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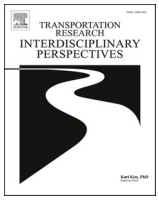

Examining the influence of personal-time-based accessibility on the frequency of public transit use among older adults across Canada

Meredith Alousi-Jones, Ahmed El-Geneidy *

School of Urban Planning, McGill University, 815 Sherbrooke St. West, Montreal H3A 0C2, Canada

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ABSTRACT

Many older adults face the prospect of driving cessation as they age. Ensuring that public transit services meet their needs could contribute to their independent mobility and long-term health. Accessibility, the ease of reaching destinations by a certain mode, is a measure that can be used to indicate how well the land use and transport systems allow people to reach their desired destinations. This paper explores how perceived and objective levels of accessibility influence older adults' frequency of public transit use in a Canadian context. Based on a survey collected in six Canadian regions (N = 2,452), we use respondents' stated reasonable travel time by public transit to generate a personal-time-based cumulative accessibility measure. We then develop a weighted binary logistic regression model to understand the impacts of the personal-time-based accessibility measure, perceived accessibility, and other personal characteristics on older adults' frequency of public transit use. The results indicate that both perceived and personal-time-based accessibility have a strong and positive impact on frequent public transit use. Older women were found to be more frequent public transit users, whereas older adults who have access to a private vehicle use public transit significantly less. Findings from this research support the utilization of accessibility by public transit as a tool to better assess and plan for the transport needs of older adults. The results can be relevant for transport planners and policy makers interested in improving the well-being and independence of older adults through increasing their use of public transit.

1. Introduction

Older adults can experience a decrease in mobility due to age-related milestones, such as retirement or residential relocation (Shrestha et al., 2017; World Health Organization, 2021). They tend to make fewer and shorter trips and rely on private vehicles to get around, especially in the North American context (Newbold et al., 2005; Spinney et al., 2009; Wasfi & Levinson, 2007). However, as driving cessation becomes more prevalent with age, older populations can lose independence, directly impacting their health and well-being (Choi & DiNitto, 2016; Mezuk & Rebok, 2008; Musselwhite & Shergold, 2013). Older adults represent an increasingly significant proportion of the world population (World Health Organization, 2021), and taking into account their changing transport needs and specific concerns is of particular importance to ensure their long-term well-being. Providing older adults with adequate transport alternatives, such as public transit, can help prevent social isolation and ensure they can maintain their independence as they age (American Psychological Association, 2021; Spinney et al., 2009; World Health Organization, 2018).

However, public transit is not always evenly supplied. There can be large gaps in service provision between large and smaller urban areas, or urban and rural areas (Diab et al., 2020; Miller et al., 2018). Moreover, public transit has generally been planned around the journey to work, optimizing the network and service to get people in and out of the Central Business District (CBD) at peak commuting hours (early morning and late afternoon), and might not be adapted to older riders' needs.

Accessibility, the ease of reaching destinations, is a measure that links transport and land use, quantifying the relationship between the spatial distribution of a region's opportunities (i.e., land use) and the transport system's expansiveness and level of service (El-Geneidy & Levinson, 2006; Geurs & Van Wee, 2004; Handy, 2020). The straightforward measure helps evaluate the efficacy of a system in getting people to their destinations and identify areas for improvement or underserved population groups (Ravensbergen et al., 2022; Salomon & Mokhtarian, 1998). This is particularly relevant for older adults, as they can experience disparities in levels of accessibility by public transit, especially during the off-peak hours (Choi et al., 2021; Ravensbergen et al., 2022). Though accessibility is gaining ground in practice, less is

* Corresponding author.
E-mail addresses: meredith.alousi-jones@mail.mcgill.ca (M. Alousi-Jones), ahmed.elgeneidy@mcgill.ca (A. El-Geneidy).

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known about older adults' particular travel needs and how they experience and understand accessibility by public transit.

An individual's travel behaviour also depends on their preferences, perceptions, capabilities, and characteristics, as well as the resources they consider having at their disposal (Scheiner & Holz-Rau, 2007; Semanjski, 2023; Van Acker et al., 2010). When applied to accessibility, these individualities can give insight into why providing people access to a large number of opportunities by public transit (i.e., increasing their level of objective accessibility) does not, alone, translate to them travelling with it to all these activities (Pot et al., 2021). For example, people might prefer to travel for shorter or longer times by public transit, which could impact their relative ease of reaching destinations around them. Moreover, people might perceive having poor or no access to certain destinations by public transit due to, among other reasons, lack of familiarity with the public transit network in their region or of transit-related skills (Cochran, 2020; Durand et al., 2024). This could lead to them choosing alternative modes of transport, regardless of their objective levels of accessibility by public transit (Curl, 2018; Lättman et al., 2016). To evaluate how well the current land use and public transport system meet older adults' needs, temporal and individual components of accessibility, though more challenging to incorporate at a large scale, could augment the measure by accounting for time constraints and personal characteristics (Geurs & Van Wee, 2004; van der Vlugt et al., 2019). This finer understanding of how older adults are impacted by varying levels of accessibility could lead to more effective encouragement of their public transit use and active, healthy aging.

This study aims to provide insights into the impacts of measured and perceived measures of accessibility on the frequency of public transit use among older populations in six metropolitan regions across Canada. This study is based on the Aging in Place survey (Alousi-Jones et al., 2023), which collected travel behaviour and transport needs, as well as extensive sociodemographic and attitudinal details, of 3,551 older adults (65 +) from six Census Metropolitan Areas (CMA): Toronto, Montréal, Vancouver, Halifax, Victoria and Saskatoon. The results from this study could help transport planners and policy makers better understand the effects of accessibility on older adults' frequency of public transit use, reducing their reliance on automobiles and having a positive impact on their health and well-being.

2. Literature review

Transport plays a key role in older people's ability to remain mobile and socially engaged, contributing to their health and so-called successful aging (Goins et al., 2015; Levasseur et al., 2015; Rowe & Kahn, 1997). Driving cessation can therefore be a deeply impactful transition in older adults' life, especially in car-centric areas such as North America. Many older adults rely heavily on private vehicles to get around (Böcker et al., 2017), but as they advance in age, they may self-regulate their driving in more challenging conditions such as no longer driving at night or during peak commuting hours (Musselwhite & Shergold, 2013; Truong & Somenahalli, 2015). This reduction in automobility can make them reliant on friends and family to get around or even prevent them entirely from meeting their travel needs (Choi & DiNitto, 2016; Delbosc & Currie, 2011; Jones et al., 2018; Luiu et al., 2016; Mezuk & Rebok, 2008). It is important that alternative modes of transport such as public transit allow them to access their desired destinations and maintain their independent mobility as they age (Mollenkopf et al., 2017).

Though a widespread preference for the car remains, older adults who have, among other supports, access to adequate public transit options are more capable of meeting their essential transport needs (Alsnih & Hensher, 2003; Coughlin, 2001). Incidental walking related to public transit use can improve older adults' level of physical activity and health (Davis et al., 2011; Twardzik et al., 2023). Older adults who use public transit more frequently tend to assign importance to the proximity of their home to transit services and believe to have favourable walking distances and conditions to their closest stops and stations (Moran et al., 2014; Truong & Somenahalli, 2015), showing the importance of "*easy access*" to their public transit system in explaining public transit use (Hjorthol, 2013).

Past research shows that increases in accessibility by public transit (to jobs/destinations using public transit) can lead to a higher public transit mode share (Cui et al., 2020). However, there still exists a lack of consistency in how this measure is calculated (Carmona & Sieh, 2008; Chen et al., 2021; Cheng et al., 2021; Chihuri et al., 2016), as well as how it impacts different groups' travel behaviour (Choi et al., 2021). More particularly, little is known about older adults' specific needs and lived experiences, and how well regular public transport serves them, especially in the Canadian context. Even when accessibility for older adults is explored in research, the destinations that are most commonly considered in the calculations (i.e., healthcare facilities and greenspace) are often chosen without an explicit rationale, making it difficult to compare to other studies or to draw any sound policy recommendations (Chen et al., 2021; Collia et al., 2003; Cui & El-Geneidy, 2019; Deboosere & El-Geneidy, 2018; Ermagun & Tilahun, 2020; Fordham et al., 2017; Geurs & van Eck, 2003). Similar shortcomings are also present in what modes of public transit are considered when calculating accessibility in a region (Chihuri et al., 2016; Collia et al., 2003; Cui et al., 2020).

Individuals' perception of their level of accessibility, or perception of one's ability to access opportunities, can have a significant and positive impact on their public transit use (Haustein & Siren, 2014; Ryan & Pereira, 2021). However, older adults have been found to experience lower levels of both objective accessibility and perceived accessibility by public transit (Choi et al., 2021; Ravensbergen et al., 2022). Older adults' use of public transit can impact their perception of the mode (Lättman et al., 2016). If they perceive their public transit service as inconvenient and maladapted to their travel needs and abilities, it is more likely they will not or will rarely use the mode (Panahi et al., 2022; Shrestha et al., 2017). On the other hand, perceptions don't always match behaviour however, and older adults can remain quite satisfied with their ability to get around though their actual level of mobility has declined (Boschmann, 2020). This variability in results points towards the need for more research exploring the differences between perceptions and travel behaviour among older populations.

In addition to individual perceptions, measuring accessibility for certain subsets of older populations is complex, as it requires accounting for diverse needs, abilities, and travel behaviours (Haustein, 2012; Hjorthol, 2013). For example, people with mobility limitations or disabilities face unique challenges accessing public transit, during the journey, and reaching their destination (Achuthan et al., 2010; Kapsalis et al., 2024). Their (mainly physical) needs have primarily been addressed in transport research by modifying established accessibility measures, such as using a lower walking speed or accounting for the universal access features of transit stations in travel cost functions (Ravensbergen et al., 2022). Few studies have directly examined how the use of assistive devices such as wheelchairs impact the accessibility of people with disabilities (Achuthan et al., 2010; Ferrari et al., 2014; Grisé et al., 2019). Older adults with disabilities have unique preferences and attitudes towards public transit, which are not easily captured by conventional accessibility measurements. They may use specific strategies to navigate their environment and manage their daily travel, but this self-regulation can lead to undue stress and leave many of their needs unmet (Cochran, 2020; Mwaka et al., 2024; Ravensbergen et al., 2022). Though certain support services can be available at the regional and community level to assist them in their daily travel (i.e., paratransit, community-based transport services, neighbourhood carpooling, etc.) (Hjorthol, 2013; Hosford et al., 2024), these services are dependent on inconsistent governing priorities and funding in Canada, making them much harder to access for people with disabilities in general (Grisé et al., 2019).

To ensure public transit systems are adapted to older adults' needs, a

greater examination of how accessibility and individual factors impact this group's public transit use is needed (Gascon et al., 2020; Pot et al., 2021; Truong & Somenahalli, 2015). This paper aims to delve deeper into the impact of this relationship on not only public transit use, but on the frequency of use among older adults in a Canadian context.

3. Methods

3.1. Study context

This study is conducted across six Canadian Census Metropolitan Areas (CMAs), Toronto, Montréal, Vancouver, Halifax, Victoria, and Saskatoon (Fig. 1), chosen in part due to them having relevant publicly available data and reflecting interesting regional differences. The three larger CMAs, Toronto, Montréal and Vancouver, are the most populous cities in Canada and have extensive and well-used public transit networks, which all include light rail (subway, metro and Skytrain, respectively). The smaller three CMAs, Halifax, Victoria and Saskatoon, have populations of less than 500,000 people, and their public transit networks rely mainly on buses. While all six cities offer paratransit services, variations in eligibility requirements and operational practices result in large differences in service quality for older adults with disabilities, therefore paratransit services were not incorporated in our analysis. Victoria has the highest proportion of older adults of the six cities, with 23.4 % of the population aged 65 or older (according to the 2021 Canadian Census). Table 1 further contextualizes the study locations.

3.2. Data collection

The data used in this study comes from the 2023 Aging in Place Survey, administered by the Transportation Research at McGill (TRAM) team in February and March 2023. This is a comprehensive online bilingual survey that captures public transport and daily travel experiences and needs of older adults (aged 65 and over) across the six Canadian CMAs. As recommended by Dillman et al. (2014), multiple recruitment methods were applied such as distribution of fliers at senior and community centres, social media advertising, senior centre mailing lists, advertisement through a press release and conducting several radio, TV and publishable news interviews, and recruitment through Léger, a firm specialized in public opinion and surveys. Various prizes were offered through a draw once data collection was completed to encourage participation in the survey. After the data collection was finalized, a nine-step cleaning process was applied to the sample. We first filtered out any response that was incomplete and where the respondent was under 65, or over 95. If more than two surveys were submitted with the same IP address (which we considered as two people living in the same household), all observations with that IP address were removed. Similarly, if more than one survey was submitted using the same email address, the observations in question were dropped. The process also excluded responses that reported an invalid home or trip destination location (home location outside the CMA, or on water or a bridge, outside the CMA for public transit trip destinations, and outside the province for car trip destinations). The final cleaning step excluded respondents who filled out the survey too quickly, i.e., in the top 2.5 % of speed for their particular sequence of questions. The final sample, after data cleaning and validation was 3,551 respondents (Alousi-Jones et al., 2023). A weight was generated using the *anesrake* R package (Pasek, 2018) for all responses based on age, gender, and income using the 2016 Canadian Census (von Bergmann et al., 2021) to ensure the findings from the final dataset are representative of the older adult population in each region.

3.3. Personal-time-based accessibility

In this study we propose a new personal-time-based (PTB) accessibility measure. This measure combines cumulative opportunities accessibility, given the measure's straightforward calculations and communicability, with acceptable travel time by public transit for every respondent from the survey. Respondents, regardless of how frequently they use public transit, were asked:

*In your opinion, what would a **reasonable travel time** to reach your desired destinations from your home by public transit in your region?*

10 minutes or less … 60 minutes or more (in 5-minute increments)

This reasonable travel time threshold was then used as the base to calculate a cumulative opportunities measure of accessibility for every

Fig. 1. CMAs selected for this research (Toronto, Montréal, Vancouver, Halifax, Victoria, Saskatoon).

Table 1
Context-specific characteristics of the six studied CMAs (from the 2021 Canadian Census).

	Toronto, Ontario	Montréal, Québec	Vancouver, British Columbia	Halifax, Nova Scotia	Victoria, British Columbia	Saskatoon, Saskatchewan
Population [persons, 2021]	6,202,225	4,291,732	2,642,825	465,703	397,237	317,480
Population Density [pop/km^2, 2021]	1050.7	919	918	64	571.3	54.1
Older pop. [% of total population, 2021]	16.2 %	18.0 %	17.4 %	17.4 %	23.4 %	14.8 %
Public transit options	Bus, Light rail (subway), Commuter train, Streetcar, Paratransit	Bus, Light rail (metro, REM), Commuter train, Paratransit	Bus, Light rail (SkyTrain), Commuter train, Ferry, Paratransit	Bus, Ferry, Paratransit	Bus, Ferry, Paratransit	Bus, Paratransit
65 + fare for monthly pass (Winter 2023)	$128.15 CAD	$58.00 CAD	$59.95 CAD	$60.00 CAD	$45.00 CAD	$29.00 CAD

survey respondent with a varying travel time threshold (personal-time-based accessibility). This choice was made to better represent how older adults assess their travel preferences and abilities, reflected in the use of their chosen reasonable travel time to calculate their corresponding level of accessibility by public transit, rather than using a generalized travel time threshold.

Cumulative opportunities measures estimate the number of activities reachable by a specific mode from any given point in a fixed travel time threshold (El-Geneidy & Levinson, 2006). To calculate the personal-time-based accessibility measure for each respondent, we obtained the Commuting Flows Tables from the 2016 Canadian Census (the most recent census not impacted by the COVID pandemic) and General Transit Feed Specification (GTFS) data for each region in 2023. The Commuting Flow tables contain information about the number of workers travelling between their home census tract (CT) and their work CT. The number of commuters travelling to a CT for work was approximated as the number of jobs available at each CT, and was then used as a proxy for the number of destinations available in that CT. The GTFS data used includes the schedules, fares, geographic transit information, arrival predictions, and vehicle positions provided by each region's public transport agencies for a given date in 2023. This data was processed in the R statistical software using the r5r package (Pereira et al., 2021). The r5r package calculates transit travel times, taking into consideration the time to reach the stop/station, wait time, in-vehicle time, and time to reach the destination, and the corresponding level of accessibility on a given date at a given time. In this study, Tuesday, February 14th, 2023, between 10 AM and 11 AM was selected to ensure an appropriate comparison between the respondents and to align the GTFS data (e.g., schedules, available routes) with the period in which the survey data was collected. It is important to note that a 10 AM departure time was chosen as older adults are found to travel outside of peak hours (Ravensbergen et al., 2022), and this time was the most reported in the travel diaries collected in the survey. Previous research has also found that using one travel time is adequately representative of accessibility levels throughout the day (Boisjoly & El-Geneidy, 2016). To account for variation in the transit schedules within the studied hour, accessibility was calculated for every minute between 10 and 11 AM and the median calculated level of accessibility was used. Using the respondents' home location (approximated at the centroid of their respective CT to match the commute flow data), the number of jobs (i.e., destinations) available in each CT and the GTFS data, the personal-time-based accessibility is calculated for each respondent according to their stated reasonable travel time as follows:

$$PTBA_{jobs,i} = \sum_{j=1}^{J} E_j f(t_{ij}) where f(t_{ij}) = \begin{cases} 1, & t_{ij} \leq t_{reasonable} \\ 0, & t_{ij} > t_{reasonable} \end{cases}$$

Where:

$PTBA_{jobs,i}$ = personal-time-based accessibility to jobs from origin census tract i (i.e., respondent home location).

E_j = number of jobs in destination census tract j

$f(t_{ij})$ = a dichotomous function to determine whether jobs in census tract j are reachable by census tract i.

t_{ij} = travel time by public transport between 10 AM and 11AM between census tracts i and j

$t_{reasonable}$ = stated reasonable travel time being used as the travel time threshold specific to each respondent

In this paper, jobs are used as a proxy for services and activities older adults seek to reach in their daily life, an assumption that has been made used in previous research (Ravensbergen et al., 2022). We assume, based on the Census flows, that the total number of commuters traveling to a CT from their home CT is a good indicator of the number of jobs located in that destination CT. These jobs can therefore represent destinations/services/activities that someone may want to access. In the context of this study, we are considering the number of jobs in a CT to be representative of the activities older adults may want to access in that CT. One could argue that considering the total number of potential destinations (i.e., jobs) is not relevant for older adults, who may access more service- or medical-related activities. Past literature has found that considering all jobs versus only certain types of jobs such as healthcare or services when calculating cumulative accessibility led to quasi-identical conclusions (Rodrigue et al., 2023). To confirm these results for this study, we also chose to rerun the final models using only certain job types that may be more associated to older adults. Basing ourselves on the National Occupational Classification (NOC) 2016, we elected to retain jobs in classes 3, 4, 5, and 6 (3 – Health occupations, 4 – Education, law and social, community and government services occupations, 5- Occupations in art, culture, recreation and sport, 6 – Sales and service occupations) (Statistics Canada, 2017). The results of the models using all jobs and using this subset of jobs were found to be almost identical (see appendix). We did not want to introduce bias into our accessibility calculations and limit the types of opportunities to those we assume older adults may want to access in their region, and therefore chose to report the measures generated from all jobs.

3.4. Perceived accessibility

To better understand older adults' perceptions of their accessibility, in the Aging in Place Survey (Alousi-Jones et al., 2023), respondents were asked if they believe they can reach specific types of destinations by public transit in their stated reasonable travel time:

To my knowledge, if I chose to use it, the public-transit system around my house.

COULD get me to the following destinations in a ***reasonable time*** *from my home:*

Please choose the appropriate response for each item:

	Yes	*No*	*I don't know*

(*continued on next page*)

(*continued*)

	Yes	*No*	*I don't know*
Work/volunteering			
Grocery store			
Visiting friends and/or family			
Medical appointment			

The four trip purposes (i.e., destinations) that were retained for this analysis are work, groceries stores, visiting friends and family, and medical appointments. This survey question was asked to all respondents, regardless of whether they use public transit to access these destinations, or go to these destinations at all, as we want to capture the impact of perceptions of accessibility to different destinations on the frequency of public transit use. Those who answered "I don't know" to any of the included destinations were combined with those who said "No", resulting in four binary variables.

3.5. Weighted binary logistic regression model Development

To explore what factors influence older Canadians' frequency of public transit use, we develop a weighted binary logistic regression model. We include variables related to measured and perceived accessibility, personal and household characteristics, and home selection considerations, retained from the survey responses. The dependent variable, i.e., frequency of public transit use, is an ordered categorical variable based on the frequency at which survey respondents reported using public transit in their region in the past 12 months. In the survey question, this frequency ranges from every day, five to six times a week, two to four times a week, once a week, twice a month, once a month, a couple of times a year, to never. Given the inequal temporal distances between the frequency categories, we first developed a weighted ordered probit model where we grouped the dependent variable into three categories; frequent transit use (use of transit once a week or more), non-frequent transit use (use of transit less than once a week), and non-use (not having used public transit in the last 12 months). However, we did not find a statistically significance difference between non-use and non-frequent transit use, which led us to combine them into one group. We moved on to a weighted binomial logit model, where the dependent variable was represented by two groups, frequent transit use and non-frequent transit use. Some transformations to the variables were done to simplify the analysis, such as categorizing income to be a binary variable (i.e., less than $60,000 CAD, or $60,000 CAD and more). Given certain region-specific characteristics such as quality of the public transit networks and size of the population, we opted to test the region's relevance in many ways, including adding it to the model as a factor variable, as dummy variable, and testing multilevel models. Unexpectedly, in all our tested models, region did not have a statistically significant impact on older Canadians' frequency of public transit use, and the variable was therefore omitted from the final model. However, we acknowledge that being able to reach 10,000 jobs in Saskatoon (total of 127,285 available jobs) vs. Toronto (total of 2,558,250 available jobs) does not represent the same level of public transit accessibility. We therefore decided to normalize the PTB accessibility for each respondent by the total number of jobs available in their region. This variable will be interpreted as the percentage of jobs in a region that is reachable from an older adult's home based on their reasonable travel time threshold by public transit. Finally, the data used in the final model is weighted based on gender, age and income from in the 2021 Canadian census, to ensure the results are more generalizable to the population in each of the studied regions.

4. Results and discussion

4.1. Descriptive Statistics

The mean values and proportion of the variables of interest of the survey sample are presented in Table 2. Though the full collected and validated sample amounts to 3,551 respondents, further cleaning was necessary for the purpose of this study, such as excluding those who did not choose to specify their household income or who did not participate in the choice of their residence (to account for self-selection biases), meaning the final sample used in this paper is comprised of 2,452 responses. Referring to Table 2, we can see that a large portion of the respondents never (25.8 %) or seldom (36.7 %) use public transport in their region, whereas around 37.4 % of the sample indicated they use public transit once a week or more.

Having asked in the survey what the respondents considered a

Table 2
Summary Statistics.

Variable		Percentage of the sample (N = 2,452)
Frequency of public transit use in the past year	Once a week to everyday	37.4 %
	A couple of times a year to twice a month	36.7 %
	Never	25.8 %
Mean reasonable public transit travel time in minutes (Standard deviation)		31.6 (12.1)
Mean normalized PTB accessibility in stated reasonable travel time in % of region's total number of jobs (Standard deviation)		5.5 (9.9)
Perceives having public transit access to…	Work/Volunteering	47.80 %
	Grocery stores	66.00 %
	Visiting friends and/or family	43.70 %
	Medical appointments	60.10 %
Personal characteristics		
Mean age in years (Standard deviation)		72.2 (5.2)
Gender	Man	46.40 %
	Woman	53.60 %
Region of residence	Toronto	27.20 %
	Montréal	41.10 %
	Vancouver	17.20 %
	Halifax	4.20 %
	Victoria	8.40 %
	Saskatoon	1.90 %
Number of household members	1	39.60 %
	2	51.50 %
	3 to 7	8.90 %
Household income	Lower income (less than $60 k)	47.10 %
	Other income (more than $60 k)	52.90 %
Work Status	Retired	84.50 %
	Homemaker	2.00 %
	Full time worker	6.10 %
	Part time worker	9.30 %
	Volunteer	7.10 %
	Student	0.60 %
Living with a disability which impacts their mobility		29.70 %
Has access to a private vehicle		74.50 %
Aware that they are eligible for a reduced (65 +) transit fare		64.70 %
Selected home location to be close to public transit		72.10 %

reasonable public transit travel time to reach a desired destination in their region, we find a mean travel time of 31.6 min, with a standard deviation of 12.1 min. This variation could be due to differences in region size, the expansiveness of the public transport network, as well as variation in destinations respondents consider when choosing their threshold. The mean normalized level of accessibility in this stated reasonable travel time (specific to each individual), meaning the percentage of their region's total jobs accessible from their home location by public transit in the travel time they specified, is 5.5 % of total jobs, with a standard deviation of 9.9 % of total jobs. This considerable variation is due to the difference in area and population size across the six studied regions, and therefore the number of available jobs/destinations and public transit service provision. In terms of respondents' perception of their accessibility to various destinations by public transport in their reasonable travel time, the destinations with the highest perceived accessibility are grocery stores, followed by medical appointments. Work and volunteering and visiting friends and family were not perceived to be very accessible by public transit. For work, this could be due to an overwhelming majority of survey respondents being retired (84.4 %). Moreover, friends and family's residences would tend to be more spatial dispersed when compared to grocery stores and medical appointments, contributing to older adults' poorer perception of their accessibility. Due in part to the survey sampling methods, a large portion of the respondents live in the Greater Montréal region. The mean age of the sample is 72.2 years old, with a standard deviation of 5.2 years, and 53.6 % of the sample are women. Due to their small sample size, genders other than man and woman were excluded from this analysis. Only 15.4 % of the sample work full-time or part-time. Most households are comprised of two people (51.5 %), and 46.9 % of households surveyed have a yearly income of $59,999 CAD or less. Only 64.6 % of the sample states knowing of the existence of a reduced (65 +) transit fare in their region, though older adults in all six cities are eligible for a reduced transit fare. More than a quarter of the sample (29.7 %) identifies as having a disability which impacts their mobility. Close to 75 % of the respondents have access to a private vehicle and 72 % of respondents selected their current home location in part for its proximity to public transit.

4.2. Perceived accessibility

For perceived accessibility, we plotted the respondents' normalized personal-time-based accessibility against their frequency of public transit use over the past year, shown in Fig. 2. The x-axis represents the percentage of total jobs in the respondent's region they have access to by public transit in their stated reasonable travel time (PTB accessibility). In each plot, survey respondents are represented by a point, coloured grey if they reported not perceiving to have access to that particular destination type in their stated reasonable travel time, and yellow if they agreed to having public transit access to it.

Across all four destinations, it is clear that those who never or seldom use public transit do not perceive as having good public transit accessibility to these destinations. This perception matches their level of accessibility, which tends to be lower. On the other hand, those who use public transit more frequently perceive as having good accessibility to these destinations, even if their level of accessibility is objectively lower, as shown by the high concentration of yellow points in the higher frequencies (respondents in agreement) even towards the lower end of the accessibility scale for all four destinations.

This suggests that perceived accessibility impacts older adults' use of public transport. Respondents who use public transit frequently have a higher level of perceived accessibility by public transit to the four relevant destinations compared to those who never or rarely use it, all

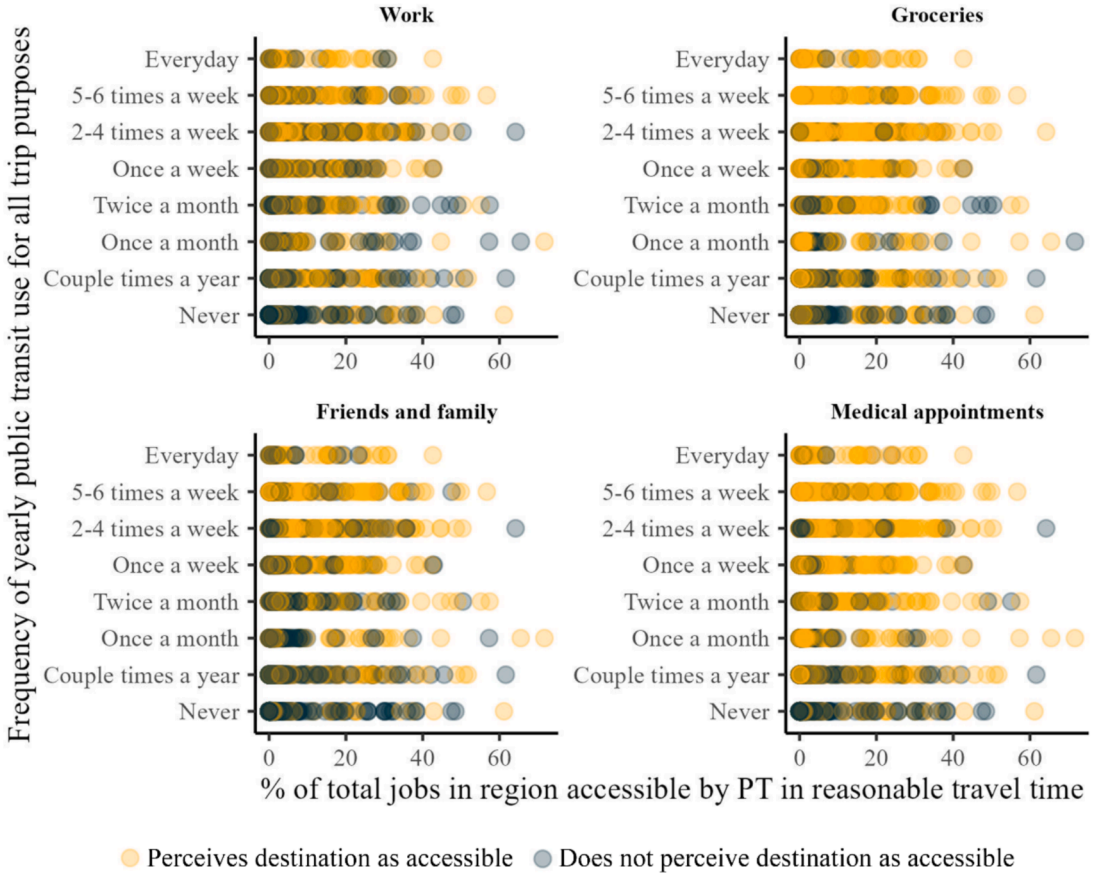

Fig. 2. Perceived accessibility to work, groceries, friends and family, and medical appointments, in terms of PT use frequency and normalized PTB accessibility.

while having similar levels of measured accessibility. We will further explore this relationship in the model in section 4.3.

4.3. Model results

Table 3 presents the results of the weighted binomial logistic regression that was developed to study the relationship between frequency of public transit use and personal-time-based and perceived accessibility, all while controlling for various individual and context-specific variables. The Tjur goodness-of-fit of the behavioural model is 0.418.

4.3.1. Personal-time-based accessibility

For PTB accessibility, i.e., the individual level of accessibility by public transit calculated with the stated reasonable travel time, both the normalized value and its squared term are statistically significant, the first being positive (more than 1) and the second negative (less than 1). This demonstrates the importance of planning transit service to allow older users to reach a relatively large number of destinations for their respective regions, within a reasonable time, as it directly and positively impacts their frequency of use. The negative sign for the squared term of accessibility indicates, moreover, that this level of service is not unachievable, and that there will come a certain optimal level (i.e., 23.4 % of the region's total number of jobs) of cumulative accessibility after which improvements will not lead to a higher frequency of public transit use among older adults. This parabolic representation of the relationship of level of PTB accessibility corroborates what has been found for the impact of objective cumulative accessibility on public transit mode share for different income groups in regions across Canada (Cui et al., 2020).

Table 3
Weighted binomial logistic regression for frequency of yearly public transit use.

Variable	*Odds Ratios*		*C.I. (95 %)*	*p*
(Intercept)	0.22	*	0.05 – 1.00	**0.049**
Personal-time-based accessibility (in percentage of total jobs in region)				
Normalized PTB accessibility	1.05	***	1.02 – 1.08	**0.001**
(Normalized PTB accessibility)^2	0.90	**	0.83 – 0.97	**0.008**
Perceived public-transit accessibility to…				
Work	1.80	***	1.42 – 2.29	**<0.001**
Grocery stores	2.05	***	1.57 – 2.69	**<0.001**
Friends and family	1.46	**	1.14 – 1.86	**0.002**
Medical appointments	1.33	*	1.01 – 1.75	**0.042**
Employment status				
Volunteer	1.27		0.87 – 1.86	0.218
Full-time	2.11	**	1.31 – 3.40	**0.002**
Part-time	1.38		0.95 – 2.01	0.089
Student	7.50	***	2.36 – 26.44	**0.001**
Personal characteristics				
Woman	1.42	**	1.13 – 1.77	**0.002**
Lower income (Less than $60 k)	1.11		0.86 – 1.43	0.415
Number of household members	0.84	*	0.72 – 0.98	**0.033**
Has access to a private vehicle	0.20	***	0.15 – 0.26	**<0.001**
Aware of eligibility for a reduced transit fare	6.43	***	4.85 – 8.62	**<0.001**
Age	0.98		0.97 – 1.00	0.072
Disability	1.20		0.93 – 1.53	0.154
Choice of home location				
Being close to public transit	1.93	***	1.43 – 2.64	**<0.001**
Observations	2452			
R^2 Tjur	0.418			
AIC	2470.1			

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

4.3.2. Perceived accessibility

When looking at the respondents' stated perceptions of accessibility to various destinations, believing to have public transit access to work/volunteering destinations, grocery stores, family and friends, and to medical appointments in a reasonable travel time positively impacts older adults' frequency of use of public transit. Interestingly, though over 80 % of the sample is retired, perceived accessibility to work is statistically significant in predicting frequent public transit use, which could be due to many work locations being concentrated in city centres, where a large number of amenities and services are located and well-served by the public transport network. The importance of access to family and friends in higher public-transit use frequency demonstrates the importance of older adults' social network and its spatial component. Transit agencies should continue increasing frequency and provision of service to these destinations and communicating these improvements clearly, especially to older adults, to increase their perceived accessibility, and promote use of public transit.

4.3.3. Personal and household characteristics

Among all the variables that were included in the regression model, one of the most (negatively) impactful on frequency of public transit use is having access to a private vehicle. To increase public transit use in this age group, making public transit a reliable and adequate alternative mode of transportation to driving is necessary, for both essential and discretionary trips (Davey, 2007; Elldér et al., 2023).

The respondents' employment status also proved to have a statically significant impact, with working (full-time) and being a student as important predictors of more frequent public transit use. This makes sense as these imply more fixed, regular commute trips that tend to be at times and to destinations that public transport networks are traditionally designed for (especially in a North American context). To get older adults who are retired to use public transit more frequently, a group which represents over 80 % of our sample, transit agencies must turn towards ensuring adequate service at off-peak times and plans routes that allow older adults to reach their desired destinations, which may be more spread out throughout their region.

Though age was not found to be statistically significant in explaining frequency of public transit use, it is important to keep in mind that the chances of driving cessation and reduction, as well as other mobility challenges, become more common as people get older. In terms of policy implications, if we are to ensure older adults remain independent and retain a healthy level of mobility, we must provide public transit services that meet the needs of those who are further along in age.

Disability was found to be statically insignificant in the model, but this requires further study, as the particular daily travel challenges of older people with a disability could lead to very different factors explaining their frequency of public transit use compared to those without a disability (Bezyak et al., 2017; Cochran, 2020; Grisé et al., 2019).

Gender was found to have a statistically significant impact, with older women being more likely to be frequent transit users when compared to men. In our sample as well as in the literature, older women are more likely to stop driving than men, and do so at an earlier age (Hakamies-Blomqvist & Wahlström, 1998), which could translate to higher public transit use.

The number of people in the household is found to be statistically significant, indicating that people who live alone are more likely to be frequent public transit users. Larger households could be linked to a higher chance of older adults being driven around by their other household members, or even suggest that these additional household members could help fulfill their needs, for example, running errands in their place (Choi & DiNitto, 2016; Jones et al., 2018).

As can be seen in the model, older adults knowing that they benefit from a reduced transit fare points towards more frequent public transit use. Across all six studied cities, the respective transit providers offer reduced fares to their older patrons (65 +), but as only 64.6 % of the

sample reported receiving a reduced fare, not all respondents seem to be aware of this reduced fare. Transit agencies must better communicate the service provided and the fare eligibility to older adults, as it could positively impact their frequency of transit use.

4.3.4. Self-selection

When looking at factors impacting the choice of residential location, having chosen one's home location while considering its proximity to public transport have a statistically significant impact keeping all other variables equal. This variable's positive impact on frequency of public transit use makes sense as it could represent a desire to remain close to public transit services, presumably intending use them. It could also indicate that before moving to their current home, respondents were using public transit and wished to continue after moving, or planned to begin using the mode after moving. It is also important to note that respondents in the larger metropolitan regions, i.e., Montréal, Toronto, and Vancouver, were more likely to have chosen their residential location based on its proximity to public transit. They may have greater opportunities to choose housing based on transit accessibility compared to those in smaller regions, reflecting the contrasting and influential levels of transit service in the six studied regions.

Conclusion

This study offers insight into the factors that influence older Canadians' frequency of public transit use and how cumulative opportunities measures can be adapted to better reflect individual's perception of accessibility. This was done by developing the personal-time-based measure of accessibility, which uses one's stated reasonable travel time by public transit to calculate cumulative accessibility at a personal level. Based on survey results which polled a large sample of older adults across six Canadian metropolitan areas, the logistic regression results indicate that both personal-time-based accessibility and perceived accessibility to various destinations have a statistically significant impact on frequency of public transit use, while keeping all other variables constant at their mean. Moreover, having access to a private car negatively impacts this frequency, whereas engaging in regularly timed activities such as having a full-time job increases the frequency of public transit use among older adults. These results indicate that more frequent and reliable public transit service, as well as better network connectivity (i.e., reaching more destinations more efficiently) could play a vital role in increasing older adults' objective levels of accessibility and their use of public transit. Finally, public transit providers should focus on bettering how they communicate their services to older adults, as having a better understanding and perception of their public transit accessibility to various destinations and of their reduced fare eligibility could result in an increase in their frequency of public transit use. Maintaining or enhancing travel-related skills through increased use of public transit could counter potential decline of mobility and social participation among older adults, ultimately improving their health and well-being. This is especially crucial for older adults with disabilities, as initiatives such as community-based transport services and travel training can increase their public transit use, facilitating their participation in desired activities and mitigating perceived barriers to independent travel (Cochran, 2020; Mwaka et al., 2024).

A few limitations of this study should be noted. Firstly, though this survey data gives important insight into what older people consider when evaluating their access to various destinations using public transit, it remains a quantitative source of information. To better understand what accessibility means to them and how it influences their travel behaviour and quality of life, interviews or analysis of open-ended questions pertaining to the topic could complement the information that has already been collected. Another limitation is that the calculations of levels of accessibility remains reliant on the available data, which is highly granular. Aggregating both respondents to their home CT centroid and jobs to their respective CT centroid can under or overestimate travel times and accessibility by public transit, especially for CTs with larger areas. Thirdly, although the goal of the paper was to get a more generalized notion of reasonable public transit travel time among older populations, this time might vary according to the destination or time of day when the travel would occur. This was slightly mediated by considering perceived accessibility to different destination types, but any potential difference could be highlighted in future research. Finally, the jobs data used is from 2016, whereas the GTFS and survey data was collected in 2023. There might be changes in geography (expansion of the CMA, sectioning or aggregation of census tracts, etc.), or changes in job locations that could have occurred in the last 7 years that limit the accuracy of results of this study. The most recent Census (2021) was not adequate to use as it was collected during the COVID-19 pandemic, so repeating this study in the future could be done using 2026 Census and 2026 GTFS data.

This study provides valuable insights for interdisciplinary researchers and practitioners by introducing novel methods to augment accessibility-based research, integrating people's perceptions to more effectively explain travel behaviour, rather than relying solely on objective measures. Beyond tools and methods, effective implementation of findings resulting in inclusive approaches and policies requires interdisciplinary collaboration among public health professionals, transit agencies, and communities.

Future research can explore more factors pertaining to travel attitudes, which might be region-specific and provide pathways to more direct strategies for public transit agencies. Segmentation of the survey sample could be interesting to explore, as we could highlight certain groups of older adults and their specific concerns regarding daily travel and the use of public transit, such as older women or people with disabilities. Moving forward with accessibility research we recommend using data that reflects the capabilities of the studied group, no matter their age, to set the travel time thresholds.

CRediT authorship contribution statement

Meredith Alousi-Jones: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, 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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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trip.2025.101381.

Data availability

The data that has been used is confidential.

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