Intention to Use Light-Rail Transit and First-Mile Mode Choice

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ABSTRACT

Increasing the uptake of active and sustainable modes of transport has become a global imperative as cities and regions around the world invest heavily in new transit infrastructure in a bid to reduce rising transport-related problems. This study explores how spatial, sociodemographic, psycho-social, health, and mobility characteristics of individuals and households influence their stated intentions to use the Réseau Express Métropolitain (REM), a new light-rail transit (LRT) system in Montreal, Canada. We further examine how these factors may relate to intended mode choice for first-mile trips from home to the station. We investigate these questions by applying weighted multi-level binary logistic regression to a subset (n=2,767) of survey responses collected from residents before the LRT's operation as part of an ongoing study into the system's potential impacts. Consistent with previous research on this topic, we find that attitudes toward the LRT project and public transport in general strongly influenced individuals' intention to use the new LRT. Likewise, socio-demographic characteristics are also strongly associated with intention, in this case being female and having an annual household income less than 90K are negatively related with intention to use. Most notably, we find evidence that physical activity and markers of active lifestyles, such as bicycle ownership, had positive impacts on both the intention to use the LRT and to access it by active modes. Based on this finding, we conclude that policy objectives promoting active lifestyles would also benefit the objective of promoting the use of sustainable modes of transport, including LRT.

Keywords: Intention to use public transit, Light-rail transit, First-mile mode intentions, Active mode choice, Public health, Travel mode attitudes, Montreal

INTRODUCTION

Montreal, Canada's $6.5 billion Réseau Express Métropolitain (REM) light-rail transit (LRT) project is poised to nearly double the region's high-frequency rail transit network in just a matter of years, potentially reshaping land-use and transportation patterns across the region. The 67-kilometer, automated light-rail—slated to come online in phases starting in 2022—is being built as Montreal and other regions around the world face an urgent need to curtail spiraling transport-related greenhouse gas emissions (GHG) as part of their response to the growing impacts of climate change. To that end, governments have begun to articulate carbon-reduction goals accompanied, in some cases, by major investments in public-transport infrastructure aimed at bolstering sustainable mode share and reducing reliance on private automobiles. Montreal, Canada, for example, aims to boost public-transport mode for all trips to 35% by 2035, from 25% in 2012 (Montréal, 2012). Gauging how well the REM project, and others like it, will advance regional transport-related economic, social, and environmental goals, requires a keen understanding of the factors that shape the adoption and use of new LRT and metro systems. To that end, this study examines the sociodemographic, attitudinal, and built-environment and transport-network factors that influence people's intention to use and access the REM.

According to the theory of planned behaviour, there is a strong association between intended and realized behaviour (Ajzen, 2011). A greater understanding of the factors that determine potential transit users' intention to use public transit can help transit agencies make important decisions about their services. This information may be particularly helpful prior to the completion of the project, as agencies can still enact policies to improve public opinion about the project, converting unlikely users to potential users. At the same time, the intended mode taken to access the new LRT stations (first-mile travel behavior) provides information for the transit agencies in not only designing the appropriate infrastructure to support the desired travel behavior of potential users to access the stations, but also shape their behavior to use more environmentally sustainable active modes that have the added benefit of improved health conditions, in accordance with their planning goals.

As such, the present study aims to answer two questions: 1) what are the determinants that influence people's stated intention to use the REM and 2) for those potential users that intend to use the REM once it is operational, what are the factors that influence the modes, including active modes like walking and biking, that they intend to use to access the stations. To answer these questions, the present study makes use of a bilingual survey of several thousand Montreal-area residents conducted as part of an ongoing longitudinal study to document the impacts of the REM LRT project on travel behavior, health and well-being at various stages of the project lifecycle. We build upon the findings of recent research by Dent et al. (2021), which used the same dataset to apply a market-segmentation approach to identify clusters of potential as well as unlikely users of the REM, but instead focus more on the specific determinants of intention to use the REM and the transport mode that future riders plan to use to access the new LRT system. The modelling approach used in our study allows us to highlight specific policies and areas of intervention to improve eventual use of the LRT system itself as well as promote the use of sustainable modes to access the LRT system.

LITERATURE REVIEW

Public transit mode choice

De Witte et al. (2013) found four primary categories of factors to affect transport mode choice: spatial, socio-demographic, journey characteristics, and socio-psychological. The idea that spatial, or built environment factors, have an impact on mode choice has been popularized through the concept of the 3Ds: density, diversity, and design (Cervero and Kockelman, 1997) and has been confirmed by various researchers (Boarnet and Crane, 2001; DeWeese and El-Geneidy, 2020; Ewing and Cervero, 2010; Handy et al., 2005; Wasfi et al., 2017). While proximity to transit, which is captured in the 3Ds, has a direct influence on public transit use, this influence has been shown to be moderated by other factors. For example, the design of the neighborhood can play a role to reduce the perceived distance to transit (Loutzenheiser, 1997). People are also more willing to travel further to access better quality transit (e.g. rail) (Cervero, 1995). Individual sociodemographic characteristics can impact mode choice in wide-ranging and complex ways. Women, for example, are more likely to use and depend on public transport (Ko et al., 2019; Limtanakool et al., 2006; Mensah, 1995; Mercado et al., 2012). Contrastingly, a study by Hsu et al. (2019) revealed how in Los Angeles, new rail line had a smaller effects on increasing transit use for women compared to men, which was largely explained by gender-associated concerns for personal safety. On the other hand, car availability, as one of the most often studied determinants of mode choice, has been found to have a negative association with public transit mode choice (De Witte et al., 2013). Journey characteristics related to quality of transit services, especially relative to alternatives such as private vehicles, have been found to inform transit mode choice. Notably, a study by Chakrabarti (2017) revealed how transit speed, frequency, and reliability relative to private vehicle were strong predictors of public transport mode choice in Los Angeles.

Socio-psychological factors such as experience with transit, attitudes towards transit, habits and lifestyle choices, while less often studied, have been shown to exert strong influences on mode choice (De Witte et al., 2013). Various studies have documented how positive attitudes towards public transport, including satisfaction with service, encourage public transport use (Bagley and Mokhtarian, 2002; Kitamura et al., 1997; Lai and Chen, 2011; Spears et al., 2013). Other studies have put forward evidence suggesting that attitudes have an even stronger impact on mode choice than built environment and demographic factors (De Vos et al., 2020; Sener et al., 2020; Şimşekoğlu et al., 2015). However, these effects are not necessarily mutually exclusive. A recent study by De Vos et al. (2021b) suggests that built environment may influence attitudes, which, in turn, may influence mode choice. Similarly, attitudes may encourage a selection of residence that is compatible with preferred modes of travel (Cao et al., 2009). In short, mode-choice models must account for a wide range of factors as identified in De Witte et al. (2013) (spatial, socio-demographic, journey characteristics, and socio-psychological factors).

Future intention to use public transit

The determinants of intent to use public transport have been explored in the existing literature. Lai and Chen (2011) and De Oña et al. (2016) found that perceptions of service quality were most strongly associated with intended use. De Vos et al. (2020) modelled future intention to use public transport among students in Quebec City. Their model showed that current satisfaction with public transport and positive attitudes towards it were strongly associated with intention to use in the future. Sener et al. (2020) examined the determinants of intention to ride a newly opened LRT in Houston. This study found that attitudes towards public transport were more strongly associated with intention to ride than environmental or socio-demographic variables, a result that is supported by Zailani et al. (2016) in Malaysia. A novelty in the study from Sener et al. (2020) is the inclusion of variables accounting for health status and awareness of the physical-activity benefits of public transport use. Investigation into the connections between health status, and particularly physical activity, with propensity to use public transport represents a gap in this body of literature that presents an opportunity for further investigation.

First-mile active mode choice to public transit

There are a variety of factors that influence the mode selected by public transport users to access public transit services. Most of these factors are examined in the context of walking to transit. Kim et al. (2007) investigated factors that encourage walking to LRT and found that socio-demographic factors, namely being a student and being a high-income rider, encouraged active access. Tilahun and Li (2015) found that higher crime rates reduce the likelihood of walking to public transport, as does vehicle ownership, while sidewalk availability increased the likelihood of walking. Lu et al. (2021) found that higher intersection density, higher accessibility to services and a more diverse land use mix near the home encouraged walking to public transport. van Soest et al. (2020), through a systematic review, found that factors that encourage walking over longer distances to public transit include being employed, having higher income (in North America and Australia but not in Asia or Europe), and living in neighbourhood with higher walkability.

The decision to use a bicycle to access public transport is found to be encouraged by being male (de Souza et al., 2017; Ji et al., 2017), younger age (Ji et al., 2017), presence of bicycle paths along the route, bicycle parking at origins and destinations (de Souza et al., 2017), and trip purposes (Ji et al., 2017). Other research has found that using public transport to access rail services is encouraged by shorter distances between home and station (Goel and Tiwari, 2016) and by improvements in bus service as measured by travel time (Halldórsdóttir et al., 2017). Factors that have been identified to encourage driving to fulfill the first-mile trip are availability of parking (Kim et al., 2007), access to a private vehicle (Azimi et al., 2021; Kim et al., 2007), and possession of a driver’s license (Azimi et al., 2021; Kim et al., 2007).

In terms of transit users’ propensity to access the station via public transit or driving, Kim et al. (2007) found that riders with valid driver’s license are more likely to drive to LRT stations in St. Louis, Missouri than those without a license. The same result is also true for vehicle availability. For users who take the bus to access LRT stations, direct bus service availability between the home and the station was found to be influential, after accounting for the effects of having a driver’s license, having an available vehicle, presence of park and ride lots and other socio-demographics factors.

STUDY CONTEXT

The REM is an automated LRT system under construction in Montreal, Canada, that is expected to begin operations progressively in phases between 2022 and 2023. When complete, the REM will connect Montreal's West Island, international airport, and southern suburbs to Downtown (shown in green in Figure 1) and is expected to have a daily ridership of 190,000 (Steer Davies Gleave, 2017).

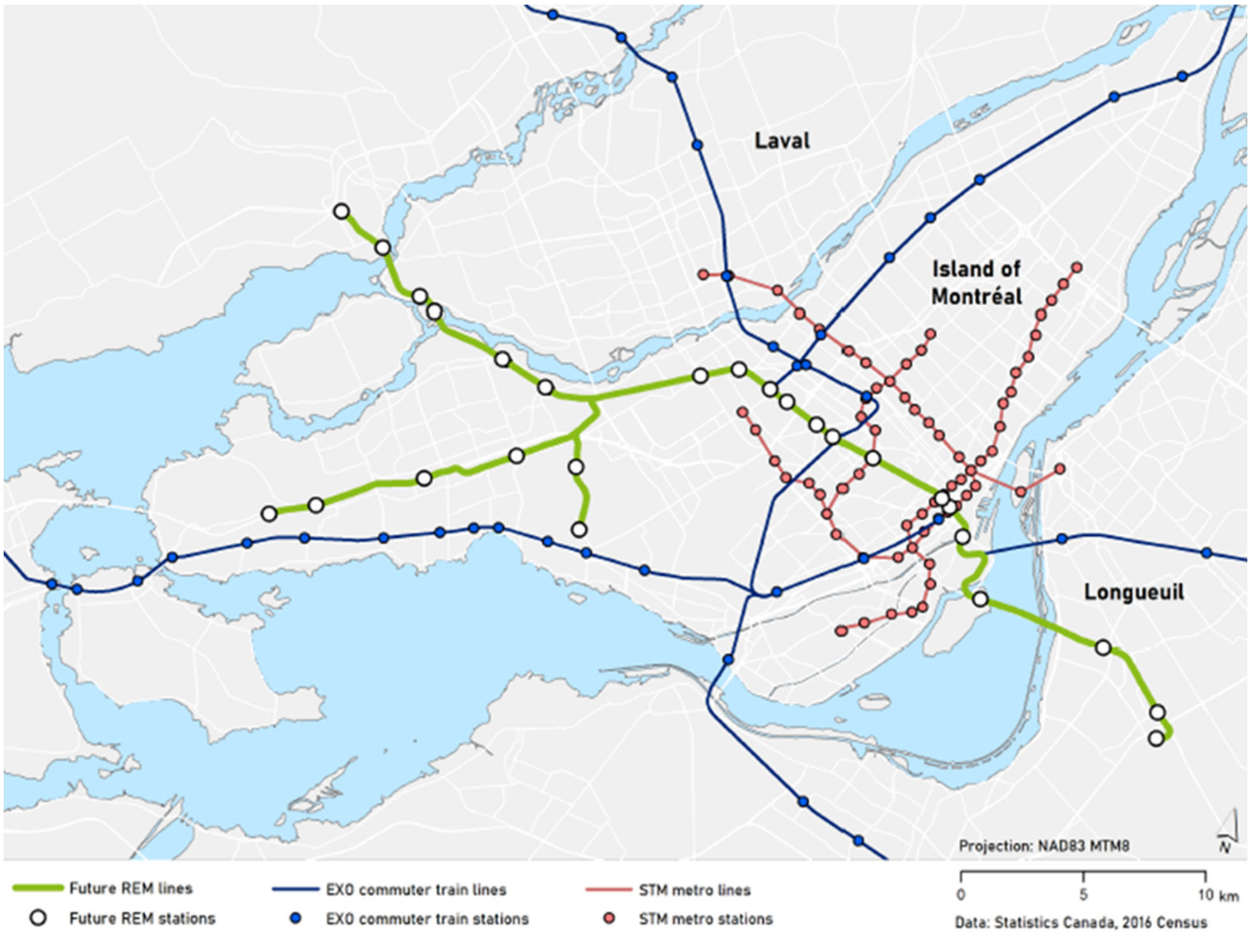

Figure 1: Map of Montreal's rapid transit and commuter rail system, including the REM.

DATA

This study uses data obtained from an online bilingual (English-French) survey conducted between October 2019 and January 2020 to collect data on the REM's potential impact on travel and wellbeing. This survey represents the first wave of data collection for a cohort study concluding in 2023. We recruited participants 18 years of age and older and included questions about perceptions of the REM and the impacts of its construction. We also collected data on current travel behaviour, physical activity, and respondents' sociodemographic characteristics. To ensure a representative sample, we employed various techniques recommended by Dillman et al. (2009) and a mix of in-person and online recruitment. We used geographically targeted Facebook advertisements, recruited participants with flyers at downtown transport hubs in

Montreal, engaged traditional media with press releases and interviews, and contracted a public-opinion survey company.

In total, we collected 5,942 responses, of which 4,148 were complete. We removed responses that were filled too quickly to be considered reliable. Survey duration depended on the types and complexity of reported travel behaviour. To identify unreliably fast responses, we constructed four complexity categories and removed the fastest 10% of respondents from each. Finally, we manually filtered out unrealistic responses, including birth years before 1920 and reporting spending more than 200 minutes per day commuting by walking or bicycle. Following this cleaning process, the remaining sample size of 3,683 responses was used in the next step.

For this study, we narrowed the dataset further to include only responses with complete and reliable information on key variables for our model (see Table 1). Respondents who had not heard about the REM project before were not asked whether they intended to use the REM and were therefore excluded. Following this exclusion process, we retained a sample of 2,767 for our analysis.

METHODS

To model intention to use the REM and mode choice for accessing REM stations, we employed a weighted multi-level binomial logistic regression approach using the R statistical programming language. Each individual response was placed in a census tract (n=674) based on the geographical information provided in the survey. We used census tracts as the second level in each multi-level model. This allows us to control for common characteristics shared in a neighbourhood that are otherwise unaccounted for in the model. To ensure the representativeness of our model, we calculated and applied observation weighting with the anesrake R package using respondents' age, income, and gender and 2016 Statistics Canada census data at the census tract level.

Intention to use the REM was determined based on the answer to the question "How likely are you to use the REM when it is complete and operational?" This data was converted into a binary variable in which respondents indicating that they were "Very likely" or "Likely" to use the REM were coded as 1, and all other individuals (responding "Neutral", "Unlikely" or "Very unlikely") were coded as 0.

Intended access mode choices were determined based on responses to the survey question "How do you plan to get to the REM?" Intention to walk, cycle, and use public transport to access the REM were all determined the same way: If the respondent ticked the response corresponding to that mode, then the corresponding dependent variable for the model was coded as 1, otherwise 0. For driving exclusively to the REM, the model variable was coded as 1 if the respondent checked any of "Drive," "Taxi or ride-hailing," and "Someone will drop me off" and did not check "Walk," "Bicycle," or "Public transport." As multiple responses were possible, we used a binomial as opposed to a multinomial logit modelling approach to investigate the variables that promote and inhibit intention to use each category of first-mile mode choice.

Our models include several independent variables either obtained directly from the survey or computed separately. These computed variables include: network distance between a respondent's home and the nearest REM station; neighborhood walkability which was obtained from Walkscore.com through an online application programming interface (API); and cumulative 45-minute weekday am peak accessibility to jobs by public transport (Hansen, 1959) based on the network as it currently exists. We calculated this measure of accessibility at the census dissemination-area level using r5r, a package for the R programming language that provides access to Conveyal's R5 java-based routing engine (Pereira et al., 2021). General Transit Feed Specification (GTFS) data for routing and accessibility calculations was obtained for all agencies in the metropolitan region. Travel time was calculated and averaged for every minute with departure time between 8:00 a.m. and 8:30 a.m. for Tuesday, May 14, 2019, selected as a representative non-holiday weekday. We also calculated the projected change in accessibility with the inclusion of the completed REM but did not retain this variable in the models because it was not significant and did not improve the model fit based on AIC and BIC statistics. The number of jobs at the dissemination area level was calculated based on census-tract level information on jobs from Census Work Flows (Statistics Canada, 2016). Table 1 includes the descriptive of the variables used in our analysis and their summary statistics. Based on VIF and collinearity statistics, we found no significant collinearity between final model variables.

Table 1: Descriptive statistics of final model variables (dollar figures in CAD)

Category	Variable name	Description	Mean	St. Dev.
Dependent variables				
Dependent variables (intentions to use the REM and intended mode of accessing the REM)	Intends to use REM	Intends to use the REM	0.542	0.498
	Walk to REM (n = 1,501)	Intends to walk to access the REM	0.421	0.494
	Bike to REM (n = 1,501)	Intends to bike to access the REM	0.209	0.406
	Transit to REM (n = 1,501)	Intends to take public transit to access the REM	0.461	0.499
	Drive to REM (n = 1,501)	Intends to drive exclusively to access the REM	0.183	0.387
Independent variables				
Socio-demographic characteristics	Female	Gender [female]	0.502	0.5
	Male	Gender [male]	0.484	0.5
	Other gender	Gender [other]	0.014	0.116
	Age	Age (in years)	45.527	15.898
	Non-White	Race [non-White]	0.126	0.332
	under $30K	Household income [under $30K]	0.104	0.305
	$30K to $60K	Household income [$30K - $60K]	0.214	0.41
	$60K to $90K	Household income [$60K-$90K]	0.191	0.393
	$90K to $120K	Household income [$90K-$120K]	0.167	0.373
	over $120K	Household income [over $120K]	0.228	0.42
	High school	High school diploma or less	0.106	0.308
	College	College diploma or trade certificate	0.238	0.426
	Bachelor's	Bachelor's degree	0.37	0.483
	Graduate	Graduate degree	0.285	0.451
	Children in household	Children under 18 years old in household	0.266	0.442
	Mobility disability	Has a mobility-related disability	0.129	0.335
	Raised urban	Grew up in an urban environment	0.394	0.489
	Raised suburban	Grew up in a suburban environment	0.453	0.498
	Raised rural	Grew up in a rural environment	0.152	0.359
Spatial characteristics	Walk Score	Walk Score of home location	68.27	26.068
	Net distance	Network distance between residence and REM station (km)	6.325	6.989
	Net distance squared	Square of network distance between residence and REM station	88.833	217.589
	Accessibility by transit	Number of jobs (10,000s) accessible within 45 minutes by transit (May 2019)	27.079	26.088
	Accessibility by car	Number of jobs (10,000s) accessible within 45 minutes by car (May 2019)	76.387	35.107
Physical activity characteristics	Transport PA hrs	Hours of active transport physical activity in past week	2.788	3.229
	Work PA hrs	Hours of vigorous physical activity for work in past week	0.413	1.987
	Recreation PA hrs	Hours of vigorous physical activity for recreation in past week	1.296	2.265
	BMI	Body mass index	26.767	6.019

Mobility characteristics	Access to vehicle	Access to a vehicle	0.751	0.433
	Driver license	Driver license	0.889	0.314
	Owns bike	Owns a bike	0.658	0.474
	Bixi* member	Has a bixi* membership	0.089	0.285
	Weekly transit rides	Number of transit rides in the previous week	2.912	3.375
	Transit non-commute	Rides transit for non-commuting purposes	0.207	0.405
Attitudinal characteristics	Transit positive attitude	Would like to ride public transit more often	0.334	0.472
	Cycling positive attitude	Would like to cycle more often	0.552	0.497
	REM bad for Montreal	Believes the REM will be bad for Montreal	0.071	0.257
	REM bad for n'hood	Believes the REM will be bad for neighbourhood	0.179	0.384
Reasons for home location variables	Having a large home	Having a large home	0.571	0.495
	Familiarity with n'hood	Familiarity with neighbourhood	0.596	0.491
	Low crime	Social safety/low crime	0.769	0.422
	Near work/school	Being near my primary work/school location	0.568	0.495
	Near health services	Being near health services	0.517	0.5
	Parks	Presence of parks and green spaces	0.808	0.394
	Schools for children	Presence of good schools for my children	0.407	0.491
	Ease of car	Ease of getting around by car	0.553	0.497
	Near public transit	Being near public transport	0.806	0.396
	Near bicycle	Being near bicycle infrastructure	0.395	0.489
Intended trip purpose using the REM	Commute	Commute to work or school	0.286	0.452
	Non-commute	Non-commuting purposes	0.553	0.497
	Multiple purposes	Multiple purposes	0.393	0.489
Personal reasons for intending to choose the REM	Good for environment	Good for environment	0.321	0.467
	Shorter travel time	Shorter travel time	0.383	0.486
	More comfortable	More comfortable	0.275	0.446

**Bixi is the public bicycle sharing service in Montreal.*

RESULTS AND DISCUSSION

Our analysis proceeds in two parts: First, we describe the data and respondents' general intentions regarding the REM. Second, we describe the results of a series of weighted multi-level logistic regression models designed to reveal the factors that influence (a) respondents' stated intention to use the REM and (b) their planned modal choice for arriving at the new train's stations. The answers to these questions have important implications for how planners and policymakers can work to ensure that major transportation investments, such as the REM, help cities and regions achieve their social, health and environmental goals.

Descriptive Statistics

Among the retained sample of 2,767 respondents, 1,501 (54.2%) indicated that they intend to use the REM when it becomes operational. Among those respondents who intend to use the REM, 632 (42.1%) indicated that they intend to walk to access the REM, 313 (20.9%) indicated they would bicycle, 692 (46.1%) indicated they would take public transport and transfer onto the REM, and 275 (18.3%) indicated that they would exclusively drive or otherwise use automobiles. Other than exclusive car users, the other categories of respondents are not mutually exclusive as respondents were allowed to select more than one access mode. Thus, a respondent can appear in more one than one model.

All Aboard? Modelling Who Will Use the REM

We first explore respondents' intention to use the REM. Broadly speaking, three principal categories of variables appear to exert an important influence on the binary decision of whether to use the REM: attitudes and perceptions regarding public transport generally and the REM, in particular; individual sociodemographic and physical activity attributes; and neighborhood and transport system characteristics (Table 2).

Eye of the Beholder: Attitudes and Perceptions

Individual perceptions and attitudes play a decisive role, as indicated by odds-ratio magnitude and statistical significance. A stated desire to ride public transport more often increased odds of intending to use the REM by 2.17 times, all else being equal. Meanwhile, a perception that the REM would be bad for Montreal reduced the odds of intending to use the REM by 57%. Similarly, a perception that the REM would be bad for one's neighbourhood reduced odds by 65%. This predominance of attitudes towards public transport in predicting propensity to use LRT over socio-demographic, environmental, and mobility characteristics reflects findings in several other recent studies (Kitamura et al., 1997; Lai and Chen, 2011; Sener et al., 2020; Şimşekoğlu et al., 2015).

Individual Characteristics and Upbringing

Identifying as female and having lower household income are both associated with a lower intention to use the REM, confirming previous research about women's propensity to use light-rail transit (Hsu et al., 2019), but contrasting findings about women's propensity to use public transit in general (Ko et al., 2019). Females have 38% lower odds of intending to use the REM than males, all other variables held constant at their mean. Respondents living in households with incomes below $90,000 per year had between 33% and 37% lower odds of intending to use the

REM compared to individuals living in households earning more than $120,000 per year, all else being equal. This finding suggests that the REM succeeds in incentivizing choice riders to use public transport, but also that the REM may service origins and destinations more effectively for higher-income groups than for lower-income groups. . It is important to note that the fare cost of using the REM has not been finalized so potential concerns over the cost of using the system may be at play, where respondents with lower household income may be less inclined to state that they would use the REM if they perceive that fares will be more expensive then they are currently. Other individual characteristics, including employment status and marital status, were not found to be significant and were excluded from the final model.

Controlling for other variables, if an individual grew up in an urban environment they were less likely to intend to use the REM than those who grew up in suburban environments. One explanation may be that the REM is designed to serve suburban communities and has already been found to appeal to suburban riders, including those who do not already use public transport (Dent et al., 2021). Only certain residential self selection variables were found to be significant, namely, the importance of having a large home and proximity to work or school seem to reduce the odds of intending to use the REM. Those who wish to have a larger home may be more accepting of a more car-oriented lifestyle and therefore will be less likely to express an interest in using the REM. On the other end of the spectrum, those who value living close to their work or school may not want to rely on transit to access these locations, and would perhaps walk or bike instead of taking the REM. Expectedly, the importance of proximity to transit increases the odds of the intention to use the REM. Interestingly, self selecting for proximity to parks and green spaces exerts a positive influence on the odds of intending to use the REM. This may infer a more active and environmentally conscious lifestyle of individuals who would be interested in taking transit despite living in a more suburban area.

Existing travel behaviour is closely related to future intentions to use the REM. Access to a vehicle had a statistically significant and negative association with intention to use the REM and every additional public transport ride in the previous week increased the odds of using the REM by 4%, all else held equal. Both of these findings are supported by existing research (Sener et al., 2020; Yazdanpanah and Hosseinlou, 2017). Possessing a Bixi (Montreal's bike share system) membership exerted a statistically significant and positive impact on the odds of intending to use the REM. We can interpret this as an indicator of how active lifestyles contribute to light-rail transit ridership, and additionally as a proxy for propensity to adopt new sustainable travel behaviours.

The model provides evidence for the positive impact of physical activity and active travel on public transport adoption: Time spent doing active transport physical activity was significantly and positively associated with intention to use the REM. All else held constant, every additional hour of active transport physical activity in the previous week increased the odds of intending to use the REM by 7%. Other variables related to physical activity carried out at work or for leisure where not significant and therefore excluded from the final model.

Location, Location, Location: Home Location, Built Environment & Transport Network

Up to a point, the further someone's home is from a station, the less likely that person is to plan on using the REM. Holding all other variables constant, every additional kilometer that a respondent lives from the closest REM station reduces their odds of intending to use the REM by about 18%. This rate of reduction in odds of intending to use the REM decreases at a rate of 0.4% with every kilometer until at around 51 kilometers, where afterwards increasing distance increases the odds, as indicated by the direction and statistical significance of the squared term. However, it is unlikely that individuals living 50 kilometers away from the REM will use it so we can generally conclude a negative relationship between distance and the odds of intending to use the REM.

Higher existing values for local (i.e. Walk Score) and regional accessibility are both associated with decreased odds of intending to use the REM, all else held equal. This is reasonable considering that the REM's network design provides benefits mainly in outlying areas not as well-served by existing public transport. People in amenity-dense neighborhoods or areas already served by frequent Metro and bus service, may have less incentive to use the REM. Population density was tested as an explanatory variable but was not statistically significant and was excluded from the model.

Table 2: Model for intention to use the REM

Predictors	Odds Ratios	Confidence Interval
(Intercept)	6.18 ***	3.54 – 10.79
Socio-demographic characteristics		
Gender (ref cat: male)		
Female	0.62 ***	0.52 – 0.75
Other gender	0.61	0.25 – 1.46
Age	0.99 *	0.99 – 1.00
Income (ref cat: over $120K)		
under $30K	0.67 **	0.50 – 0.89
$30K to $60K	0.67 **	0.52 – 0.86
$60K to $90K	0.63 ***	0.48 – 0.82
$90K to $120K	1.00	0.75 – 1.33
Raised environment (ref cat: suburban)		
Raised urban	0.79 *	0.65 – 0.96
Raised rural	0.94	0.72 – 1.21
Spatial characteristics		
Net distance	0.82 ***	0.78 – 0.85
Net distance squared	1.004 ***	1.00 – 1.01
Walk Score of home location (ref cat: 0-49)		
Walk Score 50-69	0.91	0.68 – 1.23
Walk Score 70+	0.65 **	0.48 – 0.89
Accessibility by transit	0.98 ***	0.98 – 0.99
Physical activity characteristics		
Transport PA hrs	1.07 ***	1.04 – 1.10
Mobility characteristics		
Access to vehicle	0.79 *	0.62 – 0.99
Bixi member	1.59 **	1.15 – 2.20
Weekly transit rides	1.04 **	1.01 – 1.07
Attitudinal characteristics		
Transit positive attitude	2.17 ***	1.79 – 2.62
REM bad for Montreal	0.43 ***	0.29 – 0.63
REM bad for n'hood	0.35 ***	0.27 – 0.45
Home location characteristics		
Having a large home	0.83 *	0.69 – 0.99
Near work/school	0.74 **	0.62 – 0.89
Parks	1.37 *	1.09 – 1.72
Near public transit	2.37 ***	1.85 – 3.03
Random Effects		
σ^2	3.29	
$\tau_{00\ CT\_UID}$	0.12	
Intra-class correlation (ICC)	0.04	
N_{CT_UID}	674	
Observations	2767	
Marginal R^2 / Conditional R^2	0.289 / 0.314	

* *p<0.05* ** *p<0.01* *** *p<0.001*

How Will They Get There: Access-Mode Intention

How travellers plan to reach the REM is equally important for achieving Montreal's transportation-related social and environmental goals. With this second series of models, we investigate the factors that influence self-avowed future riders' planned mode choice for accessing the REM. This analysis relies on four weighted multi-level binary logit models explaining intention to (a) walk, (b) bicycle, (c) take other public transport; and (d) drive. As discussed above, respondents, other than those who indicated they would drive exclusively, were able to indicate multiple modes and thus can appear in multiple models. Statistically insignificant variables and variables that did not improve model fit based on AIC and BIC statistics were removed from the final models presented in Table 3.

Trip Purpose

Intended trip purpose for using the REM exerts significant influence on the choice of an active mode for accessing the REM. All else held constant, an intention to use the REM for commuting to work or school more than doubles the odds of intending to walk to complete the first-mile journey to the REM compared to using the REM for only other purposes. Intending to use the REM for multiple trip purposes also exerts a strong positive and statistically significant impact on intending to walk or bike to access the REM compared to intending to use it for only commute or for only other purposes. For non-active mode users, an intention to use the REM for other purposes influences the odds of using transit and car to access the REM in opposite ways, where the intention to use the REM for other purposes almost triples the odds of intending to use transit but halves the odds of intending to drive to access the REM compared to intending to use the REM for commute trip only. This implies that those who intend on accessing the REM using a car are more likely to be making commute only trips using the REM and potential users who will be using active modes as well as other forms of transit to access the REM are interested in using the REM for more than just commute only trips.

Personal Characteristics, Attitudes, and Existing Behaviors

Identifying as female as opposed to male was negatively associated with intention to bicycle to the REM, all else being equal. Women have 44% lower odds of intending to bicycle to the REM than men. This negative association is consistent with previous research investigating the impact of gender on bicycle mode choice for first-mile trips to public transport (de Souza et al., 2017; Ji et al., 2017). Being older has a statistically significant and negative impact on intention to cycle to the REM, corroborating findings by Ji et al. (2017). Older age had a statistically significant and positive correlation with intention to exclusively drive to the REM, potentially pointing to the general trend of changing travel behavior as one's ages due to reduced mobility, increased income or changing personal values which would promote the use of private vehicles to access the REM. Having children in the household reduced the odds of intending to walk to the REM which is supported by McCarthy et al. (2017)'s review of the literature of the factors that influence mode choice for families with young children. Ethnicity and education level were only significant in the drive-only model, where being non-white and having a bachelor's degree, compared to a graduate degree, increases the odds of intending to drive to access the REM. The influence of an individual's upbringing on future travel behavior is evident in the active mode models where when compared to growing up in a suburban environment, growing up in an urban environment increases the odds of intending to walk or bike to access the REM and growing up in a rural environment decreases the odds of intending to bike.

Personal travel priorities are also closely associated with first-mile mode choice. For example, indicating a desire to take the REM for environmental reasons and shorter travel times were correlated with 79% and 45% higher odds of walking to the REM, respectively. Intending to use the REM for increased comfort had a positive and statistically significant association with intending to bicycle and use public transport to access the REM.

Existing patterns of physical activity appear to be closely related to mode-choice intention for accessing the REM. As expected, active-transport-related physical activity has a statistically significant and negative association with intention to exclusively drive to the REM. Controlling for all other variables, performing vigorous physical activity at work has a statistically significant and positive association with intention to walk to the REM. This requires further investigation as it is possible that jobs requiring more physical exertion tend to be lower income and as such, individuals may be more likely to walk instead of drive. However, there are also many exceptions to this including jobs in the trades industry.

These models show that existing mobility characteristics of the individual exert a strong influence on what mode a future REM user would choose for their first-mile journey. Interestingly, bicycle ownership does not merely possess a statistically significant and positive relationship with intention to bicycle to the REM as it is also strongly associated with greater odds of walking and using public transport to travel to the REM, controlling for all other variables. It also bears a strongly negative association with the intention to exclusively drive to the REM. We hypothesize that this is an indication of how bicycle ownership is indicative of active lifestyles, which encourage active modes of accessing the LRT and discourage exclusively driving. Moreover, being a Bixi member also increases the odds of intending to bike and, as expected, decreases the odds of intending to drive to access the REM. Car access and possession of a driver's license both increase the odds of intending to drive the REM. The former also decreases the odds of intending to use transit. These results confirm the findings from De Witte et al. (2013) and Kim et al. (2007).

Finally, attitudinal and residential self-selection characteristics also influence the intention to use different modes to access the REM in different ways. Interestingly, having a transit positive attitude (i.e. expressing a desire to ride transit more) has a negative influence on the intention to walk to access the REM. It is possible that those who walk to access the REM are doing so because they are constrained by the modes that they can take for reasons like affordability or time, so they are using transit for practical reasons and may not actually want to take transit more than they need to. On the other hand, having a positive cycling attitude does increases the odds of biking to access the REM which may imply that those who wish to bike to access the REM are choosing to bike, rather than biking because they need to. The influence of most of the self-selection variables on the intention to use a particular mode to access the REM are clearly consistent with expectations. There are a couple interesting results to be pointed out. For example, valuing familiarity with the neighborhood in residential selection seems to decrease the likelihood of walking to access the REM. While one could expect that those who walk would want to feel more comfortable walking in their neighborhood, but it may be that those who would walk to the REM may not be walking very far so would not need to be familiar with their neighborhoods but rather just the area close to their home.

Spatial Characteristics

While higher Walk Scores were negatively associated with intention to use the REM, we find that living in an area with a high Walk Score (70+) improves odds of choosing to walk to the REM by 75% among those who do intend to use it, relative to individuals who live in areas with a Walk Score below 50. This finding is consistent with research that has determined that higher local accessibility and better pedestrian infrastructure encourages walking to public transport and for longer distances (De Witte et al., 2013; Lu et al., 2021). While accessibility by transit has a significant and positive influence on potential riders' intention to use transit to access the REM, it exhibits a significant and negative influence on the intention to drive.

The influence of the distance between the home and the REM is different depending on the intended mode used to access the REM. For intending to walk to the REM, the influence of distance is negative, where for every additional kilometer that a respondent lives from the closest REM station, the odds of intending to walk to the REM decreases by about 42%. At the same time, this reduction in odds of intending to walk to the REM with increasing distance decreases at a rate of 1.5% with every kilometer until around 37 kilometers, where the trend reverses and increasing distance begins to increase the odds of intending to walk to the REM. However, very few people will walk more than a couple of kilometers to access the REM, so the general influence of distance is negative.

For potential riders intending to take transit or drive to the REM, the influence of distance is positive, up to a certain threshold. Every additional kilometer that a respondent lives from the closest REM station, increases the odds of intending to take transit to the REM by about 32% and driving by around 12%. At the same time, the increase in odds with increasing distance decreases at a rate of 0.8% and 0.3% with every kilometer until around 36 kilometers and 38 kilometers, respectively for intending to take transit and for intending to drive, where the trend reverses. Furthermore, using the quadratic relationship that we have hypothesized between network distance and odds of intending to use a certain mode to access the REM, the distances at which the odds of intending to take transit or drive to the REM are maximized are calculated to be around 18 kilometres and 19 kilometers, respectively.

Table 3: Models for modes of accessing the REM (among respondents who already intend to use the REM)

Variable name	*Intention to walk to REM*		*Intention to bicycle to REM*		*Intention to take public transit to REM*		*Intention to exclusively drive to the REM*	
	Odds Ratios	**Confidence interval**	**Odds Ratios**	**Confidence interval**	**Odds Ratios**	**Confidence interval**	**Odds Ratios**	**Confidence interval**
(Intercept)	0.81	0.42 – 1.57	0.27 **	0.12 – 0.59	0.04 ***	0.02 – 0.10	0.01 ***	0.003 – 0.06
Socio-demographic characteristics								
Gender (ref cat: male)								
Female			0.56 ***	0.41 – 0.77				
Other gender			1.00	0.24 – 4.18				
Age			0.96 ***	0.95 – 0.97			1.03 ***	1.02 – 1.04
Non-White							1.79 *	1.09 – 2.95
Educational attainment (ref cat: graduate)								
High school							1.57	0.83 – 2.98
College							1.63	0.98 – 2.70
Bachelor's							1.89 **	1.18 – 3.01
Children in household	0.64 *	0.45 – 0.90						
Mobility disability	0.58 *	0.37 – 0.92						
Raised environment (ref cat: suburban)								
Raised urban	1.37 *	1.01 – 1.86	1.41 *	1.03 – 1.95				
Raised rural	0.99	0.65 – 1.51	0.44 **	0.26 – 0.74				
Spatial characteristics								
Net distance	0.59 ***	0.53 – 0.65			1.32 ***	1.22 – 1.43	1.12 *	1.03 – 1.22
Squared of Net distance	1.014 ***	1.01 – 1.02			0.992 ***	0.99 – 1.00	0.997 *	0.99 – 1.00
Walk Score of home location (ref cat: 0-49)								
Walk Score 50-69	1.05	0.65 – 1.69						
Walk Score 70+	1.75 *	1.14 – 2.69						
Accessibility by transit					1.03 ***	1.03 – 1.04	0.95 ***	0.94 – 0.97
Physical activity characteristics								
Transport PA hrs							0.94 *	0.88 – 0.99
Work PA hrs	1.09 *	1.01 – 1.17						
Mobility characteristics								
Access to vehicle					0.48 ***	0.34 – 0.69	3.79 **	1.45 – 9.88
Driver license							3.31 *	1.26 – 8.71

Owns bike	1.63 **	1.20 – 2.22	3.15 ***	2.08 – 4.76	1.88 ***	1.40 – 2.53	0.48 ***	0.33 – 0.70
Bixi member			1.92 **	1.25 – 2.96			0.09 *	0.01 – 0.86
Weekly transit rides					1.13 ***	1.09 – 1.18		
Transit non-commute					0.26 ***	0.18 – 0.38		
Attitudinal characteristics								
Transit positive attitude	0.72 *	0.54 – 0.96						
Cycling positive attitude			1.77 **	1.25 – 2.51				
Self-selection characteristics								
Having a large home					0.50 ***	0.38 – 0.65		
Familiarity with n'hood	0.72 *	0.54 – 0.95						
Near work/school					0.73 *	0.56 – 0.96	1.50 *	1.05 – 2.13
Near health services								
Schools for children								
Ease of car			0.56 ***	0.41 – 0.76			1.73 **	1.15 – 2.62
Near public transit			0.51 **	0.32 – 0.81	2.28 ***	1.48 – 3.50	0.50 **	0.33 – 0.76
Near bicycle			2.96 ***	2.14 – 4.10				
Intended trip purpose using the REM								
Commute	2.31 ***	1.69 – 3.16						
Non-commute					2.73 ***	1.73 – 4.30	0.41 ***	0.26 – 0.65
Multiple purposes	1.58 **	1.16 – 2.15	2.09 ***	1.48 – 2.95				
Personal reasons for intending to use the REM								
Good for environment	1.79 ***	1.34 – 2.39						
Shorter travel time	1.45 *	1.08 – 1.94						
More comfortable			1.35 *	1.00 – 1.82	1.41 *	1.08 – 1.84		
Random Effects								
σ^2	3.29		3.29		3.29		3.29	
τ_{00}	1.15 CT_UID		0.14 CT_UID		0.73 CT_UID		0.67 CT_UID	
Intra-class correlation (ICC)	0.26		0.04		0.18		0.17	
N	524 CT_UID		524 CT_UID		524 CT_UID		524 CT_UID	
Observations	1501		1501		1501		1501	
Marginal R^2 / Conditional R^2	0.334 / 0.506		0.397 / 0.421		0.348 / 0.466		0.626 / 0.689	

* p<0.05 ** p<0.01 *** p<0.001

CONCLUSION

This study on the determinants of intention to use the REM and determinants of intended first-mile mode choice yields insights that can contribute to efforts to promote shared and active modes of transport through better planning and design of LRT. Five general findings from this research are notable for policy and future research. First, like several previous studies (Lai and Chen, 2011; Sener et al., 2020; Şimşekoğlu et al., 2015), we found that while sociodemographic and environmental variables tend to be directly associated with propensity to use public transport, attitudes towards public transport appear to dominate. Second, we found that in the case of the REM, there is disparity in intention to use the new infrastructure across gender categories and income strata. Accounting for differences in geography, women are less likely to intend to use the REM than men, and lower income groups are less likely to plan on using the REM than higher income groups. Third, local accessibility, as measured by Walk Score, as well as regional accessibility seem to be negatively associated with the intention to the use the REM which could be attributed to the design of the REM which would provide benefits mainly to outlying areas not already well-served by existing public transport. Fourth, we also found that higher Walk Score is positively associated with choosing to walk to access the new LRT. Fifth, we find that increased physical activity and active lifestyles contribute positively to both intentions to use the new LRT and to choose an active mode of transport to fulfill the first-mile journey.

While our modelling approach benefits from a balance of simplicity, replicability, and rigor, it is limited in that it does not account for the complex causal links that are known to exist between various sociodemographic, spatial, and psycho-social factors that ultimately inform intention and then behaviour (De Vos et al., 2021a). This study nevertheless offers important practical insights that planners and policymakers may use to inform current and future projects. Key policy recommendations to promote system uptake and active modes of access include:

- ***Plan public relations, communications strategies, and consultations to improve attitudes towards new LRT projects***: Our study and others like it have found evidence that positive attitudes towards public transport and towards specific projects strongly encourage ridership, and negative ones inhibit it. Designing responsive consultations and communications strategies that address the root of concerns and amplify public enthusiasm are not only responsible activities but ones that can meaningfully promote ridership, according to our research. Attitudes are fundamentally rooted in personal values (Paulssen et al., 2014), which are more difficult to change and critical to understand in order to effectively alter future travel behaviour.
- ***Integrate the promotion of active lifestyles and active travel into LRT ridership promotion strategies***. Our study provides evidence that physical activity and existing active lifestyles are positively associated with adoption of LRT and likelihood of using a sustainable mode of transport to fulfill the first-mile journey to the station. Based on this, policies that promote physical activity, especially active travel, will benefit public transport ridership. These can include public health and design efforts through education, better transport infrastructure, and subsidies for facilitators of active lifestyles like

bicycles. Our findings suggest that these efforts could be framed in terms of not only the benefits they afford to public health and wellbeing but also to more efficient and sustainable urban transport systems.

- ***Promote more walkable design and mixed land use around stations.*** According to our findings, higher neighbourhood walkability are associated with walking to LRT stations. More walkable station areas can benefit ridership through their contribution to promoting active lifestyles, which could improve LRT ridership. Additionally, the built environment may play an important role in shaping attitudes that also benefit public transport ridership (De Vos et al., 2021b).

In future research, gender and income disparities in intended use of this LRT system should be investigated to ensure that this LRT systems and others contribute to the achievement of equitable transport systems. An equitable transport system is one that distributes the economic benefits of a project towards groups that are systemically disadvantaged through existing transport systems or otherwise (Pereira et al., 2017). Gender differences could be caused by a possible gender difference in perceptions of safety of LRT (Hsu et al., 2019) and additionally by differences in how well the REM fulfills demand for desired trip purposes by gender category.

As the data used in this study was collected prior to the COVID-19 pandemic, it will be valuable to investigate whether and how intention to use the REM has changed as a result of the pandemic. Planned future rounds of data collection as part of this project presents the opportunity to investigate this question.

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AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Villafuerte, DeWeese, Wasfi, Kestens, & El-Geneidy; data collection and/or cleaning: Cui, DeWeese, Wasfi, Kestens, & El-Geneidy; analysis and interpretation of results: Villafuerte, Cui, DeWeese, Wasfi, & El-Geneidy; draft manuscript preparation, Villafuerte, Cui, DeWeese, Wasfi, Kestens, & El-Geneidy. All authors reviewed the results and approved the final version of the manuscript.

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