatisfaction with the trip.

It is known that some trips are based more on necessity than convenience; and commuting can be inconvenient and a source of stress (Legrain et al., 2015b; Manaugh and El-Geneidy, 2011). Inconsistent or lengthy travel times in a transport system can necessitate the inclusion of additional commuting time in personal time budgets. This means that a population's high observed travel time tolerance should not suggest satisfaction with a transport and land use system, but their acceptance of these travel times under particular constraints. Increased amounts of time spent commuting have been found to not only negatively impact trip satisfaction (Loong and El-Geneidy, 2016), but also to reduce a commuter's well-being and social participation (Delmelle et al., 2013; Farber and Páez, 2011). Moreover, dissatisfaction with travel has been found to negatively impact an individual's quality of life and overall well-being, particularly when a dissatisfying trip becomes an unavoidable routine (De Vos and Witlox, 2017). Furthermore, satisfaction with travel time has been associated with higher punctuality and energy levels at work (Loong et al., 2017). Given the importance of trip satisfaction as one example of underlying travel psychologies, this study proposes a new measure of accessibility that incorporates satisfaction with travel time. This satisfaction-based measure of accessibility adds a new tool to the professionals' toolbox for assessing a region's land use and transport systems and improving the quality of life and well-being of individuals. Satisfaction-based accessibility can then be compared to classical accessibility measures, such as the standard gravity-based measure, to identify the gaps between the measures. For example, one can identify areas with high levels of accessibility with a standard measure, but experiencing lower levels of satisfaction-based accessibility. When combined with mode share, the number of identified areas will be reduced to those with high mode share and big differences between the measures, which can help in prioritizing future interventions that aims at improving the quality of life for certain mode users.

LITERATURE REVIEW

Accessibility

Accessibility describes the ease of reaching destinations and is commonly used in urban geography and transport planning to measure the performance of land use and transport systems (Accessibility Observatory, 2016; Bocarejo and Oviedo, 2012; Geurs and Halden, 2015; Hansen, 1959; Manaugh and El-Geneidy, 2012; NSW Government, 2012; Transport for London, 2006). The most frequently-used measure of accessibility is location-based, which generates accessibility levels (typically to jobs) for specific locations using a given mode of transport. Location-based measures of accessibility have shown to be closely associated with the mode share on which it is generated (Legrain et al., 2015a; Moniruzzaman and Páez, 2012; Owen and Levinson, 2015; Wu et al., 2018). Accessibility is also known to impact travel time and the prosperity of a neighborhood (Deboosere et al., 2018; Levinson, 1998).

A gravity-based (or weighted cumulative opportunities) measure of accessibility is considered the most reflective of individuals' travel behavior (El-Geneidy and Levinson, 2006; Handy and Niemeier, 1997). This measure values closer opportunities more than further ones through the use of decay functions. Decay functions are usually generated from travel behavior data specific to the region of analysis to ensure that the accessibility measures mirror local users' perception of travel time or distance (Geurs and van Wee, 2013). Decay curves are derived from the frequency of trips at different time or distance intervals, with more people willing to travel 10 minutes than 45 minutes to reach a job or any other desired destination (Iacono et al., 2010). Different types of curves have been used to fit this trend, including the negative exponential-decay function and the negative power-decay function (Ingram, 1971; Kwan, 1998; Östh et al., 2016). The negative exponential form is most commonly used, as it is generally more closely associated with travel behavior (Handy and Niemeier, 1997; Papa and Coppola, 2012).

While gravity-based measures better captures travel behavior, assumptions on travelers' perceptions of time are made (Geurs and van Wee, 2013). These measures assume that reported trips meet a traveler's time budget, ignoring that travelling individuals may be forced to increase their time budget in response to personal or systemic constraints. In other words, if a two-hour trip is occurring, the gravity-based measure assumes that it must be acceptable to the traveler. More efforts are needed to introduce new decay functions that reflect willingness to travel by incorporating underlying psychologies like trip satisfaction in their development.

Satisfaction Measures

Satisfaction is related to a user's perceived discrepancy between their desired service delivery and the service they in fact received (Stradling et al., 2007). Travel satisfaction varies according to the unique identities and behaviours of individual users and their expectations (Friman and Felleesson, 2009). Many studies have sought to explain what causes trip satisfaction by identifying variables that increase dissatisfaction. Some variables are mode-specific, while others apply across all modes. For example, seasonality is significant in explaining cyclist satisfaction (Willis et al., 2013) while the level of satisfaction with travel among bus and car users is affected by congestion levels (Turcotte, 2011). While minimizing time and distance spent on a trip may follow a utility-maximizing function, frustration with commute times can be mitigated if individuals' perceive that this time can be used productively (Lyons et al., 2007; Ory et al., 2004; St-Louis et al., 2014) or an opportunity for taking personal time (Jain and Lyons, 2008). In line with this finding, it must also be recognized that personal attitudes towards traveling influence satisfaction levels among different mode users (Li et al., 2013).

Public transport specifically has taken a marketing approach to customer satisfaction and service provision in recent years (Molander et al., 2012). Ensuring high levels of customer satisfaction with public transport is key to increasing loyalty to the service (Olsen, 2007) and attracting potential riders. A unique factor to consider is captive riders, commuters who are limited in their choice of mode, whether by economic or personal conditions, to public transport (Krizek and El-Geneidy, 2007) and who are forced to continue their use of the mode despite their dissatisfaction (Jacques et al., 2013). This group of users can be particularly dissatisfied, such as in London, UK, where riders from lower-income areas had the lowest levels of satisfaction of all users surveyed (Grisé and El-Geneidy, 2017).

A growing body of literature has been interested in analyzing trip satisfaction across transport modes. Trip satisfaction was highest for pedestrians, train commuters, and cyclists (St-Louis et al., 2014). They found commuters of all modes saw satisfaction decrease as travel time

increase. Other studies in America and China have found active modes to be among the most satisfying travel options while identifying several other commuting variables that impact overall satisfaction (Smith, 2017; Ye and Titheridge, 2017). With each mode possessing unique variables that impact overall traveller satisfaction, commuting time represents a common variable that may facilitate comparison. While accessibility measures often use time as a travel cost, no measure has of yet incorporated satisfaction with mode-specific travel times into its results.

METHODOLOGY AND DATA

Accessibility measures

In this study, gravity-based measures of accessibility to jobs are generated for four different modes relying on a negative exponential decay function. The standard measure of accessibility is expressed as follows:

$$A_{std,i} = \sum_{j=1}^n D_j e^{-\beta_{std} c_{ij}} \quad (1)$$

Where standard accessibility at zone i ($A_{std,i}$) is equal to the sum of opportunities (D) in each zone (j) multiplied by the negative exponent of movement cost between zones i and j (c_{ij}) multiplied by a cost sensitivity parameter determined with all trips (β_{std}) (Geurs and Van Wee, 2004). Opportunities are represented by jobs for this study and the travel time expressed in minutes. The sensitivity parameter (β_{std}) is derived from a travel time decay function that includes all trips from the 2017/2018 McGill Transport Survey.

The satisfaction-based measure of accessibility (A_{sat}) uses a different sensitivity parameter (β_{sat}) derived in the same manner as above, albeit using only trips satisfied with their travel time, as described below. The formula is otherwise identical, as seen below:

$$A_{sat,i} = \sum_{j=1}^n D_j e^{-\beta_{sat} c_{ij}} \quad (2)$$

Three types of data are used to generate gravity-based and satisfaction-based accessibility measures: (i) location of jobs, (ii) travel times across the Montreal metropolitan region using different modes, and (iii) travel behavior and satisfaction data. We select the census tract level for analysis due to the availability of data and the potential for data suppression that occurs at the dissemination level of the Canadian Census. The location of jobs (D) is obtained from the 2016 commuting flow from Statistics Canada (2016a), which provides information on the number of individuals commuting to each Census Tract (CT) to work in the Montreal Metropolitan region as well as their used mode of travel (public transport, car, walking, and cycling). Considering that each commuting destination corresponds to a job, we calculate the number of jobs in a census tract as equal to the total number of commuting to work trips ending in this CT. Mode share data is obtained separately from the 2016 Canadian Census (Statistics Canada, 2016b).

The second dataset consists of four travel-time matrices, one for each of the modes studied (public transport, car, walking, and cycling). The travel time matrices are generated by calculating the travel time from each census tract centroid to each other census tract centroid in the Montreal Metropolitan region. Walking travel times are calculated using ArcGIS's Network Analyst using a pedestrian-specific network and a walking speed of 5.47 km/h (a mid-range average speed derived by (Wasfi et al., 2013) from a number of other studies). The bicycling travel time matrix is generated using the same network as above and a cycling speed of 15.62 km/h (representing the low-end of average cyclist speed found through GPS observation by (El-Geneydy et al., 2007)). With respect to public transport, travel times are derived in ArcGIS from General Transit Feed Specification (GTFS) data for all transit agencies active in the region at 8 am. Finally, driving

travel times are obtained from the Google API with an 8 am departure time using the pessimistic parameter to account for congestion. Although travel times fluctuate throughout the day, previous research has shown that an 8am measure of accessibility is appropriate to capture the accessibility pattern of the metropolitan region (Boisjoly and El-Geneidy, 2016). This dataset derives the (c_{ij}) in equation (1) and (2).

The final dataset comes from the 2017/2018 McGill Transport Survey, and is used to calculate the sensitivity parameters (B) for both equation (1) and (2). The Survey is conducted roughly every two years online, with a total of 4,859 respondents (students, faculty and staff) completing the 2017/18 version of the survey and answering questions about their most recent trip to McGill University. The survey had a response rate of 33.4%. Only respondents commuting to the University’s downtown campus are included in order to reduce variation in trip satisfaction ratings (St-Louis et al., 2014) by keeping the destination constant. Respondents are organised by mode: public transport, car, walking, and cycling. Public transport users include all users who used bus, metro, and/or train to travel to McGill. Respondents who identified using public transport in combination with walking or bicycling are categorised as public transport users, while respondents who identified using driving and public transport together were removed from the sample. The final sample included 3,794 respondents (2,142 public transport users, 403 drivers, 991 walkers, and 258 cyclists). Respondents were asked for details about their last trip to McGill, including their departure time and arrival time in fifteen-minute increments as well as satisfaction with various aspects of the trip. The travel time of each trip is obtained by subtracting respondents’ reported departure time from their reported arrival time. The travel time satisfaction is derived from the satisfaction questions related to travel time for each mode (Table 1). For each aspect, respondents were asked to rate their satisfaction from 1 to 5, with 1 being very unsatisfied and 5 being very satisfied.

TABLE 1: 2018 McGill Transport Survey Questions used to calculate satisfaction with travel time

<i>Mode</i>		Thinking of your most recent trip, please rate your satisfaction with...
Public Transport	Bus	Length of time spent on the bus
		Length of time spent to reach the bus stop
		Waiting time for the bus
	Metro	Length of time spent on the metro
		Length of time spent to reach the metro station
		Waiting time for the metro
	Train	Length of time spent on the commuting train
		Length of time spent to reach the commuter train station
		Waiting time for the commuter train
Car	Length of time spent traveling in the vehicle	
	Length of time spent looking for parking	
Walk	Length of time spent walking	
	Directness of route	
Cycle	Length of time spent cycling	

	Directness of route
	Continuous route with little or no stopping

The responses to questions listed in Table 1 are summed and averaged by respondent, with unanswered questions excluded. Respondents were considered as satisfied with their travel time when the average of their travel time responses was above three. While we equally weight each question, further research could consider applying different weights to different aspects of the trip. Table 2 represents the mean travel time in minutes, the mean travel time satisfaction, and the percentage of satisfied respondents by mode.

TABLE 2: Summary statistics by mode*

<i>Mode</i>	Number of respondents	Mean travel time (m)	Mean travel time satisfaction	% of satisfied respondents
Public transport	2142	44.49	3.7	73%
Car	402	49.24	3.5	64%
Walk	991	21.31	4.2	85%
Cycle	258	26.2	4.1	90%

*Note: Satisfied respondents are those whose average travel time satisfaction is above three.

Respondents with an average travel time satisfaction rating above three are used to derive the sensitivity parameter ($-\beta_{sat}$) for equation (2), while all respondents are used to derive the sensitivity parameter ($-\beta_{std}$) for equation (1). The respondents for each set are grouped by fifteen-minute intervals and expressed as a cumulative percentage of the whole (up to 105 minutes for public transport and car modes, and 60 minutes for walk and cycle modes), which allows for the generation of a decay curve as the percentage of all trips occurring at a given interval declines with increase in travel distance time. This process was conducted for each mode (public transport, cycling, walking, and car). Each data set is then fitted with a negative exponential curve with a set intercept of 1, and the decay factor of each curve is captured for use as the sensitivity parameter in the two accessibility calculations. Two decay curves were generated for each mode, which were then used to produce the accessibility measures, satisfaction-based and gravity-based, by each mode to jobs at the census tract level of analysis.

Accessibility Ratio

The results of the satisfaction-based measure are divided by the standard measure to generate an accessibility ratio for each mode, at the census tract level. A ratio of 100% means that the level of accessibility found using the satisfaction-based method is equal to that obtained using the standard method, while a lower ratio reflects significantly lower results found by the satisfaction-based method compared to the standard method. In other words, a low ratio suggests that the standard measure overestimates the level of accessibility a person is experiencing when not considering their satisfaction with travel time. The accessibility ratio is used to better understand the spatial patterns of discrepancy by both measures of accessibility to jobs, while also facilitating comparisons between modes.

Targeting Areas for Investigation

The next step was to build on the accessibility ratio by identifying census tracts where high mode shares for a respective transport mode and low accessibility ratios (where accessibility is overestimated by the standard measure) overlap. Areas that have a high proportion of commuters by a given mode should be further investigated as to what causes the discrepancy between the two measures. Combining the accessibility ratio with mode share data may also correspond to those where a large proportion of the population may be dissatisfied with their travel time to work by a given mode.

For each census tract, we generate a standardized score (z-scores) for the accessibility ratio (Z_R) and for the mode share (Z_M) for each mode. We then subtract the accessibility ratio z-scores from the mode share z-scores using the following formula:

$$I_i = Z_M - Z_R ,$$

The highest scores on the index are the result of a high relative mode share and a low relative accessibility ratio. We consider that areas with a high combined score are those with a potentially high proportion of captive users, as they experience a high discrepancy between the satisfaction-based and regular gravity based accessibility by a given mode yet remain users of it. Given that lower-income commuters are more likely to be captive users, we compare the results of the combined score to the top decile of census tracts on a social vulnerability index. Social vulnerability is determined through an index of four socioeconomic variables specific to the Canadian context, including median household income, the percentage of recent immigrants, the percentage of households spending over 30% of their income on housing, and the percentage unemployed (El-Geneidy et al., 2016; Foth et al., 2013). Making improvements to areas with a high combined score ensures that improvements to the transport system benefit existing captive users who may not otherwise be targeted.

RESULTS

Satisfaction-based decay function

Figure 1 illustrates the satisfaction-based and standard travel time decay functions for each mode. The satisfaction-based method appears in blue, while the standard method appears in orange. The travel time was calculated by subtracting arrival time from departure ones. Individuals were asked to report when they left home in bouts of 15 minutes and when they arrived in bouts of 15 minutes as well. This information was used to derive the decay function for travel time as it is more realistic than using modeled or assumed travel time. Also the corresponding satisfaction corresponds to this travel time and is modeled according to 15 minutes bouts as well. For both walking and cycling, little difference is observed between the standard decay curve and the satisfaction-based decay curve (with β of -0.087 and -0.085 respectively for walking, and -0.087 and -0.080 respectively for cycling). This is likely explained by the fact that a very high proportion of these respondents were satisfied with their travel time (85% and 90% respectively). Conversely, fewer public transport and car users were satisfied with their travel times, and greater difference exists between the curves for each of these modes. Lower values are found for the satisfaction-based decay curve, particularly for public transport. For example, at 30 minutes the public transport decay factors are respectively 0.27 and 0.36, for a ratio of (0.75) whereas the factors for car are respectively 0.30 and 0.38 (ratio of 0.79).

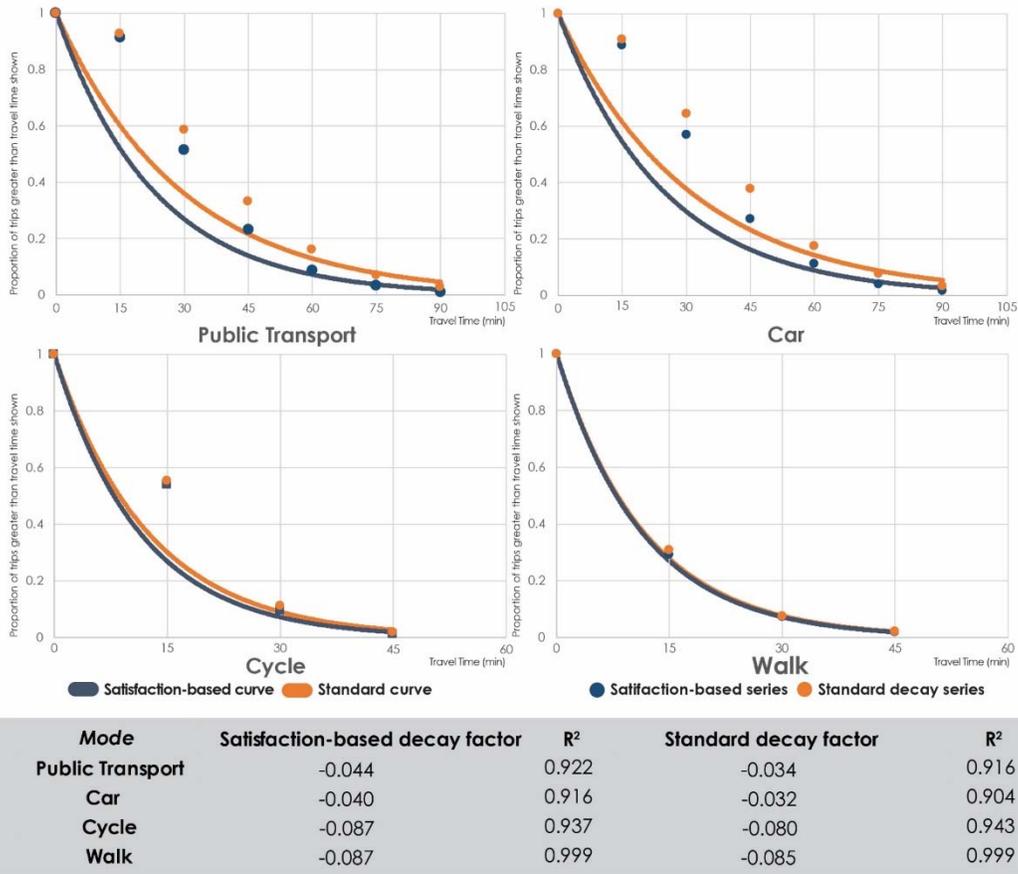


FIGURE 1: Travel-time decay curves by mode

Satisfaction-based accessibility

Using the above satisfaction-based and standard decay functions, we generate measures of accessibility to jobs for each mode. Figures 2 compare the results of both measures for car and public transport. As expected, accessibility by car is highest overall for both measures of accessibility. Accessibility by public transport is highest in the CBD and around metro and rail lines and decreases as distance from the core increases, while accessibility by car is more directly associated with distance to CBD.

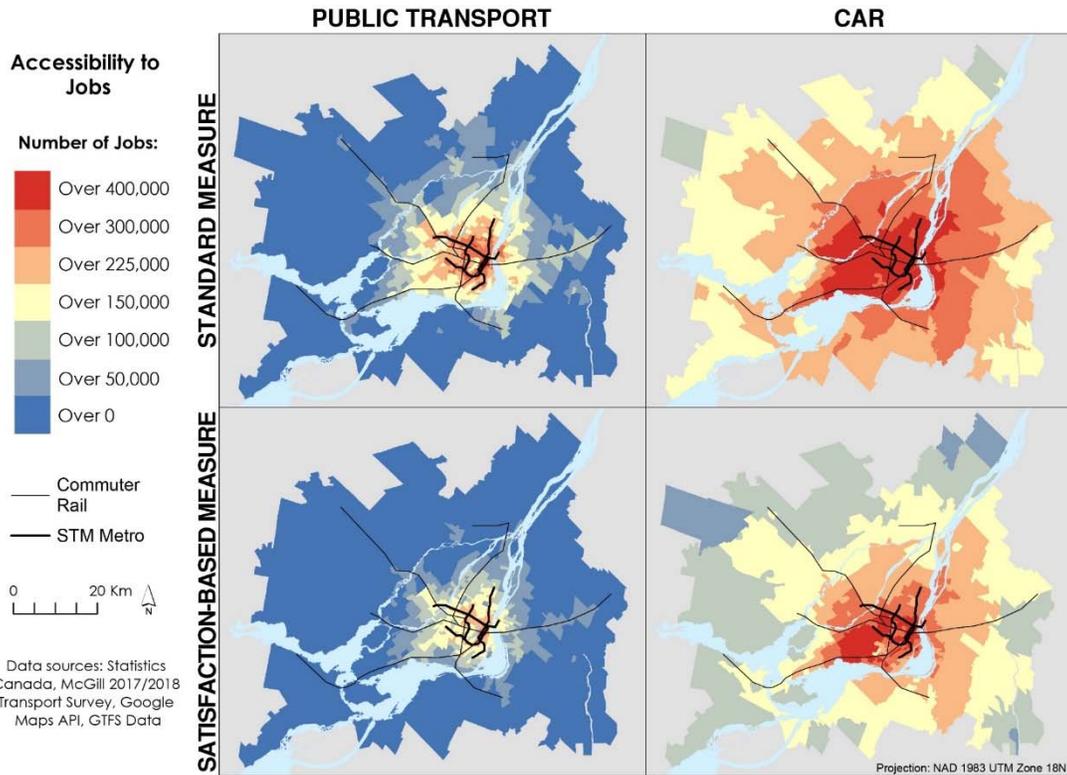


FIGURE 2: Comparison of accessibility to jobs by method, public transport and car modes

With respect to walking and cycling (Figure 3), accessibility is highly concentrated in the core of the region. When comparing the satisfaction-based measure with the standard measure, it is clear that significant changes occur in both public transport and car modes. For both modes, a reduction in accessibility occurs across the region when using the satisfaction-based measure, although the patterns remain similar. While there are some changes in cycling and walking between the satisfaction-based and the standard measure, they are not as visible as those observed for public transport and car.

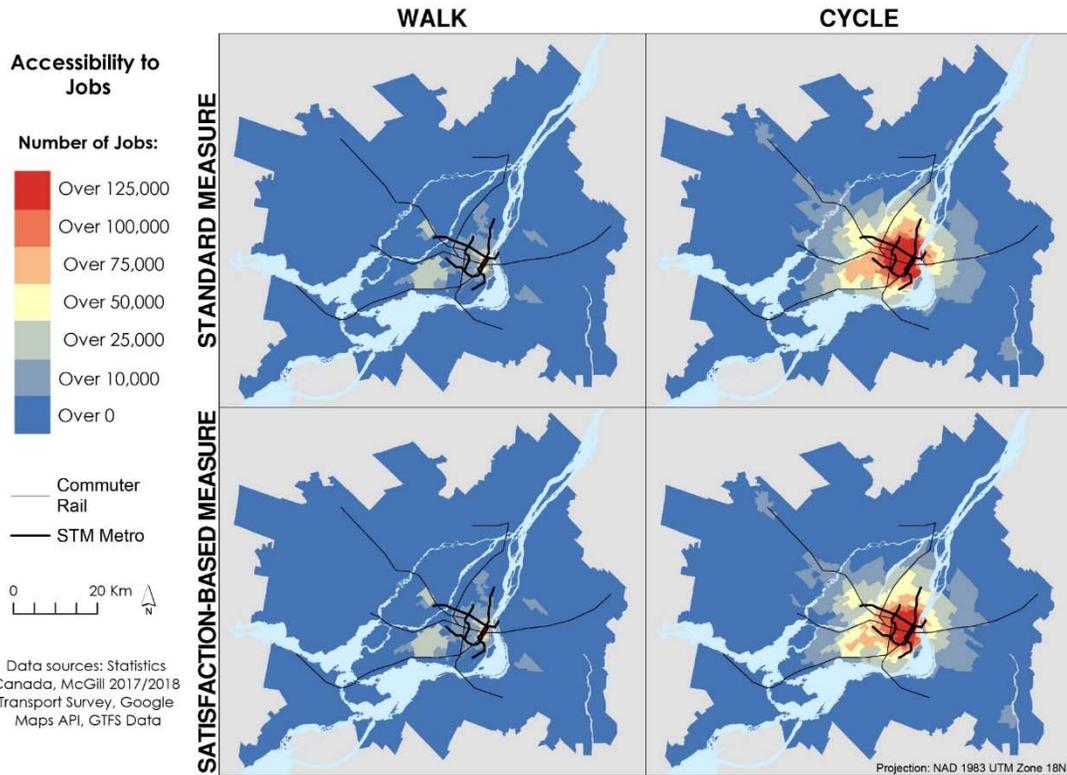


FIGURE 3: Comparison of accessibility to jobs by method, cycle and walk modes

Accessibility Ratio

In order to better understand the differences between both methods and clearly identify areas where this difference is most pronounced, we proceed by presenting the accessibility ratio (Figure 4). The largest ratios are found in walking and cycling, with most of the region maintaining 80% to 99% of accessible discounted jobs under the satisfaction-based measure. For cycling, some areas have a lower ratio (60%-79%), likely due to high travel times to employment clusters from these tracts. The standard measure compares favorably to the satisfaction-based measure when applied to active modes.

Accessibility to jobs by car is further reduced when using a satisfaction-based measure, with a ratio between 60% and 79% across most census tracts. This ratio is relatively consistent throughout the region, suggesting similar travel times to employment clusters corresponding to the largest gap between the satisfaction-based and standard decay curves. Accessibility to jobs by public transport, however, sees inconsistent ratios across the region, with significantly lower ratios than other modes (mainly between 20% and 59%). This reflects levels of service provision by public transport, as areas with higher levels of service and shorter travel times (such as those around the metro) have higher ratios. It is important to note that some peripheral census tracts have a high ratio due to a lack of public transport service – only local jobs are counted as accessible, with no change observed between methods.

The accessibility ratio demonstrates the magnitude of discrepancy when using a standard accessibility measure, especially for public transport and car. Areas where the ratio is low are areas where many travel times can be expected to be dissatisfying. In other words, residents of these areas are more likely to be dissatisfied with their travel time if using a given mode. Understanding what mode these residents are using, however, requires the addition of mode share data.

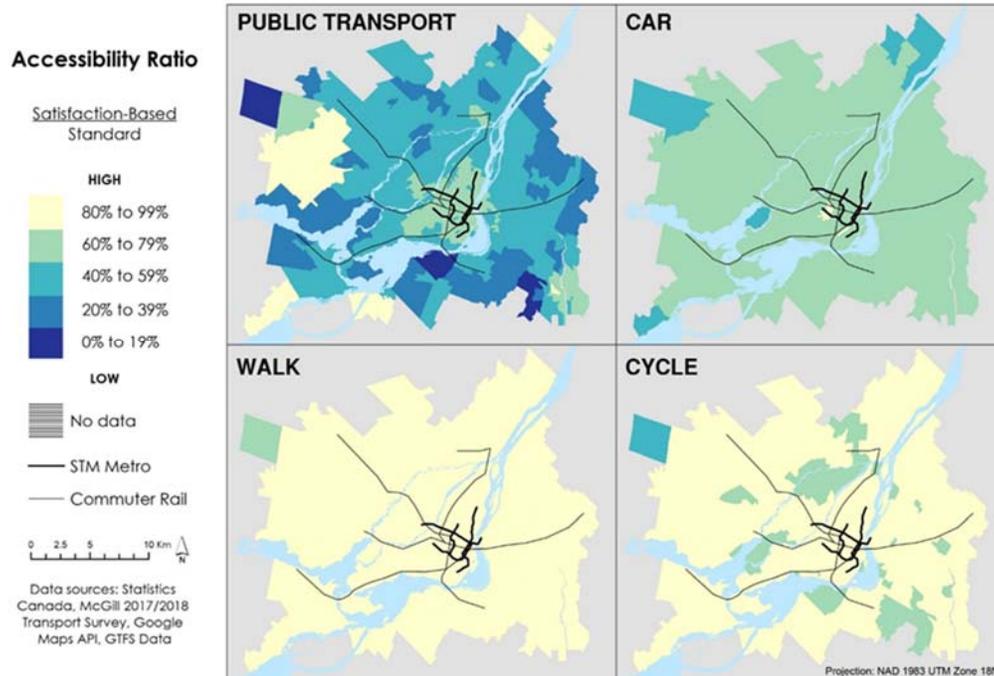


FIGURE4: Accessibility ratio to jobs, satisfaction-based method over standard method

Targeting Areas for Intervention

While the accessibility ratio highlights areas of high discrepancy for each mode, the question remains what causes the discrepancy between both measures and what may be done to improve it. To that end, identifying areas where the accessibility ratio is lowest and where the proportion of residents using that mode is high acts as a starting point. By combining mode share data and the accessibility ratio, we identify areas where the discrepancy between standard- and satisfaction-based accessibility is high and many users of a given mode may be impacted. The findings are presented in Figure 5, with the focus put on the center of the Montreal region where mode share is more divided between the four modes. A high combined score appears in dark red. We compare the results to the 10% most vulnerable census tracts in order to test whether the overestimation corresponds with social inequity.

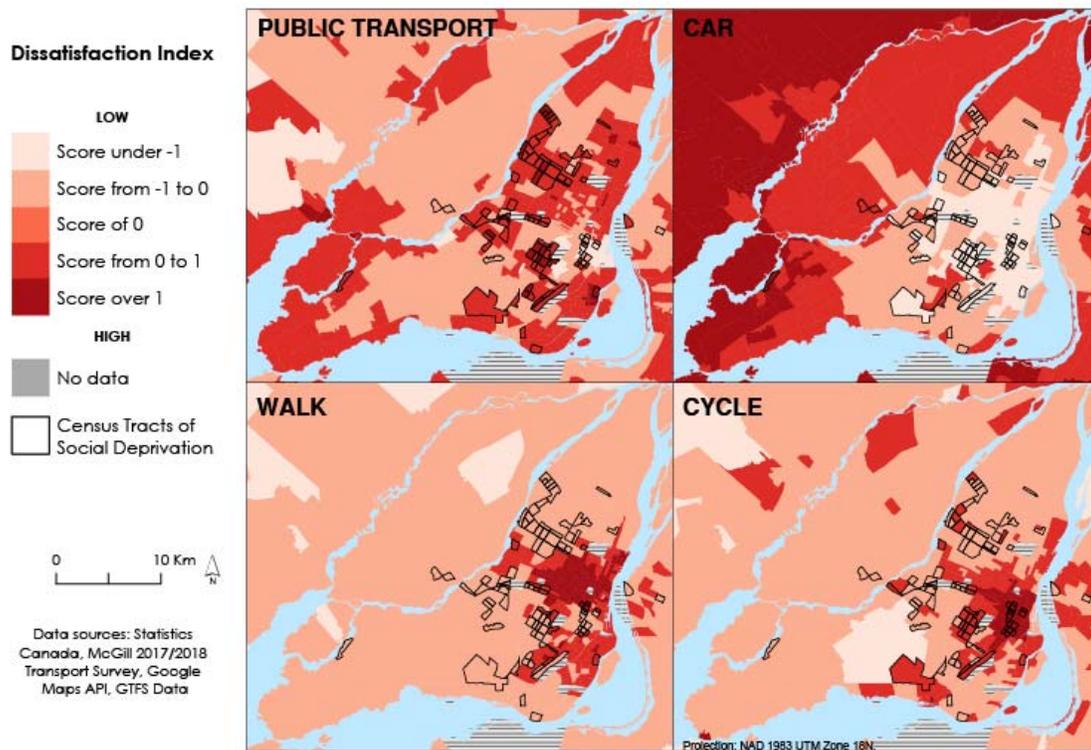


FIGURE 5: Dissatisfaction index by mode and census tracts of high social vulnerability

It should be noted that in the case of cycling and walking modes, the discrepancy is low across the region and its mode share heavily influences the combined score. The areas identified are thus those most used by walkers and cyclists, and further study or interventions in these areas would do little beyond reaching the greatest number of walkers and cyclists. They may also not have a large effect on the most vulnerable residents of the region, except in areas north of downtown for walking and in the north west of downtown for cycling, where there is some correlation of high vulnerable groups.

A similar conclusion can be drawn when considering the combined scores by car, with the highest scores clustered in the periphery of the region where the dominant travel mode is by car. These areas do not overlap with the most vulnerable census tracts. It would appear that the discrepancy for car drivers is largely due to their distance from employment centers. As a result, prioritising interventions in travel time by car for these areas may improve satisfaction for drivers, but must also be considered alongside the sustainability goals and car reduction strategies of the region. These interventions do not overlap with the most socially-vulnerable census tracts and will not affect the transport system's most vulnerable car users.

The combined score shows the most complex spatial relationship for public transport, with the highest scores found across the center of the region. There is a large correlation between areas with a high combined score and highly vulnerable census tracts. With the exception of some tracts located in the core, most socially vulnerable census tracts are largely impacted by the discrepancy between measures for public transport and are heavy users of public transport. One potential interpretation of this finding is that the discrepancy is due to captive riders, unable to switch to a different mode that would provide a more satisfying travel time. Targeting these areas for further research and interventions would go furthest in understanding the gap between the two measures

while also ensuring interventions benefit the most vulnerable users of the region's public transport system.

DISCUSSION AND CONCLUSION

Our findings have shown that a significant discrepancy exists between a satisfaction-based measure and a standard measure of accessibility, especially for public transport and car. This highlights the importance of considering satisfaction when aiming to identify areas where improvements can be prioritized. Areas experiencing high differences between the two measures of accessibility and with high mode share are areas where regular accessibility scores high and will generally fall out of the radar for future improvements, as it will be assumed that these groups of individuals are happy with their choices as they use the mode and accessibility by that mode is fine. Using the satisfaction-based method is a particularly viable approach for public transport as it is the only commuting option available to some populations while at the same time the mode where the discrepancy between the two measures is highest. As increasing public transport mode share can play a key role in meeting equity and sustainability goals for a regional transport system, using a satisfaction-based measure will more realistically demonstrate a population's willingness to use the system. Accordingly, such measure can help in prioritizing the interventions in a time where there are scarce resources to improve the quality of service.

Increasing satisfaction-based accessibility can be achieved in two ways. The first, a traditional approach, is to reduce travel times to employment clusters for commuters. Shortening the travel times to jobs will increase the number of jobs accessible with a satisfying commuting time and increase the satisfaction level of currently existing trips. This can be done by either creating more jobs closer to commuters' homes or improving the frequency of service, speed and directness of the transport system. The second approach consists of increasing satisfaction with travel time (without changing the travel time), which may include a variety of policies aimed at decreasing the displeasure of commuting. Providing clean and comfortable facilities, frequent service, customer information screens, and affordable fares are examples specific to public transport that can increase satisfaction, or reduce perceived travel time, without necessarily decreasing travel time (Fan et al., 2016; Lagune-Reutler et al., 2016). In identifying areas with the highest discrepancy between measures and large proportions of their population using a given mode, future research and interventions in decreasing displeasure in the regional transport system can be directed. The inclusion of a social vulnerability index adds a final consideration of social equity in these decisions, particularly as it relates to improving the satisfaction and quality of life of the most vulnerable transport system users, which is a goal that many transport professionals are trying to achieve. It is important to note that satisfaction-based accessibility measures should be used in parallel with regular accessibility measures such as the standard travel time-based gravity or cumulative opportunities in land use and transport planning as they offer a nuance understanding of the existing systems.

Our use of the McGill Transport Survey to generate satisfaction-based and standard measures of accessibility may not be broadly applicable due to the unique nature of the commute to McGill's downtown campus. Different trip environments (downtown vs suburban areas) might yield different satisfaction with travel times. Also travel times were calculated in the bouts of 15 minutes as they were reported that way, other researchers can have more accurate travel times if needed. Our method does however represent a simple and replicable approach to including satisfaction that may be made more or less complicated according to one's needs. We have

demonstrated the viability of a method that may be applied by any interested agency or jurisdiction provided access to satisfaction ratings is available. Currently various municipalities around the world are collecting satisfaction surveys for different modes, while satisfaction surveys for public transport are commonly present at every public transport region around the world. The application of this method can be easily done through collaborations with local public transport authorities to test our targeted areas for dissatisfied riders. The study also highlights the need for adequate and consistent satisfaction ratings in transport planning, without which agencies would have difficulty generating a satisfaction-based measure or even evaluate their own land use and transport system from a user's perspective. Finally, including the trip satisfaction of commuters represents an important advance in generating accessibility measures, which can prioritise improvements in the land use and transport planning for vulnerable groups. In doing so, planners are better equipped to improve satisfaction with travel times, and thereby contribute to increased quality of life and well-being.

This paper proposed a simple measure for including satisfaction in the generation of accessibility measures. In this paper, we focused on introducing satisfaction measures as a new approach to accessibility rather than a new decay curve. Further research could build on the approach presented here using more complex decay functions (such as a Gaussian function). Furthermore, future research could test an alternative approach that would modify the travel costs between zones rather than the sensitivity parameter. By using satisfaction as a travel cost, jobs could be discounted according to the degree of dissatisfaction associated to the trip by a given mode. For example, two jobs reachable with a trip satisfaction rating of 50% may be worth one job reachable with a satisfaction rating of 100%. This would enable the use of satisfaction-based accessibility in an easily-understood cumulative opportunities framework. Combining perceived (or reported) travel time (as distinct from objectively measured travel time using GPS) with satisfaction in accessibility measures is another direction for future research. The issue, which cannot be addressed with current data sets, is the extent that dissatisfaction already embeds higher perceived travel times, or the degree to which they are two distinct phenomena.

COMPETING INTERESTS

The authors confirm no competing interests in their participation to this study.

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