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Thinking regional and acting local: Assessing the joint influence of local and regional accessibility on commute mode in Montreal, Canada

P. Lussier-Tomaszeski (Polytechnique Montreal) & G. Boisjoly (Polytechnique Montreal)*

*corresponding author
G.Boisjoly
Department of civil, geological and mining engineering
Polytechnique Montreal, Montreal, Canada, H3T 1J4
Email: gboisjoly@polymtl.ca

ABSTRACT

Accessibility indicators, measuring the ease of reaching destinations via a specific mode of transport, are increasingly used in planning and research as they support integrated land use and transport planning. Research has shown that increased local accessibility (walkability for example) is associated with an increase in walking mode share, whereas increase in public transport accessibility is associated with a greater use of public transport. Yet, while public transport agencies are promoting the combination of active and public transport options to address one's diverse mobility needs, local and regional accessibility are rarely addressed together in research or practice. This research aims to determine the joint influence of local and regional accessibility on the transport mode used for work trips in the Montreal metropolitan region, while controlling for socio-demographic characteristics. Data come from the 2013 Origin-Destination survey, 2016 Canadian census, 2017 public transport data and DMTI Enhanced points of interests. A multinomial logistic model is used to understand how local and regional accessibility are associated with walking, cycling or taking public transport to work across individuals. The results demonstrate that increases in both local and regional accessibility are associated with a higher probability of using sustainable modes. The predicted probabilities suggest that local accessibility is more closely associated with a decrease in car use. This study sheds light on the interaction between local and regional land use and transport systems and is of relevance to planners and policymakers wishing to develop neighborhoods that support the use of sustainable modes.

Keywords: Sustainable mobility, Accessibility, Commuting mode share, Transport planning

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INTRODUCTION

Governments, municipalities and transport authorities are increasingly promoting a combination of active transport modes (walking and cycling), public transport and shared mobility services to address households' diverse mobility needs and decrease car dependency (City of Stockholm, 2010; Communauté métropolitaine de Montréal, 2012; Gouvernement du Québec, 2018). At the same time, accessibility indicators, measuring the ease of reaching destinations via a specific mode of transport, are increasingly used in planning and research to support integrated land use and transport systems that foster the use of active and public transport modes (Acheampong & Silva, 2015; Boston Region Metropolitan Planning Organization, 2015; Metrolinx, 2016; Metropolitan Council - St-Paul, 2015; Transport for London, 2006). Yet, local (neighborhood) and regional (metropolitan) accessibility are rarely addressed together in research or practice, most research and applications focusing on either a single mode of transport or a comparison between car and public transport accessibility, or a combination of modes (e.g.: public transport and bicycle), mostly at the regional level (Benenson et al., 2011; Boisjoly & El-Geneidy, 2017a; Kelobonye et al., 2020; Salonen & Toivonen, 2013; Stentzel et al., 2016). For example, research has demonstrated that regional accessibility, by public transport, is a significant predictor of commuting mode share (Cui et al., 2020; A. Owen & Levinson, 2015; Wu et al., 2019), whereas local accessibility (for example at the neighborhood level) is associated with higher walking rates around home (Adkins et al., 2017; Cole et al., 2015). It is nonetheless expected that local accessibility can also play a significant role on commuting mode share, given its influence on habit formation, car ownership and accessibility to public transport (Moniruzzaman & Páez, 2012).

This study seeks to model the joint relationship between local and regional accessibility and the mode used to commute to work, while controlling for commuters' socio-demographic characteristics. Two accessibility measures are generated using a variety of data sources: (i) local accessibility on foot to services and amenities and (ii) regional accessibility to jobs by public transport. Using the 2013 Montreal Origin-Destination (OD) survey, a multinomial logistic model is generated to assess the likelihood of commuting by public transport, cycling or walking, as compared to the car, as a function of accessibility indicators and individual and household characteristics. This study sheds light on the interaction between local and regional land use and transport systems and is of relevance to planners and policymakers wishing to develop neighborhoods that support the use of sustainable modes. Also, by jointly modelling local and regional accessibility to understand commuting behaviours, this study presents a novel avenue for bridging an important gap in accessibility research.

LITERATURE REVIEW

Accessibility, the ease of reaching destinations, is a key measure of land use and transport interactions (Geurs & van Wee, 2004; Handy & Niemeier, 1997) that is increasingly included in land use and transport modelling and planning (Acheampong & Silva, 2015; Boston Region Metropolitan Planning Organization, 2015; Metrolinx, 2016; Metropolitan Council - St-Paul, 2015; Transport for London, 2006). As such, accessibility indicators are used by transport engineers and planners as they are especially relevant to model the benefits of land use and transport systems across a region.

A key outcome associated with accessibility is travel behavior. The literature has demonstrated that a series of factors influence the use of public transport, car or active modes, including socio-economic characteristics as well as transport and land use variables. As such, gender, age and household income are strongly associated mode choice (Buehler, 2011; Hamre & Buehler, 2014; Manaugh & El-Geneidy, 2011a; Sottile et al., 2019; Tilley & Houston, 2016; Ton et al., 2019). Among the land use and transport variables, diversity, density and access to destinations by a variety of modes have been identified as key determinants of mode share (Ewing & Cervero, 2010; Stevens, 2017).

More specifically, several studies have shown that greater accessibility to jobs by public transport is associated with a greater proportion of public transport commuters (Cui et al., 2020; Dill et al., 2013; Legrain et al., 2015; Moniruzzaman & Páez, 2012; A. Owen & Levinson, 2015; Wu et al., 2019), while it is conversely associated with lower car use (Ewing & Cervero, 2010). Such studies typically use place-based measures of accessibility to jobs, counting the number of jobs that can be reached within a specific travel time threshold, from every zone in a metropolitan region. For example, A. Owen and Levinson (2015) measured accessibility to jobs at peak hours for every census block, calculated as the number of jobs that can be accessed within different travel time thresholds, in the Minneapolis–Saint Paul. A mode share model was then developed and accessibility to jobs was found to be significantly associated with a greater share of public transport trips, while significantly improving the model fit. Similarly, in a study conducted across metropolitan regions in Canada, Cui et al. (2020) demonstrate that accessibility, measured as the number of jobs within 45 minutes by public transport of every census tract, is associated with a greater proportion of workers commuting by public transport. In line with this body of research, several metropolitan planning agencies now include such indicators of accessibility to jobs by public transport to support higher modal shares of public transport and reduce car dependency. For example, Transport for London and the Boston Region Metropolitan Planning Organization selected the number of jobs accessible within 45 and 40 minutes of travel time respectively as a key indicator (Boston Region Metropolitan Planning Organization, 2015; Transport for London, 2006). In a study conducted in Perth, Australia, Kelobonye et al. (2019) used a 30 minute threshold for job accessibility, in line with the "30-min cities" concept that was put forward by the national government.

Another stream of research focuses on the influence of the local environment on walking rates, through local accessibility measures. Typically, as is the case for regional accessibility, place-based measures are used, although calculated at a finer spatial resolution. The presence of local amenities and services, such as commercial and leisure destinations, within walking distances are calculated (Leslie et al., 2007; McCahill, 2018; Wasfi et al., 2016). Different thresholds are used by researchers, ranging typically from 400 to 1,500 metres, and rarely up to 2,400 metres (Frank et al., 2006; McCormack et al., 2008; Negron-Poblete et al., 2016; Vale et al., 2016). A commonly used measure of local accessibility, both in research and practice, is the Walk Score index (Chiu et al., 2015; Cole et al., 2015; Gilderbloom et al., 2015; Wasfi et al., 2016). The Walk Score is measured through the gravity-based approach, which discount destinations based on their distances. Destinations up to 2400 metres away are included in the calculation of the index. In this case, street connectivity is also included in the calculation of the indices. The association between the Walk Score and walking rates has been validated by several researchers (Carr et al., 2010; Duncan et al., 2011; Koschinsky et al., 2017; Weinberger & Sweet, 2012). Overall, research demonstrates that higher local accessibility is associated with a higher proportion of walking trips for non-work trips (Manaugh & El-Geneidy, 2011a; N. Owen et al., 2007). While other factors such as street connectivity and presence of pedestrian infrastructures can also be included, walking distances to destinations are central in local accessibility studies as they are strongly associated with walking (Ewing & Cervero, 2010).

Although few studies have explicitly assessed the joint influence of local and regional accessibility, research suggests that the local built environment does have an impact on the proportion of commuting trips made by car. In the early 2000s, Cervero (2002) demonstrated the contribution of local built environment attributes to commuting mode choice. Namely, land use diversity and density have been shown to be associated with a higher likelihood of commuting by public transport. Meta-analysis studies have later confirmed that these factors are associated with greater public transport use and lower car use (Ewing & Cervero, 2010; Stevens, 2017). Conversely, a recent study has demonstrated that local accessibility to non-work destinations is associated with a lower automobile mode share for commute trips (McCahill, 2018). Local accessibility to public transport facilities has also been shown to be associated with higher shares of public transport to commute to work, even when controlling for accessibility to employment by public transport (Ewing & Cervero, 2010; Moniruzzaman & Páez, 2012). Finally, in a specific study of Transit-Oriented-Developments (TOD) in Brisbane, Australia, Kamruzzaman et al. (2015) found that the proportion of commute trips made by public transport was associated with higher land use mix and densities, although all areas were located near rapid public transport stations. Furthermore, research has shown that travel behaviour, namely mode, is largely influenced by descriptive norms and symbolic factors (Anable, 2005; Buys & Miller, 2011; Lo et al., 2016). Accordingly, local environments developed around the automobile might support greater car use, although accessibility to jobs by public transport is relatively high. In a complementary manner, Barr et al. (2019) assessed how local and regional accessibility jointly related to walking, and found that both were associated with more minutes walking.

While a few studies have focused on specific local built environment or transport characteristics and their influence on commute mode share, no study has, to the authors' knowledge, focused on the joint contribution of both regional and local accessibility to commuting mode. This is also reflected in planning practices: local and regional accessibility are not addressed together in metropolitan plans (Boisjoly & El-Geneidy, 2017a). In fact, most plans only include regional accessibility indicators, without explicitly discussing indicators or objectives at the neighborhood level. The authors found one study explicitly analyzing the joint influence of local and regional accessibility, shopping trip distance and number of trips (Handy, 1993).The present study aims to fill the gap between local and regional accessibility research to provide a deeper understanding of how local and regional development can together contribute to reducing car use.

CASE STUDY AREA

The study area is presented below (**Figure 1**) and represents the Montreal Census Metropolitan Area (CMA), which is divided into eight regions and comprise around 4 million residents. Downtown Montreal is the economic pole of the CMA, with higher densities of population and jobs found in central neighborhoods. Most of the areas located outside the island of Montreal consist of lower-density suburbs, whereas the West and East regions of the island are characterized by a mix of suburban and mixed-used neighborhoods.

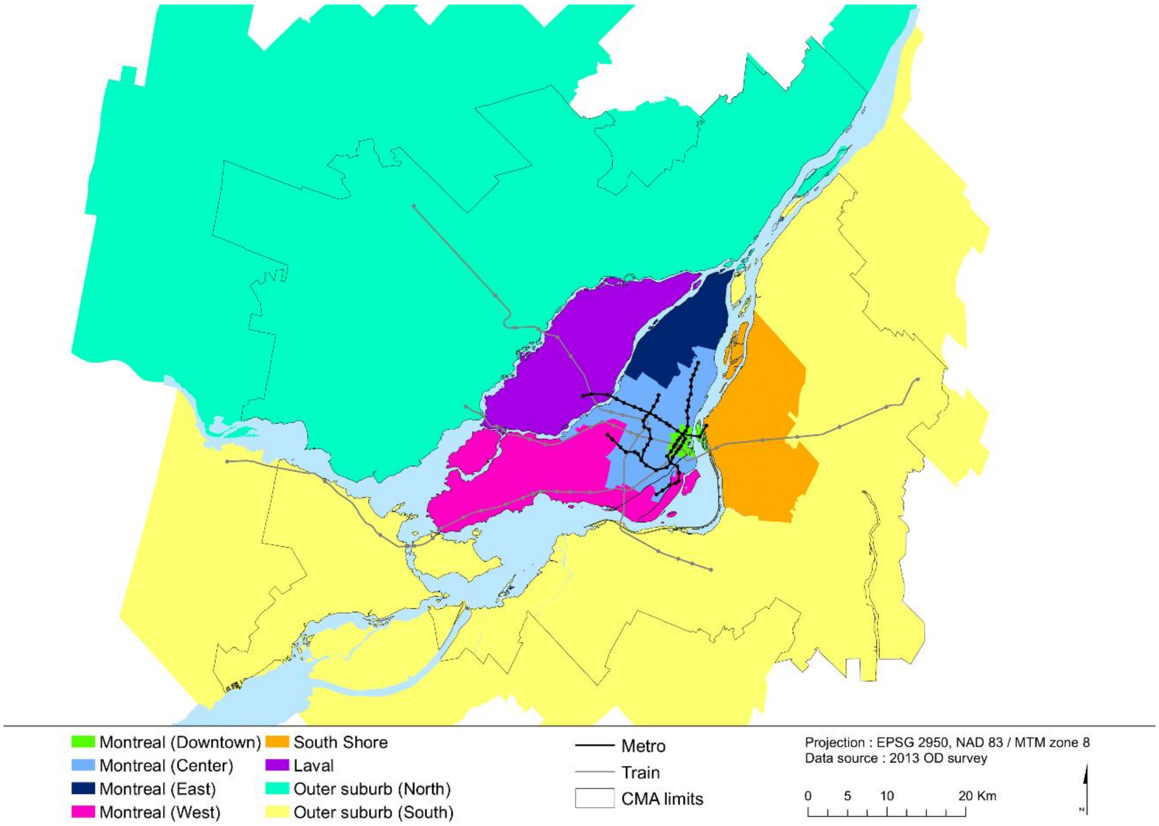

Figure 1 Montreal Census Metropolitan Area

Montreal CMA's recent development has been largely influenced by a car-oriented approach. As a result, a large proportion of household rely on the private automobile: as of 2013, 64% of commuters travelled to work by car (Lachapelle et al., 2020). While the region wants to increase the share of trips made by sustainable modes, it faces several challenges. The public transport network is mainly concentrated in central areas. It consists of four metro lines, all located in the Center of Montreal with a few stations in Laval and the South Shore, and a commuter rail network mainly designed to connect suburban areas to downtown. The bus system covers most of the territory, but its frequency and performance vary significantly between neighborhoods. The central areas are characterized by a high density of bus routes, with high-frequency service. In contrast, the suburban areas have limited bus lines and frequencies. Furthermore, with the exceptions of the central neighborhoods (mainly located in the Montreal Downtown and Center regions), the CMA is dominated by low-density, single-used neighborhoods.

DATA AND METHODS

The key data source used in this study is the 2013 Montreal regional travel survey (Origin-Destination (OD) survey). The OD survey is a quinquennial survey which provides a trip-based dataset describing all trips made by a household the day prior to the survey. The survey is typically conducted in the fall and surveys approximately 5% of the households on the territory. As typically done in regional accessibility studies, and since this is the focus of the present research, the analysis is based on the transport mode used to get to work and only trips originating from home are included in the model. As a result, only home-based work commute trips were selected for the analysis. Also, only workers (full-time or part-time) were included. The transport mode was divided into four categories: private car (driver or passenger), public transport (metro, bus, train), cycling and walking. Other types of transport, such as taxi trips, were excluded as they did not represent a significant number of trips. After removing incomplete data, the dataset is composed of 37,090 observations, where each observation represents a trip made by a worker from home to work.

Two measures of accessibility were generated and combined with the OD data, based on the workers' home location. Cumulative-opportunity measures, which are commonly used in research and practice, were calculated as they have been shown to be highly correlated with gravity-based measures (Boisjoly & El-Geneidy, 2016; El-Geneidy & Levinson, 2006). These measures represent the number of opportunities that are available within a specified travel time threshold, using a specific mode, and are calculated as follows:

$$A_i = \sum_{j=1}^{n} O_j f(C_{ij}) \qquad (1)$$

$$f(C_{ij}) = \begin{cases} 1 \text{ if } C_{ij} \leq t \\ 0 \text{ if } C_{ij} > t \end{cases} \quad (2)$$

where A_i is the accessibility at point i to all opportunities in zone j, O_j the number of opportunities in zone j and $f(C_{ij})$ the weighting function. C_{ij} represents the time cost of travel from the centroid of zone i to the centroid of zone j and t, the travel time threshold. To generate such measures, two types of information are required. The first one concerns the location of destinations, while the second one allows the calculation of the travel time matrix (travel times between origins and destinations).

Regional accessibility was defined in this study as the number of jobs accessible by public transport within 45 minutes of travel time and departing at 7 am on a weekday, at the census tract level. As found by Boisjoly and El-Geneidy (2016), the peak-hour measure is adequate to model travel behaviour. As for the 45-minute travel time threshold, this is the most commonly used for accessibility goals and indicators included in metropolitan transport plans (Boisjoly & El-Geneidy, 2017b). This threshold is namely used by the transport planning authority in Montreal (Authorité régionale de transport métropolitain (ARTM), 2020). These parameters are consistent with the ones typically used in regional accessibility research and applications. Travel times were calculated between census tracts centroids using 2017 GTFS data and the number of jobs by census tract was obtained from the 2016 census.

For local accessibility, the number of services and amenities within 1500 metres of walking distance were considered. Highways were excluded from the street network to exclude non-walkable areas. The following destinations have been selected, as done in previous studies and indicators (Leslie et al., 2007; WalkScore, 2020; Wasfi et al., 2016): supermarkets and grocery stores, pharmacies, daycare, primary and secondary school, restaurants and banks. These destinations are typically included in local accessibility studies as they represent services and amenities that are associated with higher walking rates when within walking distances (Wasfi et al., 2016). The location of services and amenities was obtained from 2014 DMTI Enhanced Points of Interest dataset. Local accessibility was measured at the dissemination area level, to better capture local variations of the built environment. Knowing that the average distance walked by Montrealers is around 1000 metres (Lachapelle et al., 2020), a threshold of 1500 metres has been selected, to include destinations that are potentially within walking distance.

To explore the joint relationship between local and regional accessibility and the mode used to commute to work, a multinomial probabilistic model was generated, where the dependent variable is the mode used to commute to work. Since most trips were made by car (71% as shown in **Table *1***), and since this study is specifically interested in how land use and transport networks can reduce car use, the car was selected as the reference category. Local and regional accessibility were associated with each observation based on the home location of the respondent. More specifically, the accessibility value of the area (census tract or dissemination area) in which the home is located was attributed.

The dependent variables were selected based on the literature review and using a stepwise approach. **Table *1*** presents the summary statistics of all variables used included in the final model. Transport mode, gender, household income, driver's licence and departure time are represented as factor variables. The household income was grouped into three categories. For the departure time class, peak represents trips made from 6 a.m. to 9 a.m. and from 3.30 p.m. to 6.30 p.m. Off-peak represents all other departure times. In line with the literature on travel behaviour and since as it improved the model fit, age was included with a squared term. Regional accessibility and local accessibility are represented as numeric variables. As commonly done in accessibility research (Manaugh & El-Geneidy, 2012; Paez et al., 2010), a standardized score was computed for local and regional accessibility, using the z-score formula, to facilitate the interpretation of the results. This allows translating accessibility measures into relative accessibility, reflecting the accessibility of an observation relative to the rest of the population.

A car ownership variable has also been tested in the model, but as it often the case, it was highly correlated with income and affected the stability of the model. It was therefore removed from the final model. Another reason for removing car ownership, and keeping the income variable instead, is that car ownership is also largely influenced by local and regional accessibility.

Table 1 Summary statistics of the variables included in the multinomial logistic regression model (N=37,090)

	Number of observations (%)		
Transportation mode			
Car	26,382 (71)		
Public transport	7,848 (21)		
Bike	960 (3)		
Walk	1,900 (5)		
Age of respondent			
min	16		
median	46		
max	87		
mean (sd)	44 ± 12		
Square age of respondent			
min	256		
median	2116		
max	7569		
mean (sd)	2,111 ± 1,050		
Gender of respondent			
Man	19,389 (52)		
Woman	17,701 (48)		
Respondent's income class			
Low (< $59,000)	12,523 (34)		
Medium ($60,000 to $119,000)	17,027 (46)		
High (> $120,000)	7,540 (20)		
Driver's licence			
Yes	33,856 (91)		
No	3,234 (9)		
Departure time			
Peak	25,540 (69)		
Off-peak	11,550 (31)		
Number of people in the household			
min	1		
median	3		
max	13		
mean (sd)	3 ± 1		
Relative local accessibility		**Absolute local accessibility**	
min	-0.64	min	0
median	-0.37	median	45
max	11.40	max	1998
mean (sd)	-0.00 ± 1.00	mean (sd)	105 ± 165
Relative regional accessibility		**Absolute regional accessibility**	
min	-0.87	min	210
median	-0.63	median	70065
max	2.23	max	910910
mean (sd)	-0.00 ± 1.00	mean (sd)	251,612 ± 288,635

RESULTS

Figure *2* shows the spatial distribution of local accessibility to services and amenities across the territory, by quintiles, aggregated at the census tract level to allow comparison with regional accessibility and mode share. As shown in **Table *1***, local accessibility ranges from 0 to 1998 with a median of 45. As expected, local accessibility is higher in central neighborhoods, where there is a high density and mix of usage. This results in a high number of services and amenities that are within walking distances. Also, most areas located near metro stations are within the 4^{th} and 5^{th} quintile of local accessibility. In contrast, almost all areas near train stations are characterized by lower levels of accessibility (1^{st} to 3^{rd} quintile). Finally, most areas located in the outer suburbs are within the lowest accessibility quartile, with the exception of a few clusters.

Regional accessibility to jobs, by public transport, is presented on **Figure *3***. The first observation is that regional accessibility is more extended across the island of Montreal than local accessibility, with only a few census tracts within the 1^{st} and 2^{nd} quintile, mainly at the eastern and western tips of the island. We can also more clearly see the impact of metro stations on regional accessibility: all census tracts characterized by the highest accessibility quintile are located around metro stations. This is not surprising, as the public transport system in the Montreal region is mainly designed around the metro network. As a result, the metro offers a rapid access to a high number of jobs distributed across the region. Looking now at the near suburbs (Laval and the South Shore), regional accessibility is typically lower than in the central areas of the island, except for a few areas near metro stations. Finally, census tracts located in the outer suburbs are mainly characterized by the lowest accessibility quintile, with the exception of a few census tracts near commuter rail stations.

The two maps (**Figure *2*** and **Figure *3***) present distinct accessibility patterns, suggesting discrepancies in the relative levels of local and regional accessibility. Namely, some areas exhibit relatively high levels of regional accessibility, whereas their local accessibility is relatively low. This is the case in several census tracts in the West portion of Montreal. We see mostly a high level of regional accessibility, but a mostly low level of local accessibility. This area is typically well connected to jobs by public transport, but the built environment is not as favourable to walking as in the central neighborhoods.

Interestingly, many of these areas are characterized by a high percentage of individuals commuting by car (more than 72%), as depicted in **Figure *4***. Conversely, central neighborhoods on the island of Montreal and areas near metro stations are characterized by a higher share of public transport, cycling and walking commuters. These are areas that present high levels of both regional and local accessibility. Outside the island of Montreal, the distribution of commuting mode shares is more uneven. Along several train stations, the percentage of individuals commuting by car is relatively high (more than 83%). This supports the hypothesis that for people living in areas with relatively high levels of regional accessibility but low levels of local accessibility, a high proportion of them rely on car to access work.

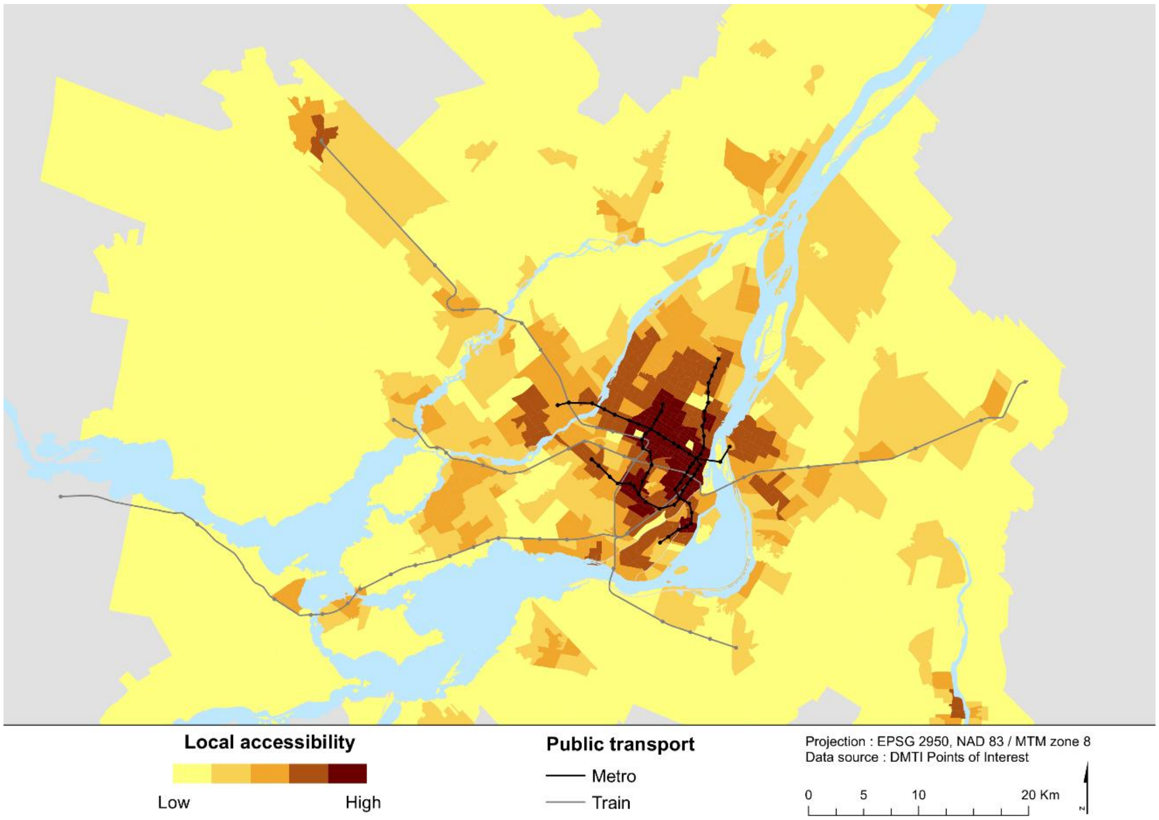

Figure 2 Local accessibility on foot to amenities and services in the Montreal CMA

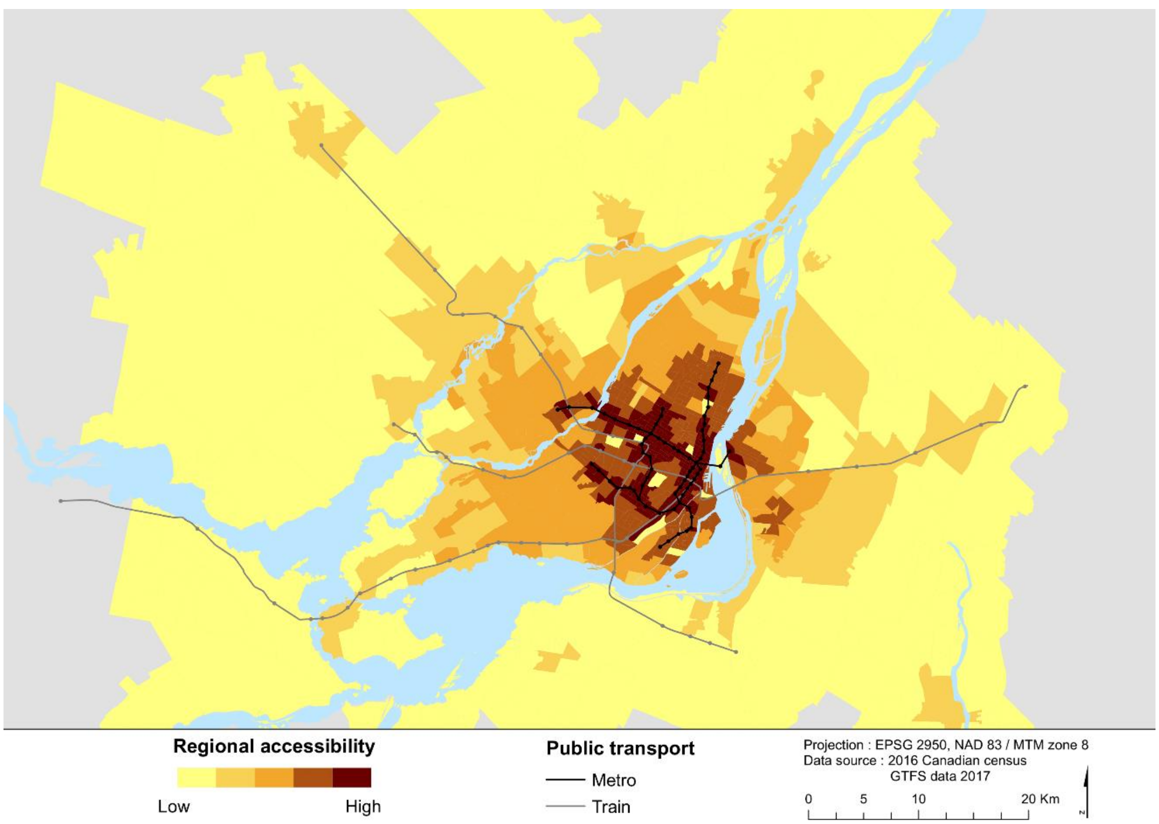

Figure 3 Regional accessibility to jobs by public transport in the Montreal CMA

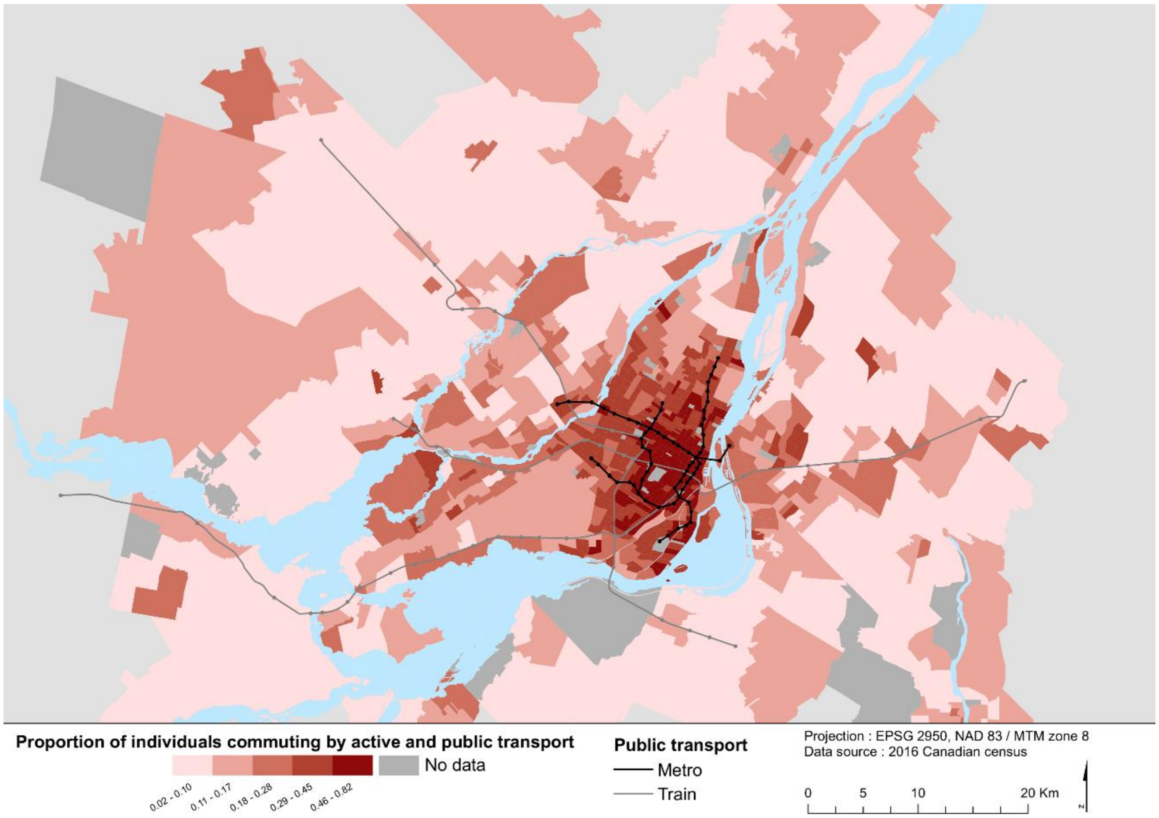

Figure 4 Proportion of individuals commuting by active and public transport in Montreal Census Metropolitan Area, based on the 2016 data

To further explore the relationship between local accessibility, regional accessibility and commute mode, **Figure *5*** presents the percentage of commuting trips made by car as a function of the regional accessibility quintile (x-axis). Then, each line represents a local accessibility quintile, with the blue lines being associated with the lowest levels of local accessibility. Consistent with the literature, the modal share of car decreases as regional accessibility to jobs, by public transport, increases. Most importantly, as a general trend, for the same level of regional accessibility, the proportion of commuting trips made by car decreases as local accessibility increases. For example, for the 4th regional accessibility quintile, around 68% of commuting trips are made by car for the first three quintiles (lower local accessibility), while the proportion of the commuting trips made by car is only 48% for the last quintile (highest local accessibility). This is a diminution of 20 percentage points. Therefore, within similar regional accessibility levels, local accessibility seems to have an impact on the use of the car for commuting to work in the CMA. As there are very few areas with very low regional accessibility and very high local accessibility, few trips are made in these quintiles, explaining the absence of data for the low-low combination.

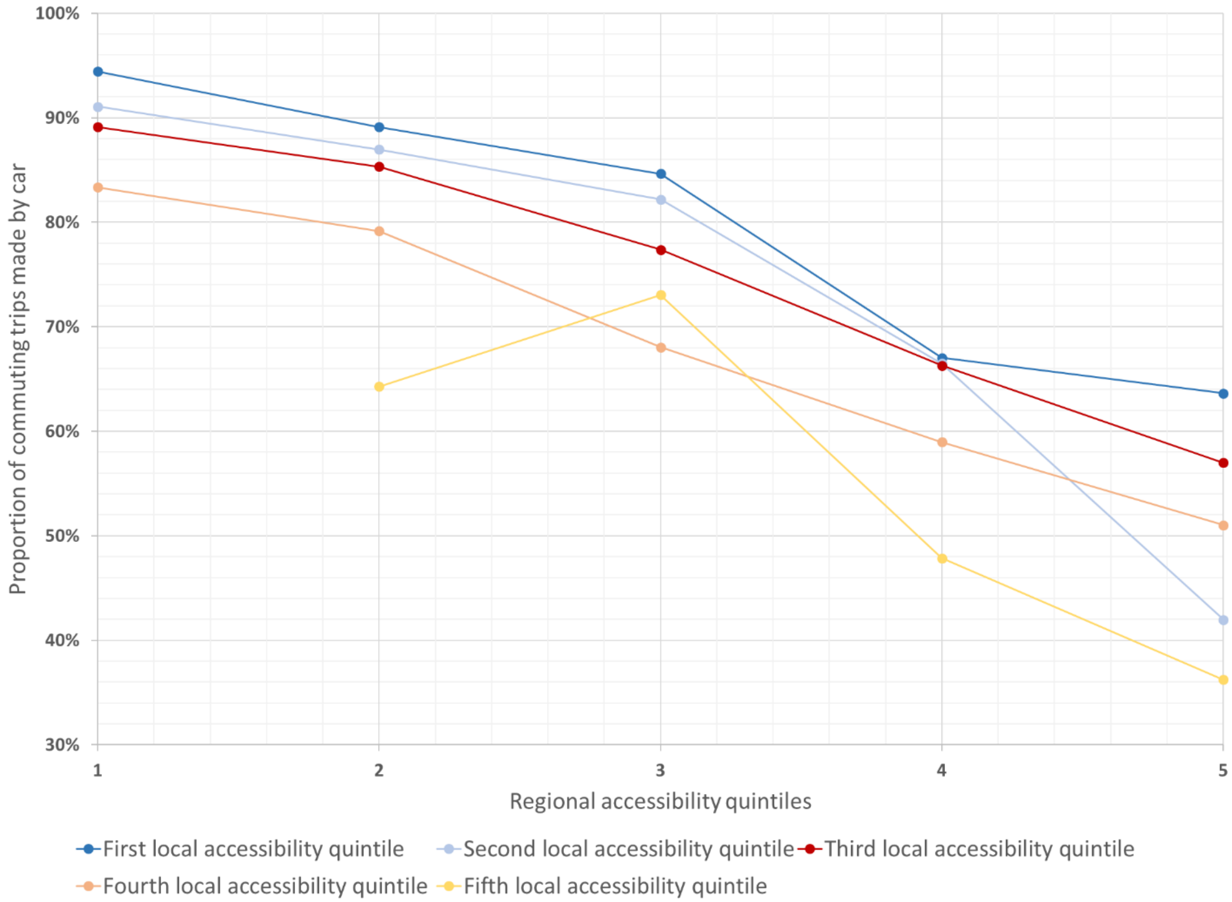

Figure 5 Proportion of car trips for work motives according to local and regional accessibility quintile

The results of the multinomial logistic regression model, controlling for socio-demographic characteristics, are presented in **Table 2**. The dependent variable is the mode used to commute to work, with the car as the reference. For each mode (public transport, cycling and walking), the probability of using this mode instead of the car is estimated.

Starting with the socio-demographic characteristics, the results are generally consistent with the literature. As expected, not having a driver's licence is significantly associated with a higher probability of commuting by public transport, cycling and walking. Being a woman is significantly and positively associated with walking and using public transport, while the inverse relationship is observed for cycling, as found in previous studies (Buehler, 2011; Tilley & Houston, 2016). Also, as found in the literature, workers within low- and medium-income households are more likely to commute by public transport and on foot compared to their counterparts in high-income households (Ton et al., 2019). With respect to cycling, medium-income household workers are more likely to cycle, whereas low-income household workers are less likely (although in this case, the variable is non-significant). This is consistent with the literature, which found both positive and negative associations between income and cycling (Hamre & Buehler, 2014; Manaugh & El-Geneidy, 2011a; Sottile et al., 2019; Ton et al., 2019). A quadratic relationship is observed with respect to age. For public transport and cycling, the probability of using this mode first increases with age, and then decreases from the age of 24 and 32 for public transport and cycling respectively. The opposite relationship is observed for walking from the age of 45. When the number of people in the household increases, the probabilities of walking or using public transport decrease compared to the car. Finally, commuting during off-peak hours is associated with a lower probability of commuting by public transport, which is likely due to the low frequency of service outside peak hours (Lachapelle et al., 2020). Conversely, the probability of walking as compared to commuting by car increases, which is potentially related to the presence of traffic during peak hours.

Looking now at the variables of interest, regional and local accessibility, both are significantly and positively associated with a higher likelihood of using public transport, walking and cycling, as compared to the car. This suggests that both variables have an influence on the mode used to commute to work, even when the other one is controlled for. The same model, without the local accessibility variable, has been tested and resulted in a lower Log-Likelihood and McFadden R^2, suggesting an increase in the model performance when local accessibility is included. A likelihood ratio between the two models has been conducted and resulted in a small p-value (<2e-16), indicating that the inclusion of the local accessibility variable is a significative improvement of the model. It is also important to note that the model remained stable.

Table 2 Results of the logistic regression model explaining the transportation mode used to get to work

	PUBLIC TRANSPORT			WALK			BIKE		
Variables	**Coefficient estimate**		**Prob-value**	**Coefficient estimate**		**Prob-value**	**Coefficient estimate**		**Prob-value**
Mode (intercept)	**-2.32E+00**	***	< 2.00E-16	**-3.24E+00**	***	< 2.00E-16	**-5.15E+00**	***	< 2.00E-16
age	**1.56E-02**	.	5.48E-02	**-4.97E-02**	***	4.90E-05	**3.71E-02**	.	5.88E-02
age^2	**-3.30E-04**	***	4.50E-04	**5.59E-04**	***	6.00E-05	**-5.92E-04**	**	9.25E-03
Woman	**2.75E-01**	***	< 2.00E-16	**5.65E-01**	***	< 2.00E-16	**-3.38E-01**	***	2.10E-06
Income									
Low	**2.10E-01**	***	2.00E-06	**3.71E-01**	***	2.30E-06	**-1.40E-01**		1.84E-01
Medium	**1.33E-01**	**	1.30E-03	**1.33E-01**	.	8.09E-02	**2.89E-01**	**	1.97E-03
No driver's licence	**2.97E+00**	***	< 2.00E-16	**2.73E+00**	***	< 2.00E-16	**2.23E+00**	***	< 2.00E-16
Off peak	**-5.32E-01**	***	< 2.00E-16	**1.81E-01**	***	7.50E-04	**-1.42E-01**	.	5.84E-02
Number household's people	**-7.05E-02**	***	6.80E-08	**-5.34E-02**	*	1.79E-02	**-5.58E-02**	.	5.99E-02
Relative local accessibility	**1.28E-01**	***	2.60E-09	**5.23E-01**	***	< 2.00E-16	**3.15E-01**	***	< 2.00E-16
Relative regional accessibility	**7.95E-01**	***	< 2.00E-16	**5.10E-01**	***	< 2.00E-16	**1.04E+00**	***	< 2.00E-16

Log-Likelihood:	-24100
McFadden R^2:	0.204
Number of observations:	37 090

Since the magnitude of the coefficients in a logistic regression cannot be directly interpreted, **Table *3*** presents the predicted probabilities for the minimum, median and maximum values of local and regional accessibility respectively, while other variables are kept at their mean. Looking at the minimum and maximum values of local accessibility, the probability of commuting by car starkly decreases (from 0.69 to 0.05) when the value of accessibility decreases. As expected, most of this decrease is compensated by a stark increase in the probability of walking, from 0.02 to 0.76. Nonetheless, the probability of using public transport also increases with local accessibility: it is in fact around three times higher when local accessibility increases from its minimum to its maximum value (0.04 to 0.13). Finally, the probability of cycling decreases with local accessibility. This is likely due to the fact that individuals may opt for walking instead of cycling when local accessibility is high, as local accessibility is more closely associated with the presence of destinations within walking distance.

The probability of using the car also decreases significantly (from 0.90 to 0.42) when regional accessibility goes from its minimum to its maximum value, although to a smaller extent than for local accessibility. This decrease is compensated by an increase in the probabilities for all other modes, especially public transport and cycling, where the probability increases by 0.09 (9 percentage points) and 0.37 (37 percentage points) respectively. The probability of walking increases by 0.2.

Taken together, the results suggest that increases in local and regional accessibility, when all other variables are kept constant, are associated with a comparable increase in the probability of commuting by public transport (almost 10 percentage points between the minimum and maximum values). Yet, with respect to car commuting, the probability decreases more importantly when local accessibility increases (64 percentage points vs 48 percentage points for regional accessibility). This has important implications in terms of metropolitan transport planning, as most efforts are typically concentrated on increasing regional accessibility.

Table 3 Predicted probabilities for varying values of local and regional accessibility

Local accessibility	**Minimum (0)**	**Median (45)**	**Maximum (1,998)**
Car	0.69	0.68	0.05
Public Transport	0.04	0.04	0.12
Walk	0.02	0.02	0.76
Bike	0.25	0.26	0.08
Regional accessibility	**Minimum (210)**	**Median (70,065)**	**Maximum (910,910)**
Car	0.90	0.88	0.42
Public Transport	0.01	0.01	0.10
Walk	0.01	0.02	0.03
Bike	0.08	0.09	0.44

Lastly, since the variations in probabilities depend on the initial values of accessibility, the marginal effects were also calculated for the minimum, median and maximum values of local and regional accessibility respectively, while other variables were kept at their mean. These effects, presented in **Table 4**, represent the change in the probability of using a mode when the independent variable changes by one unit (in this case, 1 point in the standardized score of accessibility). As a general trend, the changes in the probability of using a mode are higher at the minimum and median accessibility values, both for local and regional accessibility. For example, the probability of walking decreases by 0.51% and 0.13% with an increase of 1 unit from the minimum and maximum values of local accessibility respectively. With respect to the minimum and maximum values of regional accessibility, the probability of using public transport increases by 0.79%, 0.71% respectively. This suggests that efforts aiming at improving local and regional accessibility in areas with lower levels of accessibility are likely to yield better results.

Table 4 Marginal effects (in percentage) for varying values of local and regional accessibility

Local accessibility	**Minimum (0)**	**Median (45)**	**Maximum (1,998)**
Public Transport	0.12	0.12	0.11
Walk	0.51	0.51	0.13
Bike	0.23	0.23	0.29
Regional accessibility	**Minimum (210)**	**Median (70,065)**	**Maximum (910,910)**
Public Transport	0.79	0.79	0.71
Walk	0.50	0.50	0.49
Bike	0.96	0.94	0.58

DISCUSSION AND CONCLUSION

This paper assessed the joint influence of local and regional accessibility on the mode used to commute to work in the Montreal CMA, using the 2013 Montreal OD survey. Local measures of accessibility to services and amenities, by walking, and regional measures of accessibility to jobs, by public transport, were generated. The results show distinct spatial patterns for local and regional accessibility, several areas exhibiting relatively high levels of regional accessibility, but relatively low levels of local accessibility. The analysis demonstrates that for similar levels of regional accessibility, the modal share of car decreases as local accessibility increases, highlighting the joint influence of both accessibility. The results of the multinomial regression confirm that both local and regional accessibility are associated with a decrease in car use to commute to work, and conversely with an increase in walking and public transport. Furthermore, local accessibility seems to be more closely associated with a decrease in the probability of commuting by car.

These results have significant implications in terms of transport policies, both from a sustainability and an equity perspective. First, the results suggest that increasing local accessibility in the Montreal metropolitan region could play an important role in supporting modal shift from the car to more sustainable modes (public transport, cycling and walking). This could also contribute to reducing car dependency, thereby reducing the social inequities associated with car-dependent societies (Banister, 2019). Another important point is that increasing local accessibility contributes to a much higher probability of walking, which is a mode that low-income individuals and individuals without access to a car often rely on (Manaugh & El-Geneidy, 2011a, 2011b). This is in line with the findings of a recent report suggesting that increasing local accessibility in areas concentrating low-income households is an avenue for increasing transport equity in the region (Lachapelle et al., 2020). Furthermore, the changes in the probability are especially important in areas with lower levels of local and regional accessibility. While a lot of efforts have been placed in central neighborhoods in recent years, the findings suggest that improving local and regional accessibility outside these areas could contribute to achieving a higher share of commuters using sustainable modes to access work.

There are some limitations to this study. First, public transport travel times were calculated during the peak-hour period and do not explicitly account for the frequency of public transport services. Since frequency of service is known to affect travel behaviour and public transport accessibility varies throughout the day, the current measure of regional accessibility might be overestimating the level of regional accessibility provided to commuters throughout the day. It is important to note, however, that the model has been tested by only including workers commuting during the peak-hour periods and the results were consistent. Second, cumulative-opportunity measures were selected, as they are most commonly used and easily applicable to planning, but they are less theoretically sound than gravity-based measures. Building on the present study, further efforts could be deployed to test different measures of local and regional accessibility and assess how they relate to the commuting mode. Similarly, different threshold times could be investigated. While local accessibility focused here on distances, an interesting avenue would be to assess accessibility measures that include features of the built environment, such as the presence and quality of pedestrian infrastructure and the street design. Further research could also address bicycle accessibility by developing a measure that accounts for the presence of bicycle lanes. Similarly, car accessibility could be included in future studies to account for the differentiated levels of access by different modes. In terms of accessibility by public transport, different spatial and temporal refinements could also be tested. On another note, while this study has focused on the commuting mode, further research could assess the joint effect of local and regional accessibility on the mode used for other trip purposes, namely shopping. Other outcomes such as vehicle miles travelled and car ownership could also be explored. Also, future studies could delve deeper into the specific factors and mechanisms related to varying levels of accessibility and that contribute to reducing car use, namely through questionnaires and qualitative methods. Nonetheless, the study has contributed to shed light on the determinants of car use to commute to work and demonstrated the relevance of modelling commuting mode as a function of both local and regional accessibility indicators. This study is, to our knowledge, the first one to bridge this gap.

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