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Subjectivity matters: Investigating the relationship between perceived accessibility and travel behaviour☆

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ABSTRACT

Accessibility, the ease of reaching destinations, encompass local and regional metrics used to evaluate the performance of the land use and transport systems in a region. These measures are known to impact individuals' travel behaviour, which led to their adoption in practice as performance indicators to evaluate transport projects and plans, monitor progress towards equity goals, and evaluate changes induced by various policies. However, calculated measures of accessibility do not account for individuals' experiences and perceptions, which play a pivotal role in travel behaviour. This research examines the relationship between travel behaviour and perceived accessibility, while accounting for calculated accessibility, residential selection, travel identity, and individual characteristics. Using data from a large-scale bilingual online survey administered in Montreal, Canada in Fall 2023 (N = 5,277), we perform statistical analyses at both local and regional levels to model weekly mode shares for walking and public transit, respectively. Calculated accessibility is accounted for locally using Walk Score® and regionally using cumulative opportunities accessibility measures by public transit. Our findings reveal that perceived accessibility by walking and public transit positively impact the weekly walking and transit mode share, respectively, for all purposes. Accounting for calculated accessibility and travel identity is important to avoid overestimating the influence of perceived accessibility on travel behaviour. This research provides transport professionals a nuanced understanding of the link between accessibility (perceived and calculated) and travel behaviour, offering insights for promoting the use of sustainable travel modes.

1. Introduction

In recent years, there has been a significant shift in the transport planning field, transitioning its focus from emphasizing the mere movement of people (mobility) to prioritizing the ease of reaching destinations (accessibility) as a key performance measure (Handy, 2023). Accessibility is the most comprehensive measure that links land use and transport systems, offering a multi-dimensional evaluation of their performance (El-Geneidy and Levinson, 2022; Levinson and Wu, 2020; Wachs and Kumagai, 1973). It is often used to explain the equity impacts of urban policies and projects (Deboosere and El-Geneidy, 2018; Foth et al., 2013; Geurs et al., 2016). Calculated measures of accessibility can be generated at the regional or local scales. Regional scales usually concentrate on accessibility by public transit or car, while local accessibility concentrates on accessibility by walking or cycling. Calculated measures

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of accessibility are one of the important determinants of mode choice. For example, areas with higher levels of regional accessibility by public transit were found to have higher public transit mode share (Cui et al., 2020; Moniruzzaman and Páez, 2012; Negm and El-Geneidy, 2024; Owen and Levinson, 2015), while areas with higher levels of local accessibility by walking (walkability) experience higher pedestrian activities (Cervero, 2002; Lin et al., 2017; Manaugh and El-Geneidy, 2011; Zuniga-Teran et al., 2017).

Despite accessibility's increasing prominence as a planning tool, we still do not fully understand how it is perceived and experienced by individuals and how these perceptions can affect their choices and subjective well-being (Lionjanga and Venter, 2018; Reardon et al., 2019; van Wee and Geurs, 2011). Discrepancies between the effects of calculated and perceived accessibility may hinder the anticipated outcomes of efforts aimed at improving accessibility levels to influence travel behaviour. For instance, people living in areas with high levels of measured accessibility might still perceive challenges in reaching their desired destinations with a certain mode due to social differences (Curl, 2018) and travel attitudes. Recent research has been calling for more nuanced studies linking perceived accessibility to travel behaviour (De Vos et al., 2023; Pot et al., 2021), as the relationship between these concepts remains understudied with only few studies briefly exploring the topic (Andersson et al., 2023; Lättman et al., 2020; Mehdizadeh and Kroesen, 2025; Tanimoto and Hanibuchi, 2021; Vafeiadis and Elldér, 2024).

This study contributes to the literature by investigating the relationship between perceived accessibility and weekly travel behaviour, while accounting for calculated accessibility, residential selection, travel identity, and individual characteristics. We use data from Wave 4 (Fall 2023) of the Montreal Mobility Survey (MMS), a bilingual longitudinal travel survey conducted yearly by the Transportation Research at McGill group in Montreal, Canada (Negm et al., 2023). This survey wave collected data on participants' self-reported perceived accessibility, weekly travel behaviour, travel identity, residential selection, and socioeconomic characteristics. Retrieved Walk Score® and calculated regional accessibility measures for public transit were linked to the survey data to represent calculated accessibility measures. We conduct a series of weighted linear regression models using a stepwise approach with weekly walking and public transit mode shares as the determinants of travel behaviour on the local (N = 4,679) and regional (N = 2,985) levels, respectively, controlling for confounding factors to reveal the impact of perceived accessibility on travel behaviour. As accessibility gains more prominence in transport planning, understanding how its perception impacts travel behaviour is vital. This insight enables transport professionals to effectively allocate resources, whether by increasing calculated accessibility through built environment improvements or by enhancing perceived accessibility through campaigns that help individuals recognize the actual quality of the transport system within their reach.

2. Theoretical background

2.1. Calculated and perceived accessibility

Local accessibility presents the amount and variety of amenities accessible in a neighborhood through active travel modes (i.e., walking and cycling) (Forsyth and Krizek, 1978). In recent years, local accessibility has been gaining more interest in research and practice, especially in the ideas of the x-minute city (Logan et al., 2022; Lu and Diab, 2023). Local accessibility sometimes referred to as walkability is known to impact travel behaviour (Ewing and Handy, 2009; Lo, 2009; Maghelal and Capp, 2011). For instance, Manaugh and El-Geneidy (2011) found that walkability indices are highly correlated with walking trips for non-work trip purposes. They found that each of the different indices have strength explaining the variation in walking trips to specific destinations with Walk Score® (walkscore.com) being a reliable measure for walkability. Elldér et al. (2020) argue that while the increase in active travel is associated with increased local access, this relationship is not necessarily linear and it depends on the geographical context, which is similar to other studies finding that the built environment-travel behaviour relationship is often non-linear (Cui et al., 2020; Ding et al., 2021; Hatami et al., 2023). Research on perceived walkability showed prominent links to well-being and walking behaviour (De Vos et al., 2023; van der Vlugt et al., 2022; Van Dyck et al., 2013).

Regional accessibility is one of the most inclusive measures linking land use to transport systems to assess how they benefit the population in reaching opportunities around them (El-Geneidy and Levinson, 2022; Levinson and Wu, 2020). Regional measures of accessibility can be generated for a specific mode of transport at a specific time of day (Geurs and Van Wee, 2004). Several methods are used to measure regional accessibility, among which two are the most used in practice: cumulative opportunities and gravity-based measures (Boisjoly and El-Geneidy, 2017a; Boisjoly and El-Geneidy, 2017b). The cumulative opportunities measure is one of the most commonly used, due to its ease of interpretation and communication to the public and policymakers (El-Geneidy and Levinson, 2022). In this measure of accessibility, all the opportunities (destinations) available within a predefined travel time (TT) threshold are weighted equally (Geurs and van Eck, 2001). Meanwhile, gravity-based accessibility weighs opportunities based on the TT necessary to reach them. This method allows for the inclusion of opportunities that could be discarded in the cumulative measures if they are not within the set time threshold. While this measure improves the approximation to reality, it requires an extensive amount of additional data and is more challenging to compute, interpret, and communicate to policymakers and the public. Comparison between cumulative opportunities and gravity-based measures found a high correlation between the two measures in the North American context (Giannotti et al., 2021; Kapatsila et al., 2023; Palacios and El-Geneidy, 2022), suggesting that using cumulative opportunities is sufficient to represent the built environment adequately.

While many studies focused on the calculated side of local and regional accessibility, only a few have studied the notion of perceived accessibility, especially at the regional scale (Pot et al., 2021; Ryan and Pereira, 2021; van Wee, 2016). The Perceived Accessibility Scale (PAC), developed by Lättman et al. (2016), has been lately used as one of the tools to study perceived accessibility by public transport (Al-Rashid et al., 2021; Al-Rashid et al., 2023; Sheng and Zhang, 2022; Watthanaklang et al., 2024) and by the main mode of travel in general (Lättman et al., 2020; Lättman et al., 2018; Pot et al., 2024; Pot et al., 2023a, b; Sukhov et al., 2023; Warner et al., 2021; Wolday and Böcker, 2023). This scale consists of four self-reported questions that attempt to capture key aspects of subjective accessibility based on previous literature; however, it includes overarching notions such as life satisfaction and assumes equal weights between the four statements which can render some interpretations to be inaccurate. Other studies utilized a more focused approach to measuring perceived accessibility depending on statements about ease of performing specific trips with specific modes rated on a Likert-scale (Vafeiadis, 2024; Vafeiadis and Elldér, 2024).

While the existing literature examined the connection between perceived accessibility and several factors such as public transit service quality (Sukhov et al., 2023; Watthanaklang et al., 2024), social exclusion and life quality (Al-Rashid et al., 2023; Andersson et al., 2023), activity participation (Al-Rashid et al., 2021; Pot et al., 2024), and behavioural intentions (Sheng and Zhang, 2022); few studies explored the possible connection between perceived accessibility and travel behaviour (Andersson et al., 2023; Lättman et al., 2020; Mehdizadeh and Kroesen, 2025; Tanimoto and Hanibuchi, 2021; Vafeiadis and Elldér, 2024).

Lättman et al. (2020) and Tanimoto and Hanibuchi (2021) evaluated the perceived accessibility (PAC) of car users under hypothetical driving restrictions, finding that their perceived accessibility would significantly decrease. However, the results from these studies are inconclusive as they relied on hypothetical scenarios rather than using panel data from the same users. Vafeiadis and Elldér (2024) found that frequent car users have high levels of perceived accessibility by car and low levels by all other modes. While Mehdizadeh and Kroesen (2025) suggest that travel behaviour has a larger impact on perceived accessibility than the reverse effect, they use a measure for perceived accessibility that focuses on accessibility to the participants' neighborhoods rather than from the neighborhoods to the participants' desired destinations. This measure does not align with the conventional definition of accessibility that focuses on the ease of reaching destinations (Levinson and Wu, 2020; Wachs and Kumagai, 1973). This approach could overlook aspects of how travel behaviour is influenced by the range of destinations that individuals seek to access by certain travel modes.

Some studies investigated the (mis)match between calculated and perceived accessibility. Pot et al. (2023a, 2023b) found that perceived accessibility by the main mode of travel tends to be more evenly distributed than calculated accessibility at rural, urban, and national levels, highlighting a general discrepancy between the two measures. Pot et al. (2021) and Vafeiadis (2024) stress the importance of measurement as inaccuracies can be a potential cause of the differences between perceived and calculated measures of accessibility. At the local scale, more studies explored perceived accessibility and found that it mainly in line with the calculated one (Arvidsson et al., 2012; Gebel et al., 2009; Van Dyck et al., 2013) and that it has a positive impact on walking behaviour (Hinckson et al., 2017; Solbraa et al., 2018).

Recently, studies by Pot et al. (2021) and De Vos et al. (2023) produced generalized conceptual frameworks that link perceived and calculated accessibility. However, these frameworks were not practically validated. While calculated accessibility has been continuously discussed and measured in the transport literature (Handy, 2023; Hansen, 1959), perceived accessibility is a newer term that researchers are still trying to understand (Pot et al., 2021; Vafeiadis, 2024), measure (Lättman et al., 2018; Vafeiadis and Elldér, 2024), and link to behaviour (Pot et al., 2023a, b; Vafeiadis and Elldér, 2024).

2.2. Mode choice determinants

To make a specific trip, an individual usually weighs their options through a matrix of objective and subjective determinants to select the mode they would use based on their personal characteristics (Panter and Jones, 2010; Scheiner and Holz-Rau, 2007). On the personal characteristics side, determinants of mode choice encompass age, gender, income, and household attributes (Patterson et al., 2005; Scheiner, 2014). The literature has consistently shown that gender and age are among the determinants of mode choice (Ha et al., 2020; Legrain et al., 2015). Income and car ownership are among the household characteristics that influence travel behaviour the most (Buehler, 2011). Lower-income individuals are also shown to react differently to varying levels of objective measures compared to those with higher incomes (Cui et al., 2020).

Among the objective determinants are spatial and temporal considerations. Spatial factors such as density, land use distribution, and the availability of a certain mode play a significant role in favouring one mode over the other (Cervero, 2002; Lin et al., 2017). Temporal factors include the flexibility in the time of departure and the travel time, which are major determinants of mode choices (Scheiner and Holz-Rau, 2007). Limited transport options at the time of travel often lead travelers to use certain modes despite their higher level of inconvenience because alternatives do not exist (Manaugh and El-Geneidy, 2011). These spatial and temporal considerations can be combined in one calculated measure, accessibility, which is one of the major determinants of mode choice (Moniruzzaman and Páez, 2012; Negm and El-Geneidy, 2024; Owen and Levinson, 2015; Ton et al., 2020).

Subjective measures encompass travel attitudes and preferences, including residential self-selection (Cao et al., 2009; Handy et al., 2005; Kamruzzaman et al., 2015; Parkany et al., 2004). Attitudes and preferences mainly stem from personal beliefs (Mann and Abraham, 2012) and habits (Verplanken and Orbell, 2003). They represent the degree to which a person would favour a mode over another because they link it to some positive aspect in their life (De Vos et al., 2022). There is a constant debate in the literature on whether travel attitude influences behaviour or vice-versa. Kroesen et al. (2017) argue that they both mutually influence each other over time but that behaviour influences attitudes more. Based on the theory of cognitive dissonance (Festinger, 1957), people are likely to change their attitudes or behaviours to align with each other (McCarthy et al., 2023). Among the factors that can be classified under travel attitudes is the perception of the possible benefits and challenges of using a specific mode. Studies showed that the perception of challenges negatively impacts a certain mode choice (Ball et al., 2007; Titze et al., 2008). Many studies focused on the perception of public transit quality (Gilbert and Foerster, 1977; Habib et al., 2011; Zhao et al., 2013) and how positive perception increases transit use. The link between perceived accessibility by different modes and travel behaviour remains underexplored. This research will expand on the studies that address the perception of accessibility in their attempt to fill the gap in the literature by developing a better understanding of this notion and applying it in transport planning to encourage the use of sustainable modes.

3. Data and methods

This research focuses on investigating perceived accessibility and its impacts on travel behaviour in Montreal, Canada at the local and regional scales. Spatial census data from Statistics Canada is utilized with the MMS survey data to achieve this goal. Spatial data is mainly used to generate regional calculated accessibility measures while survey data is used to gather perceived accessibility measures and travel behaviour. Local accessibility is concerned with the neighborhood-scale level where individuals can reach their destinations using non-motorized modes. For this scale, we focus on walking as it is a generally more accessible mode to travel than bicycles. Meanwhile, regional accessibility is considered at the city-scale level, allowing the comparison between the number of potential opportunities for interaction between different areas of the city. We define these areas as the Census Tracts (CT). To be able to move between the CTs in a reasonable amount of time, individuals would need to use travel modes that cover long distances quickly (i.e., car and public transit).

3.1. Spatial data

Local accessibility was accounted for using Walk Score®, an indicator that uses a decay function to evaluate access to various amenities (dining and drink, groceries, parks, schools, shopping, culture and entertainment, and errands) within a 30-minutes walk of a certain location (Walk Score, 2024). The index is linearly expressed on a range from 0 (car dependent) to 100 (walker's paradise). It is often used in the transport literature as an indicator of the density of the built environment and the utilitarian walking potential (Hall and Ram, 2018) and has been validated in the past (Manaugh and El-Geneidy, 2011). Using an API, we retrieved Walk Score® for each participant based on their home location in December 2023.

For regional accessibility, Canadian population census and commuting flows (CCF) (Statistics Canada, 2017, 2023a) is used to identify the number of jobs present in each CT in the Montreal metropolitan region. The number of jobs in an area is often used in the accessibility literature as a proxy for the quantity and diversity of services and products that the area offers (El-Geneidy and Levinson, 2022); thus, representing the different opportunities that individuals seek to reach. The latest polygon shapefiles for Montreal's CTs were retrieved from the 2021 Canadian population census. The centroid for each polygon was then calculated to be used as a reference point for the CT. In some instances, the centroids would fall into inaccessible areas, such as water, mountains, or agricultural land. These centroids were then manually moved to the closest dense area in their corresponding CTs. The CCF tables provide the number of workers commuting between their home and work CTs. In 2021, numerous jobs relied entirely on telecommuting due to the COVID-19 pandemic, which may not accurately reflect the most recent circumstances. We determined that utilizing the 2016 CCF tables would provide a more representative depiction of the current situation, as many areas restored pre-pandemic activity even though telecommuting has become more ubiquitous (Anik and Habib, 2023; Javadinasr et al., 2022). The 2016 jobs (commuters arriving in the CT) were then proportionally fitted to the 2021 CT since some 2016 CTs were subdivided into multiple CTs in 2021.

The regional accessibility by public transit to jobs at the CT level was calculated using the number of jobs per CT, General Transit Feed Specification (GTFS) data, and OpenStreetMap networks. GTFS data was obtained from Transitland using an application programming interface (API) for October 2023, to match the public transit services at the time of collecting the MMS. The OpenStreetMap street network was obtained for the Montreal Census Metropolitan Region (CMA) through BBBike extracts. We used the r5r package in R with GTFS data and the OSM network for the Montreal CMA as inputs to calculate a travel time matrix (TTM) between CT centroids for every minute in a predefined period of the day (Pereira et al., 2021). This TTM represents the shortest travel time (TT) by public transit between each origin and destination (CTs) for a regular Wednesday travelling at any minute between 8 AM and 9 am, which is then averaged to account for schedule variability. The calculated TT includes access, egress, waiting, in-vehicle, and transfer times if applicable. To calculate the cumulative opportunities measure, the travel-time threshold was set to 45 min as it is closest to the mean TT by public transit in Montreal (Statistics Canada, 2023b) as suggested by Kapatsila et al. (2023).

3.2. Survey data

MMS is a bilingual longitudinal online survey that collects travel behaviour data as well as opinions on major transport projects in the region (Negm et al., 2023). Across four waves, the MMS has collected data about sociodemographic characteristics, attitudes towards transit, current and past travel behaviour, and residential self-selection. In this study, we use the fourth wave of the survey, which was conducted in October 2023. Any incomplete responses were dropped, and a thorough validation process enforced a set of exclusion criteria to eliminate unreliable responses. This process used participants' e-mail and IP addresses, the time they took to fill out the survey, the location pins or addresses they indicated for home, work and/or school, household structure, and age and height data for participants who filled out previous waves of the MMS. The fourth wave's recruitment resulted in a total of 5,277 complete and valid responses.

To link spatial data with survey data, calculated local accessibility (Walk Score®) was linked to each participant based on their postal code. Calculated regional accessibility by public transit was linked to the survey for each participant through the CT of their home location. Among the travel behaviour variables, the MMS asked the participants the number of trips they performed per week for work, school, shopping, healthcare, and leisure and which travel mode they used for these trips. There were four main travel mode categories: car, transit, walking, and cycling. To account for travel identity, participants were asked to identify the travel mode they associate themselves with. They were provided with the option to choose multiple modes (e.g., I consider myself as both a driver and a pedestrian). Finally, for perceived accessibility, participants were asked to evaluate the statement "(Travel Mode) is a suitable mode of travel for me to reach my desired destinations" on a 4-point Likert scale from strongly agree to strongly disagree. Walking is used as the travel mode for the local scale analysis, while public transit is the mode used for the regional scale analysis.

For both local and regional analysis, we only maintained participants whose weekly trip count fell within the range of four to thirty trips as we consider them mobile individuals for whom we can reliably calculate mode share percentages. For the regional scale analysis, we performed two additional inclusion criteria. Firstly, we included only participants who performed at least 50 % of their trips by car and/or transit. Secondly, we excluded those who identified only as pedestrians or cyclists as they are more concerned with local accessibility. In other words, participants can identify as pedestrians, but they must also identify as car and/or transit users to be considered in the analysis as those interested in regional accessibility. This filtering resulted in a final sample of 4,679 participants for the local level analysis and 2,985 participants for the regional level analysis.

3.3. Methods

The analysis in our study aims to examine the relationship between perceived accessibility and travel behaviour at the local and regional scale. We first conduct an exploratory analysis through scatterplots to visualize the relationship between calculated accessibility, perceived accessibility, and travel behaviour. We then investigate this relationship by estimating multiple linear weighted regressions at the local and regional scales to predict travel behaviour. To represent travel behaviour, we use the percentage of walking trips for weekly activities for the analysis at the local scale, whereas we use the percentage of public transit use for the analysis at the regional scale. The use of weighted regressions accounts for any sampling bias in the survey. The weighting is calculated for all valid responses using the anesrake R package (Pasek, 2018), which follows an iterative ranking process (DeBell and Krosnick, 2009). The weights were calculated to match the census-tract information of age, income, and gender obtained from Statistics Canada 2021 census (Statistics Canada, 2023a), which was retrieved through the cancensus R package (von Bergmann et al., 2021). We use a stepwise approach for the statistical modelling. In the initial regression models, we incorporate three sets of independent variables: sociodemographic factors, residential self-selection, and calculated accessibility. The second model introduces perceived accessibility as an additional variable. Finally, the third model builds on the second and controls for travel identity. We follow the same procedure for constructing the models at the local and regional scales using respective variables.

Table 1
Descriptive statistics by mean (standard deviation).

			Local (N = 4,679)	Regional (N = 2,985)
Travel Behaviour [Weekly mode share]	Public Transit	[%]	21.04 (25.97)	24.51 (29.55)
	Private car		43.32 (37.87)	60.83 (35.24)
	Walking		27.59 (27.37)	12.96 (14.81)
	Cycling		8.05 (18.81)	1.69 (6)
Sociodemographic	Gender	[1 = female]	0.51 (0.5)	0.54 (0.5)
	Age	[Years]	47.21 (16.61)	46.96 (16.73)
	Household income	[1 k CAD]	99.74 (57.41)	103.75 (56.72)
	Household size	[Persons]	2.42 (1.28)	2.58 (1.32)
	Employment	[1 = Full time]	0.57 (0.49)	0.6 (0.49)
Residential selection	Near transit	[1 = Imp, 0 = Unimp.]	0.72 (0.45)	0.65 (0.48)
	Move by car and park		0.48 (0.5)	0.59 (0.49)
	Walkable neighborhood		0.73 (0.45)	0.68 (0.47)
Calculated Accessibility	Accessibility by public transit within 45 mins	[10,000 jobs]	26.32 (24.5)	17.76 (21.74)
	Walk Score®	[0 to 100]	76.75 (22.13)	70.13 (22.76)
Perceived Accessibility […is suitable to reach desired destinations]	Public transit	[1 = Agree, 0 = Disagree]	0.65 (0.48)	0.52 (0.5)
	Walking		0.63 (0.48)	0.53 (0.5)
Travel Identity [I consider myself a…]	Transit user	[1 = Yes]	0.69 (0.46)	0.61 (0.49)
	Car user		0.65 (0.48)	0.79 (0.41)
	Both transit and car user		0.37 (0.48)	0.4 (0.49)
	Pedestrian		0.82 (0.38)	0.74 (0.44)
	Cyclist		0.39 (0.49)	0.28 (0.45)

4. Results and discussion

4.1. Descriptive statistics

Table 1 includes descriptive statistics of the data used in the models. For both local and regional groups, people perform less trips by walking or public transit than by car on average per week. For the regional group, as we have removed any participants whose weekly percentage of walking plus cycling trips constitute more than 50 % of their weekly trips, the mean for the weekly trips done through walking or cycling is significantly lower compared to transit or car. Despite the lower mode share of transit compared to car in that group, more participants stated that they chose to live in a neighborhood near transit rather than one where it is practical to move around by car. For both the local and regional group, on average, it is most important to live in a walkable neighborhood. Most of the local sample (82 %) identified themselves as pedestrians, while most of the regional sample (79 %) identified themselves as car users. For the statistical analysis, we converted the 4-point Likert scale used to measure perceived accessibility into a binary one. About 63 % of the local sample consider walking as a suitable mode for reaching their desired destination, while half of the regional sample perceive public transit as a suitable mode for the same purpose.

4.2. Contextual maps

The distribution of the home locations of the local and regional participants is displayed in Fig. 1and Fig. 2, respectively. The figures show the level of calculated accessibility in Montreal and the perceived accessibility of the survey respondents. In Fig. 1, calculated local accessibility is represented by Walk Score® for each postal code. In Fig. 2, calculated regional accessibility is represented by cumulative accessibility by public transit within 45 min of travel time for each CT. In both figures we observe little spatial correlation between perceived accessibility by walking (for the local group) or public transit (for the regional group) and their respective calculated accessibility. Some people living in high calculated accessibility areas perceive their accessibility levels to be low, and vice versa. We further examine this relationship through plots and statistical regressions.

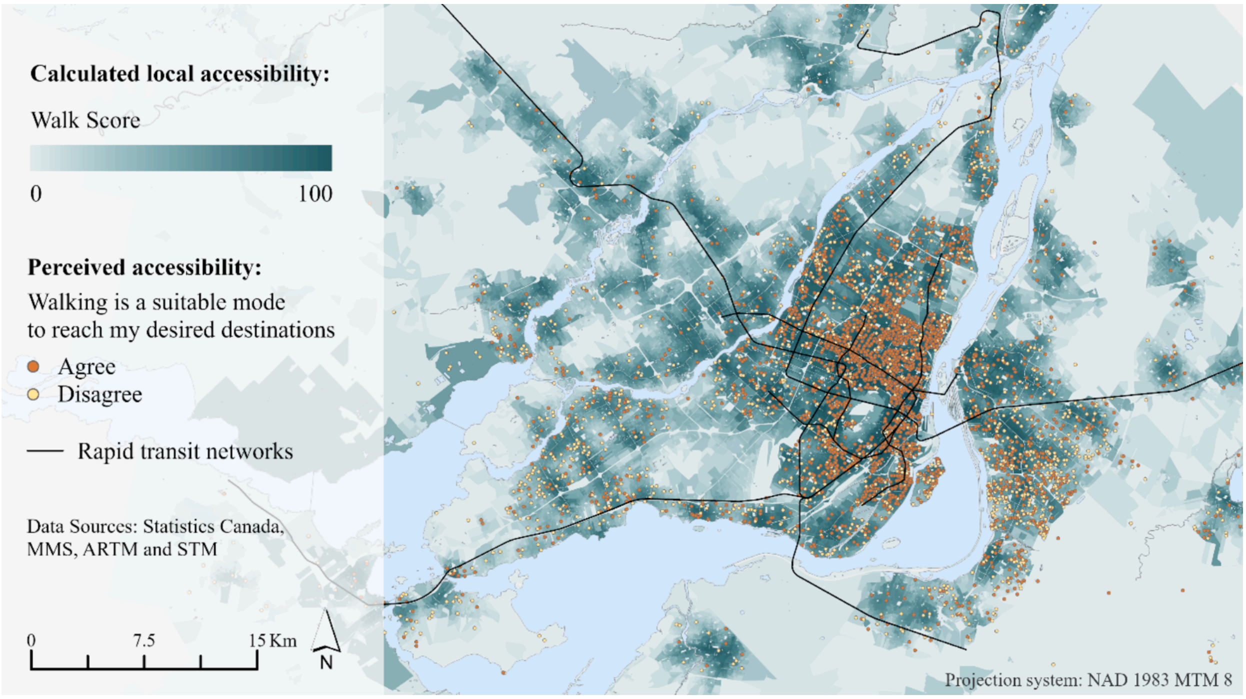

Fig. 1. Walk Score® and perceived accessibility by walking for 4,679 survey respondents.

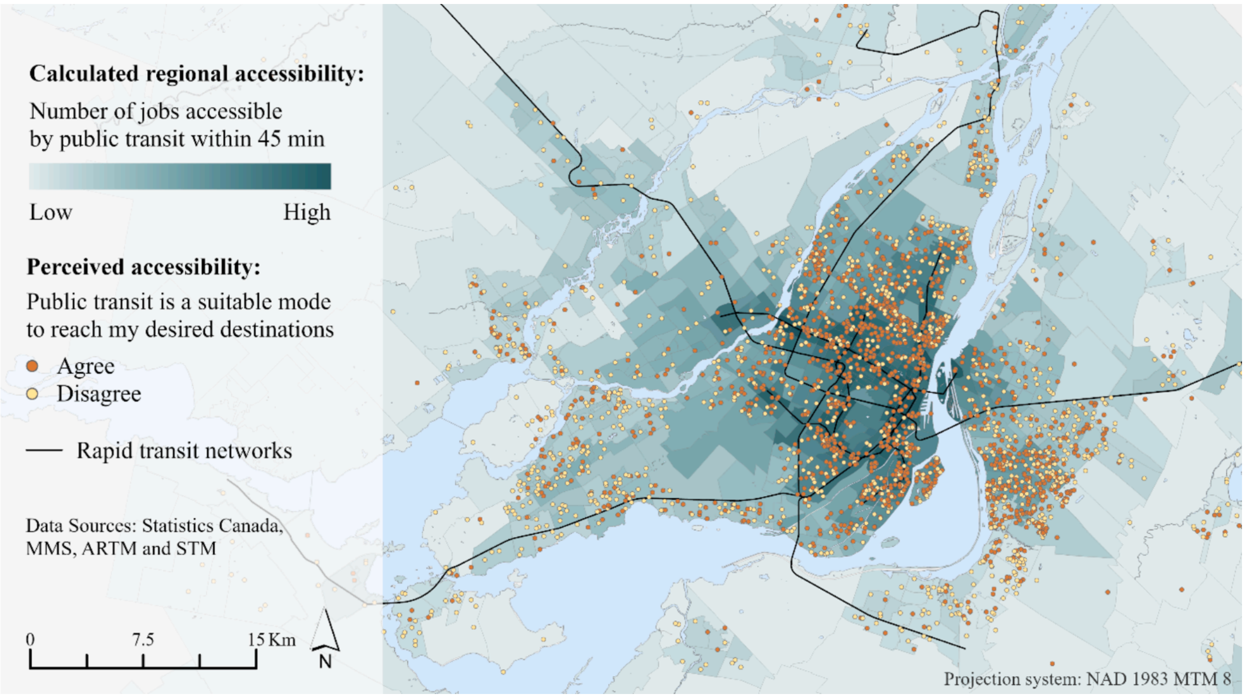

Fig. 2. Accessibility by public transit in 45 min at the CT level and perceived accessibility by public transit for 2,985 survey respondents.

4.3. Accessibility and travel behaviour

Exploratory plots at the local level are presented in Fig. 3and regional level in Fig. 4 providing an overview of the relationship between calculated accessibility (x-axis), travel behaviour (y-axis), and perceived accessibility (color). Each dot in the figure represents a survey respondent. According to the figures, there seems to be no direct relation between perceived and calculated measures of accessibility, which aligns with the mismatch found in previous studies (Pot et al., 2023a, b; Vafeiadis, 2024; Vafeiadis and Erik, 2024). We observed no clear correlation between transit or walking mode share and calculated measures of accessibility as in many instances people who walk or use public transit frequently resided in areas with low levels of accessibility. Meanwhile, we noted that pedestrians

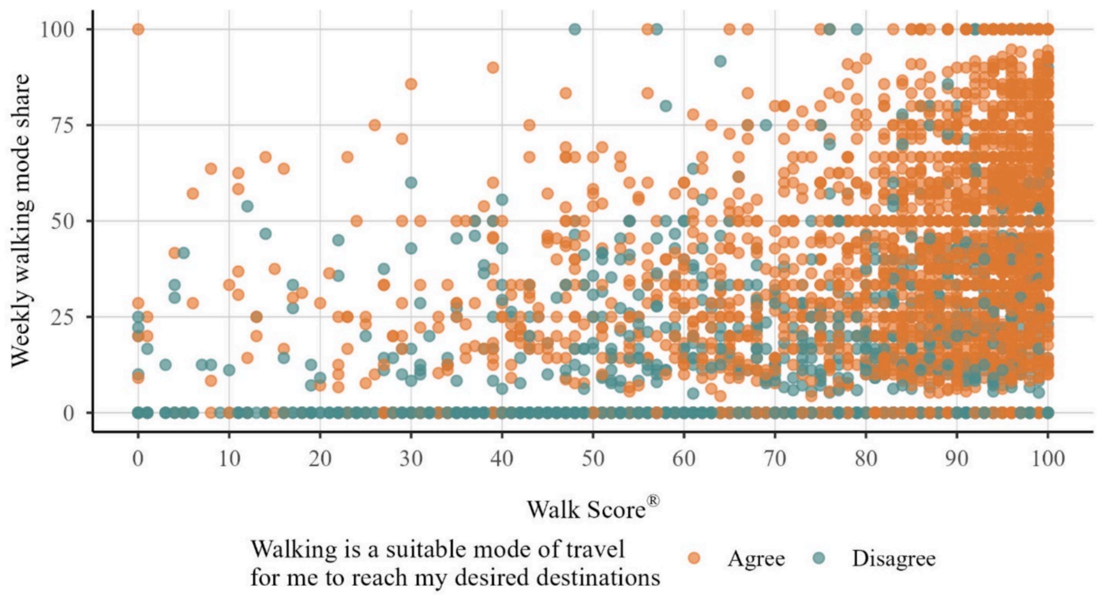

Fig. 3. Walk Score® and weekly walking mode share colored by perceived accessibility.

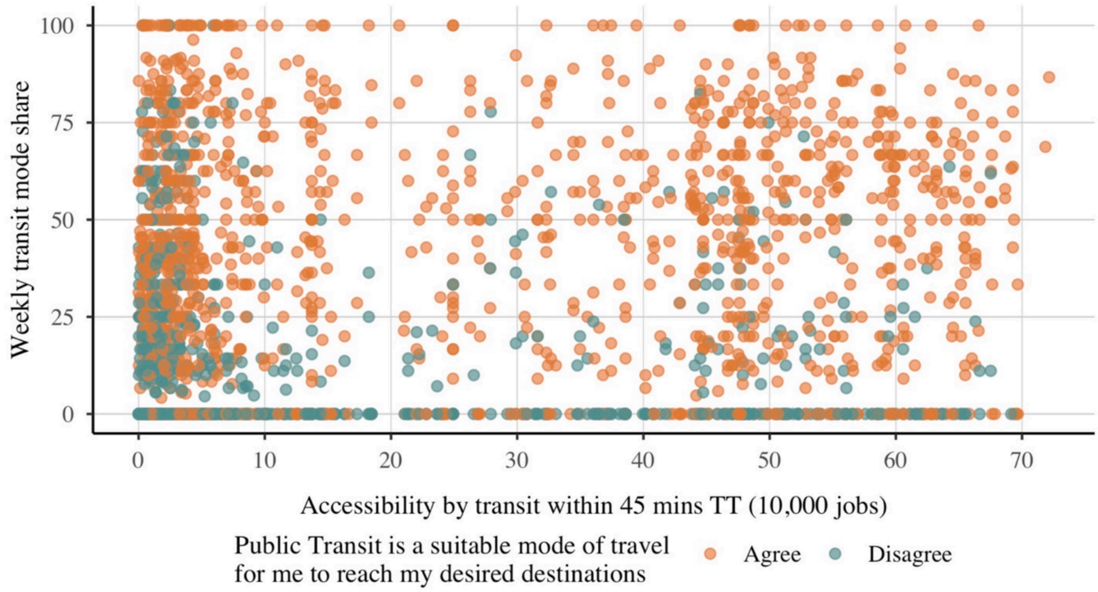

Fig. 4. Calculated regional accessibility and weekly transit mode share colored by perceived accessibility.

Table 2
Local level analysis: weekly walking mode share weighted linear regression model.

Variables	Model L1 Coef.	95 % CI	Model L2 Coef.	95 % CI	Model L3 Coef.	95 % CI
(Intercept)	0.46	−4.21, 5.13	−2.51	−6.91, 1.90	**−8.61** ***	−13.13, −4.08
Gender [1 = woman]	−0.11	−1.55, 1.32	−0.08	−1.44, 1.27	−0.02	−1.36, 1.32
Age	0.02	−0.02, 0.06	0.02	−0.02, 0.06	**0.04** *	0.00, 0.09
Income [1 k CAD]	**−0.03** ***	−0.04, −0.01	**−0.03** ***	−0.04, −0.02	**−0.03** ***	−0.04, −0.02
Household size	**−1.97** ***	−2.60, −1.35	**−1.52** ***	−2.11, −0.93	**−1.47** ***	−2.05, −0.88
Full time empl.	**−6.09** ***	−7.66, −4.53	**−6.04** ***	−7.51, −4.57	**−5.74** ***	−7.20, −4.29
RS walkable	**3.58** ***	2.86, 4.30	**2.14** ***	1.45, 2.83	**1.78** ***	1.10, 2.47
Walk Score®	**0.44** ***	0.41, 0.48	**0.33** ***	0.29, 0.36	**0.31** ***	0.27, 0.34
Walking is suitable			**18.72** ***	17.20, 20.24	**15.53** ***	13.91, 17.16
Ident: Pedestrian					**10.35** ***	8.32, 12.39
Observations	4,679		4,679		4,679	
R^2 / R^2 adjusted	0.207/ 0.206		0.296/ 0.295		0.310/ 0.309	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Table 3
Regional level analysis: weekly transit mode share weighted linear regression model.

Variables	Model R1 Coef.	95 % CI	Model R2 Coef.	95 % CI	Model R3 Coef.	95 % CI
(Intercept)	**68.25** ***	63.68, 72.82	**52.56** ***	47.96, 57.16	**36.65** ***	32.23, 41.07
Gender [1 = female]	−0.32	−2.14, 1.49	0.07	−1.64, 1.79	0.53	−1.04, 2.11
Age	**−0.66** ***	−0.72, -0.60	**−0.55** ***	−0.60, -0.49	**−0.41** ***	−0.46, -0.36
Income [1 k CAD]	**−0.06** ***	−0.07, -0.04	**−0.05** ***	−0.06, -0.03	**−0.05** ***	−0.06, -0.03
Household size	**−0.84** *	−1.59, -0.09	**−0.90** *	−1.61, -0.19	**−0.95** **	−1.60, -0.30
Full time empl.	**−8.16** ***	−10.11, -6.22	**−5.79** ***	−7.64, -3.94	**−4.25** ***	−5.95, -2.54
RS near transit	**12.25** ***	10.25, 14.25	**7.14** ***	5.18, 9.10	**1.92** *	0.08, 3.77
RS move by car	**−17.45** ***	−19.41, -15.49	**−13.73** ***	−15.62, -11.85	**−9.85** ***	−11.61, -8.09
Accessibility by transit in 45 mins	**0.15** ***	0.11, 0.20	**0.08** ***	0.04, 0.13	**0.07** ***	0.03, 0.11
PT is suitable			**18.78** ***	16.85, 20.70	**10.57** ***	8.68, 12.46
Ident: Transit user					**23.91** ***	21.94, 25.88
Observations	2,985		2,985		2,985	
R^2 / R^2 adjusted	0.343 / 0.341		0.415 / 0.413		0.508/0.506	

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

and frequent transit users hold a positive perception of accessibility, regardless of their calculated accessibility levels. On the contrary, individuals with a negative perception of accessibility tended to walk or take public transit less, even in areas characterized by very high accessibility levels, revealing a potential relationship between perceived accessibility and travel behaviour, which we further investigate through statistical analyses.

4.4. Statistical model and discussion

We further explore the relationship between calculated and perceived accessibility and travel behaviour using a stepwise regression approach. This approach allows for the systematic comparison between models by incrementally adding variables to evaluate their contributions to the model fit. It helps identify the most significant predictors of travel behaviour while controlling for potential confounding factors. The weighted linear regression models are reported in Table 2 for the local (L) analysis and Table 3 for the regional (R) analysis. The dependent variable in the local analysis is the weekly walking mode share per individual, while for the regional analysis, it is the public transit mode share.

For each analysis level, we run three statistical models. Models L1 and R1 include only sociodemographic, residential self-selection, and calculated accessibility variables. Models L2 and R2 include the perceived accessibility variable. Finally, Models L3 and R3 include a travel identity variable to account for the possible indirect relationship between perceived accessibility and travel behaviour.

Comparing the model fit (R^2) in the three models for each analysis level, Models L3 and R3 explain the highest variation in the dependent variable. We find that for each analysis level, these models are the one with the smallest ranges in the confidence intervals, particularly for the regional analysis. This shows that some of the variance caused by perceived accessibility and travel identity was captured by other variables in the other models. For these reasons, we will focus our discussion on these models. The findings of Models L3 and R3 validate our hypothesized relationship between perceived accessibility and travel behaviour.

In our models of interest, income, age, household size and residential self-selection followed the expected direction and statistical significance, which is similar to previous research (Buehler, 2011; Ha et al., 2020; Legrain et al., 2015). In the regional analysis, age has a negative and statistically significant impact on public transit mode share, keeping everything else equal. Every additional year decreases weekly transit use by 0.4 %, all else kept constant. This can be attributed to the progression in life stages that makes driving a more affordable and comfortable option, which is consistent with previous research (Grimsrud and El-Geneidy, 2014). Meanwhile, it has a positive but slight impact on walking mode share in the local level analysis. This suggests that as people grow older, they tend to make more of their daily trips by walking.

For every 10,000 CAD increase in income, the weekly walking mode share decreases by 0.3 % and public transit mode share decreases by 0.5 % ceteris paribus, according to L3 and R3, respectively. This aligns with previous research suggesting that higher-income households tend to depend more on driving than other transport modes (Buehler, 2011). Full-time employees make 5.74 % less walking trips and 4.25 % fewer trips using public transit compared to retirees, students, or homemakers, ceteris paribus. An increase in household size has a statistically significant negative impact on weekly walking and public transit mode shares, where it decreases by 1.47 % and 0.95 % for every additional person, respectively, keeping all other variables constant at their mean.

We account for residential self-selection to avoid overestimating the influence of the built environment on travel behaviour (Cao et al., 2009). The relationships between the relevant residential self-selection variables and travel behaviour were statistically significant. Based on the local model (L3), respondents who value residing in a walkable neighborhood tend to make 1.78 % more walking trips, holding all other variables constant. According to the regional model (R3), individuals who prioritize residing near public transit tend to use it for 1.92 % more of their trips compared to those who do not, keeping other variables unchanged. Meanwhile, respondents who find it important to be in a neighborhood where it is practical to drive and park make 9.85 % fewer trips using transit, keeping all else constant.

The impact of calculated accessibility on weekly walking and public transit mode shares decreases when we include the perceived accessibility and travel identity variables. However, it remains positive and statistically significant, similar to previous studies on local accessibility (Elldér et al., 2020; Manaugh and El-Geneidy, 2011) and regional accessibility (Cui et al., 2020; Moniruzzaman and Páez, 2012; Negm and El-Geneidy, 2024; Owen and Levinson, 2015). For every one-point increase in the Walk Score® index, the weekly walking mode share increases by 0.31 %, keeping all else constant. And for every 10,000 jobs accessible by public transit, the weekly public transit mode share increases by 0.07 %, keeping other variables at their mean value. This translates to 12.6 % weekly transit mode share for a person who can access 180,000 jobs in Montreal, which is the mean number of accessible jobs by public transit within 45 min for our regional sample.

Perceived accessibility has a positive and statistically significant impact on travel behaviour in L3 and R3, confirming the hypothesized relationship shown in the exploratory plot (Fig. 3 and Fig. 4). People who perceive walking to be a suitable mode to reach their desired destinations make 15.53 % more of their trips by walking compared to those who do not consider it as a viable mode of transport, keeping all else constant. Similarly, people who have positive perceived accessibility by public transit make 10.57 % more of their trips by public transit compared to those with negative perceptions, keeping all else constant.

The relationship between perceived accessibility and travel behaviour can be indirect. In these statistical models, we incorporate a binary variable based on the self-reported question “I consider myself a pedestrian” in the local model and “I consider myself a transit user” in the regional model to represent travel identity. This variable serves to address this indirect relationship concern and isolate the effect of perceived accessibility on travel behaviour. This approach is similar to accounting for residential self-selection when exploring how contextual factors tied to location (e.g., calculated accessibility) influence travel behaviour, as suggested in previous studies (Cao et al., 2009; van Wee, 2009). Including the travel identity variable allows us to account for individuals’ subjective preferences and better isolate the impact of perceived accessibility. Accounting for travel identity and attitudes is essential to avoid overestimating the effect of perceived accessibility on travel behaviour.

Previous frameworks hypothesize that travel behaviour is impacted by perceived accessibility (De Vos et al., 2023; Morris et al., 1979; Pot et al., 2021). Consistent with this theoretical background, our empirical findings confirm a positive and statistically significant relationship between the two variables. By drawing on strong theoretical foundations, accounting for confounding travel behaviour variables, and assuming temporal anchoring—where perceived accessibility precedes travel behaviour—we infer a causal relationship. However, we acknowledge that this relationship could also be bidirectional, with travel behaviour influencing perceived accessibility. Due to the limitations of our cross-sectional data, addressing this bidirectionality remains a challenge. Future studies employing panel data could better explore this possibility.

5. Conclusion

In this study, we examined the impact of perceived accessibility on travel behaviour, building upon previous research by Pot et al. (2021) and De Vos et al. (2023). We hypothesize that travel mode choice is impacted by multiple factors including individual characteristics, travel identity and attitudes, residential selection, calculated accessibility, and perceived accessibility. To validate this hypothesized relationship, we use a series of weighted linear regression models at the local and regional level to analyze the weekly walking and transit mode share, respectively, as the dependent variables.

The findings from the models confirm our hypothesis about the positive impact of perceived accessibility on weekly public transit mode share for all purposes, namely work, school, leisure, healthcare, and shopping. We find that individuals who agree that walking is a suitable mode to reach their desired destinations perform about 15 % more of their trips on foot. Similarly, those who find public transit suitable for their needs make about 10 % more of their trips by public transit compared to those who do not have the same positive perception of their accessibility levels. We control for travel identity in our final statistical models, which is crucial to avoid overestimating the influence of perceived accessibility on travel behaviour.

This research provides valuable insights for transport professionals aiming to promote the use of sustainable modes by highlighting the role of perceived accessibility in shaping travel behaviour. Our findings emphasize the importance of enhancing perceptions of walkability and public transit accessibility, particularly in regions with high accessibility levels. Planners and policy makers should aim to address how infrastructure improvements are communicated and perceived by the public. Enhancing the perception can be achieved through conducting advertising campaigns introducing the existing services to those residing in areas characterized by high levels of accessibility. Campaigns like car-free day, which include free public transit use, can be used as a tool to change the perceived accessibility as non-users will be encouraged to use public transit for that day for societal and environmental purposes. Similarly, this can be applied during large events to reduce the pressure on the transport network and introduce walking and public transit as viable alternatives. Improving first- and last-mile connectivity, through investments in the microscale-built environment around transit stops, can encourage residents to explore their areas and improve their perceived accessibility; thus, encouraging active travel and public transit use. Leveraging technology and real-time data to provide intuitive, user-friendly public transit interfaces can further improve perceptions of accessibility and attract more users to sustainable travel modes (Pot et al., 2023b). Future research can delve deeper into the demographic construct of perceived accessibility as understanding how it varies across different groups can help develop equitable policies that prioritize underserved communities.

While our findings provide evidence of the positive and statistically significant impact of perceived accessibility on travel behaviour, the cross-sectional nature of our data limits the ability to confidently establish time precedence, thereby hindering the examination of bidirectional relationships between the two constructs. Future research can explore the constructs of perceived accessibility and the possible bidirectional relationship with travel behaviour in more detail through advanced statistical methods such as structural equation modelling (SEM). However, it is important to note that while SEM can offer insights into complex relationships, it has certain limitations, including the need for a large sample size and detailed measures for latent constructs. Additionally, the complexity of SEM models can present challenges in interpretation and communication with broader audiences. Future studies can also utilize panel data that collects travel behaviour, perceived accessibility, travel attitude, and sociodemographic information from the same participants overtime allows for longitudinal analysis that reveals details about the changes in these constructs, facilitating the confirmation and validation of causal relationships and helps explain discrepancies between calculated and perceived accessibility. Although we focus on the local and regional scale in Montréal, our study can be replicated in other contexts to confirm our evidence and at different scales such as national and international levels. The national and international scale of perceived accessibility can be collected to measure its impacts on mode choices between rail and car when traveling between cities and countries where the travel time is short and such modes are competitive.

CRediT authorship contribution statement

Hisham Negm: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Ahmed El-Geneidy:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to

influence the work reported in this paper.

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Data availability

The data that has been used is confidential.

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