Driving to Suburban Rail Stations

Understanding Variables That Affect Driving Distance and Station Demand

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Current research focuses on pedestrian access to transit; however, commuter trains in outlying urban regions serve populations in low-density areas where many people drive rather than walk to transit services. The determinants that influence how far people are willing to drive to train stations and the factors that determine boardings at suburban train stations have not been formally studied. This paper models suburban commuter travel demand by use of the 2003 Montreal, Quebec, Canada, origin–destination survey and onboard survey data from the Agence Métropolitaine de Transport to identify characteristics of individual trips and station characteristics that influence the driving distance to commuter rail and demand at stations. The models show that methods for estimating pedestrian access distance and number of boardings per transit stop can easily be transferred to estimating driving access distance and the number of boardings per station in the park-and-ride context. The model for passenger boardings by station can be used for estimating either demand for a planned station or the effect of service interventions (e.g., parking spots) on boardings at existing stations. The paper also shows that these approaches can be a valuable tool to transit planners interested in increasing passenger demand on commuter rail through a better understanding of service characteristics.

Public transit agencies are trying hard to provide reliable transit service between suburbs and main employment centers. In doing so, several transit agencies have built commuter rail lines to the suburbs and provided park-and-ride facilities. The aims of these services are to decrease the total number of vehicles entering employment centers and to relieve congestion levels along existing networks, especially in older city centers. Transit accessibility to commuter rail stations should consider accessibility by private vehicle, because an important proportion of trips to train stations is by car. The study described in this paper examines the effects of station and individual characteristics on passenger demand and driving distances for commuter rail services in Montreal, Quebec, Canada. The analysis presented in this paper uses methods developed in evaluating pedestrian access to transit to the park-and-ride context. In so doing, the factors influencing how far people are willing to drive to commuter rail stations are evaluated. Service catchment areas based on driving distances are also developed to understand service and facility characteristics that attract users. A better understanding of train commuter travel behavior will enable the enhancement of commuter rail services to increase ridership and achieve some of the sustainability goals that local transportation agencies are trying to reach.

The paper begins with a literature review of transit performance measures, which is followed by a description of the study region. The next section details the methodology, data, and results for the model for driving distance to rail station (distance to station model). The subsequent section describes the model for passenger boardings by station (passenger boardings model). The final sections include a discussion of the model results and concluding remarks.

LITERATURE REVIEW

The aim in improving the attractiveness of commuter rail is to encourage users to switch from driving all the way to their destination to using public transit as part of their trip. Transit can be more attractive by having a shorter travel time than driving by car (*1, 2*). Encouraging a mode shift to public transit can help decrease congestion and negative environmental impacts (*2, 3*). Park and ride is accompanied by two cold starts per day, which contributes to overall car emissions. However, cold starts in a suburban area have less of an effect on the urban environment, because leafy streets and lawns help generate net carbon sinks during the spring and summer (*4*). Therefore, attracting riders to use park-and-ride facilities is expected to have a sustainable outcome, although not as much as that from walking to transit. It is noteworthy that designing commuter trains with high speeds to which all users have access by walking is not possible, because commuter trains can make only a few stops to maintain high speeds and low-density suburbs would require many stops, which would render high-speed rail inefficient (*5*). The alternative is to provide reliable high-speed rail services that can be supported by either feeder buses or park-and-ride facilities. Both methods help in increasing the level of access to transit (*1*), but the feeder bus option is more costly, especially in suburban environments.

Transit access measures the ease with which residents and workers can reach transit services (*6*). Free parking near transit stations can encourage commuters to use rail instead of driving the entire trip distance (*7*). Wulkan and Henry emphasize that residents of outlying areas of cities mostly drive to transit (*8*). Park-and-ride facilities can attract commuters to use rail when they otherwise would have driven directly to employment centers (*9*). Merriman's study found that an increase in boarding based on increased capacity diminishes over time, and each new parking space is able to attract only one new rider;

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depending on the time period, a parking space can attract anywhere from 0.6 to 2.2 new passengers (*10*).

Murray defines transit access as the ability to reach a destination (*3*). Service reliability (consistency in on-time performance and maintaining headways) makes it easier for users to coordinate arrival at rail stations with transit arrival times, thus reducing waiting time (*11*). Most transit access research has focused on pedestrian access. In pedestrian research, individual, household, and station or stop characteristics have been found to affect the distances that people are willing to walk to a transit facility (*12, 13*). These same characteristics are expected to have an effect on driving distance to rail stations, yet at a different scale.

Transit service areas provide an understanding of the portion of the population that is served by transit (*6, 14, 15*). Service areas are used to understand the demand for transit. They can be generated by using either network or Euclidean buffers in a geographic information system environment. It is widely acknowledged that network buffers provide more accurate estimates of distances and coverage areas (*7, 14, 16*). Transit service areas are commonly measured by using a given threshold distance in which people are willing to walk to transit. Because demand around transit stations is not equally distributed, distance decay curves are often used to understand the demand in service areas better (*6, 12, 13, 15, 17*). Distance decay measures the probability of traveling to a station as a function of travel impedances (*18, 19*). This measure was first introduced in planning with Hansen's (*20*) explanation of gravity-based measures of accessibility (*14, 15, 21*). Zhao and colleagues used the 2000 Southeast Florida travel survey to calculate an exponential decay curve based on walking distances to transit services (*6*). Kimpel and colleagues compared different distance decay functions and multiplied the population in an area by the decay curve function (*15*). This output is used to estimate transit demand at individual transit stations. They estimated their distance decay functions without using travel survey data, and the functions were mainly based on trial and error. Generation of accurate distance decay curves with travel survey data is expected to produce a better representation of service areas that can be used to estimate demand in a similar manner.

CASE STUDY

Montreal is the second most populous metropolitan region in Canada, with 3.7 million residents in 2006. The Agence Métropolitaine de Transport (AMT) is an agency created by the Quebec Ministry of Transport that is responsible for regional transit in the Montreal metropolitan region. In this study, the region served by AMT will be used as the case study. AMT operates five commuter rail lines, 16 intermodal terminals, 60 park-and-ride facilities, two express bus routes, and 85 km (52.82 mi) of bus, taxi, or high-occupancy vehicle lanes. Figure 1 shows a map of the Montreal metropolitan region and commuter rail lines.

According to the 2003 Montreal origin–destination (O-D) survey, 69.3% of trips are made by car, 13.7% by public transit, 10.2% by foot, 4.8% by school bus, and 1.1% by bicycle during a 24-h period for all trip purposes (*22*). The O-D survey is conducted every 5 years and samples approximately 5% of households in the Montreal region. The survey records the trips of all individuals in the household for a typical day. It includes information on the transport modes used for each trip, as well as detailed public transit routes. The data include *x* and *y* coordinates for the origin, junction (e.g., transit station), and destination (*22*). For trips by train, 38.3% of respondents reached the train station by car, 13.3% went as car passengers, 34.3% went by foot, and 14.1% went by bus. The trip purposes for people using commuter rail in Montreal were 77% for work, 21% for school, and 2% for some other purpose. The destination of 72% of train users is the downtown area.

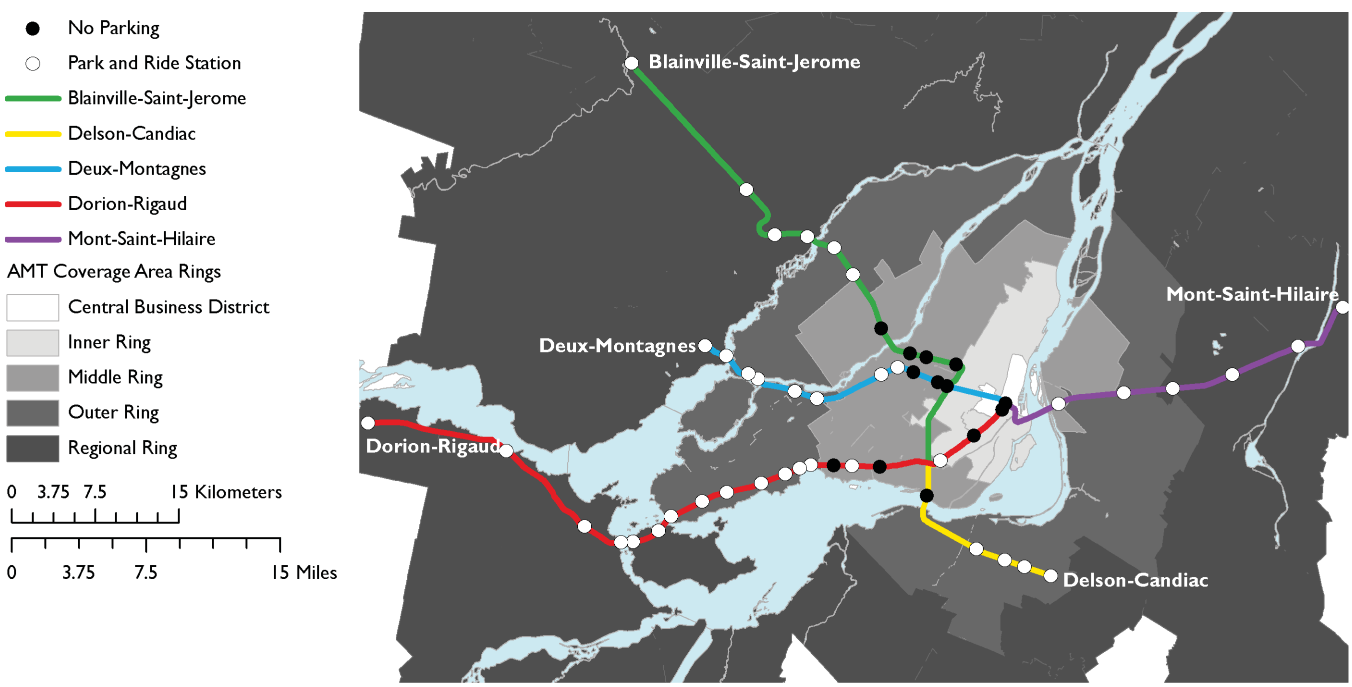

FIGURE 1 AMT commuter rail stations (Projection NAD 1983 MTM 8). (Source of data: DMTI Spatial data, Agence Métropolitaine de Transport.)

ANALYSIS

The analysis includes two statistical models. The first model estimates driving distance to rail, whereas the second model estimates passenger demand at the station. The objective of the first model is to understand the distances driven to commuter rail stations on the basis of individual, trip, and station characteristics. The second model tries to capture the effects of parking facilities and other factors on transit demand at stations to identify policies that can enhance this demand in the future.

Driving Distance to Rail Station Model

Methodology

The use of detailed travel data from the O-D survey makes it possible to document how far commuters drive to rail stations in the study region. In this study, only park-and-ride trips as the driver to a train station during morning peak hours (6:30 to 9:30 a.m.) were used (432 trips). The return home and dropping off of a passenger (i.e., kiss-and-ride trips) were excluded, because the focus of this study is on the distance driven to rail to park en route to a final destination. Furthermore, a majority of trips were work related, so nonwork trips were omitted. The ArcGIS program (version 9.3) from Environmental Systems Research Institute, Inc., was used to calculate network distance from origin to transit station.

The model is specified as follows:

driving distance to commuter rail station = *f*{gender, age, station parking capacity, distance to destination from origin, number of bus stops near origin, number of a.m. peak train departures, and distance from terminus}

This model measures the effects of several variables on driving distance (Table 1). The distance to destination variable provides an estimate of the distance that a person would have traveled if he or she had driven directly to the destination instead of using commuter rail. Including this variable measures the effects of total trip distance on driving distance to a rail station. Individual characteristics are represented in the model with a gender dummy variable and age.

It is expected that driving distance will increase with more parking spots and more frequent train service. More available parking is expected to increase demand (*10*), encouraging people to drive farther to rail stations instead of driving directly to the central business district (CBD). Frequency of service is a main attractor to transit (*2*), and it is expected that rail stations that provide more regular or frequent inbound trains will attract users to drive farther distances; therefore, a significant positive relationship will exist between the two variables. It is expected that a significant positive relationship will exist between driving distance and total trip distance. Travel times by train become competitive with travel time by private vehicles as the trip distance is longer, thus making train travel a desirable option (*2*).

TABLE 1 Description of Variables in Driving Distance to Rail Station Model

Variable	Description
Driving distance	Free-flow network distance to train station from origin in kilometers
Male	A dummy variable equal to 1 if the respondent is male
Age	Age of respondent
Distance to destination	Network distance to destination from origin in kilometers
Parking spots	The number of parking spots at train station
No. of a.m. peak departures	The number of inbound trains that depart from a station during the a.m. peak
Distance to terminus	The distance to the downtown terminus from the station in kilometers

TABLE 2 Driving Distance to Rail Station Model Descriptive Statistics

Variable	Mean	Median	Std. Dev.	75th Percentile	85th Percentile
Distance driven (km)	6.06	4.49	4.91	7.93	9.98
Male	1.56	2.00	0.49	2.00	2.00
Age	38.24	38.00	10.95	46.00	50.00
Parking spots	589.37	555.00	328.11	776.00	1,090.00
Distance to destination from origin (km)	25.80	25.70	8.19	30.36	33.52
No. of a.m. peak train departures	6.18	6.00	1.98	8.00	8.00

Data

This analysis included 432 trips to transit. The trips include only morning peak inbound trips. Two stations (Rigaud and Candiac) were omitted from the analysis because they were not located on the Montreal street grid that was used and the driving distance to these stations could not be calculated. The median driving distance was 4.49 km (2.79 mi), the 75th percentile driving distance was 7.93 km (4.93 mi), and the 85th percentile driving distance was 9.98 km (6.20 mi) (Table 2). The median distance from origin to destination (i.e., the total trip distance) was 25.7 km (15.97 mi). The median parking capacity per station was 555 with a standard deviation of 328.7, showing that the number of parking spots provided at each station varies greatly. It should be noted that only stations that people drove to are included in this calculation. The median number of inbound trains was six, and the median rail station distance from the downtown terminus was 23.6 km (14.66 mi). The average age of the respondents was 38 years.

Table 3 shows the distribution of trip origins and destinations by region. Larsen and colleagues divided the Montreal region into five rings (see Figure 1 for detailed ring distribution) (*23, 24*). About 85%

TABLE 3 Regional Distribution of Trips in Driving Distance to Rail Station Model

Region	Trip Origins (%)	Trip Destinations (%)
CBD	0	84
Inner ring	0	14
Middle ring	16	1
Outer ring	45	0
Regional ring	40	0

TABLE 4 Results of Driving Distance to Rail Station Model

Variable	Coefficient	*t*-Value	Significance
Male	0.125	2.180	0.030
Age	−0.005	−1.810	0.071
100 parking spots	0.038	3.570	0.000
Distance to destination from origin	0.033	9.740	0.000
No. of a.m. peak departures	0.069	4.480	0.000

NOTE: Dependent variable: natural log of driving distance to transit at origin (kilometers); $N = 432$; R-square = .847; adjusted R-square = .845.

of the sample trips originated in the outer and regional rings, whereas 16% of the trips originated from the middle ring. The final destination for a majority of trips (84%) was the CBD. In the sample, 14% of respondents ended their trip in the inner ring and 1% of the respondents ended their trip in the middle ring. AMT commuter rail users during the a.m. peak are generally from outlying areas and use the train to reach destinations in downtown Montreal.

Results

A multivariate regression was used to measure the effects of individual, trip, and station characteristics on driving distance. Several model specifications were tested, and the model below was found to be the best suited for the data (Table 4).

All variables are statistically significant, and the model explains 84.7% of the variation in driving distances. Individual characteristics, gender and age, had a statistically significant effect on driving distance. Males tend to drive 12.5% longer than females, and driving distance decreases by 0.5% for every year increase in age. Analysis of trip characteristics found that people drive an additional 3.3% for every 1 km (0.62 mi) between the origin and destination. This indicates either that people prefer taking the train over driving a car for longer commutes or that this is an indicator that people must drive longer distances if their trips are originating from the outer rings, where transit is sparse. Travel time by train is competitive with, or in some cases lower, than that by private automobile for longer trips in the Montreal region.

The station characteristics provide the most interesting variables in the model. Parking spots were statistically significant, but every 100 parking spots at a station increased the driving distance by 0.38%. Driving distances are 6.9% longer for every train that departs from a station during the morning peak period. People tend to drive farther to stations that have higher train frequencies. This model shows that individual, trip, and station characteristics affect driving distances. The most notable variables are gender, distance from origin to destination, and train frequency.

Passenger Boardings by Rail Station Model

Methodology

The second linear regression model uses morning peak boardings at rail stations as the dependent variable. The objective of the second model is to build a service area based on driving distances and to understand the relationship between station characteristics and boardings at each station (Table 5). The model compares boardings at the station during morning peak hours with the following variables: parking capacity, service population, and street connectivity. Because train departures and travel times are highly correlated with train lines and other route characteristics, the station model uses train line dummies instead of service variables. Station service population is defined as the population around a station that has access to the transit service. A distance decay curve was applied to the population to represent the probability of driving to transit better; this method will be explained further in the following section. Street connectivity measures the number of street intersections within 1 km (0.62 mi) of a rail station. This variable measures urban form around the station and how it affects boarding at a rail station. The specifications for the station model are shown below:

$$\text{a.m. boardings at station} = f\{\text{station parking capacity, street connectivity, service population, and train line dummies}\}$$

In the second model, it is expected that boardings will increase with increased street connectivity and train line service performance. In this case, train line dummy variables are used as proxies for service characteristics. These expectations parallel and come from the traditional transit demand literature (*2*, *10*). More available parking is also expected to increase demand. The service population should have a significant negative relationship with passenger boarding. Although it is commonly found that larger service populations are correlated with larger ridership (*15*), a study of light rail transit demand in Portland, Oregon, by Peng et al. provided evidence that the relationship between ridership and population is negative in low-density areas that are served by transit (*25*).

TABLE 5 Description of Variables in Passenger Boardings by Station Model

Variable	Description
a.m. peak boardings	Number of passengers boarding at a station during the a.m. peak (6:30 to 9:30 a.m.)
Parking spots	Number of parking spots at a train station
DM	Dummy variable equal to 1 if the train line is Deux-Montagnes
RI	Dummy variable equal to 1 if the train line is Dorion-Rigaud
BL	Dummy variable equal to 1 if the train line is Blainville
SH	Dummy variable equal to 1 if the train line is Mont-Saint Hilaire
DE	Dummy variable equal to 1 if the train line is Delson-Candiac
Street connectivity	Number of street intersections within a 1-km network distance from a rail station
Station service population	Proportion of the population surrounding a transit station using a distance decay function

TABLE 6 Passenger Boardings by Station Model Summary Statistics

	Mean	Median	STD	75th Percentile	85th Percentile
a.m. peak boardings	657.41	520	573.41	806.25	1,065.4
Service population	109,256.70	76,138.32	88,773.28	159,940.59	255,189.10
Parking	304.87	241.00	304.09	445.50	641.85
Street connectivity	62.20	58.00	34.96	85.25	105.40

Data

The boarding and parking data are from the 2009 AMT onboard survey. The number of boardings at each station was collected from September 15, 2009, to October 1, 2009. The median morning peak hour boarding was 520 passengers, the 75th percentile boarding was 806 passengers, and the 85th percentile boarding was 1,065 passengers. The median parking capacity for rail stations is 241. Parking capacity is different in the two models, because parking was added between 2003 and 2009. Also, the first model was looking at people who drove to rail stations and several stations without park-and-ride lots would have been excluded from the descriptive statistics, which is why the second model has a much lower median parking capacity than the first model. Like the first model, two stations (Rigaud and Candiac) were also omitted from the second model. Downtown stations (Gare Centrale, Montréal-Ouest, Vendome, and Lucien L'Allier) were omitted as well, because they are connected to multiple train lines and are the final stations for many users. Street connectivity was calculated by using Network Analyst in ArcGIS and measuring the number of street intersections within a 1-km (0.62-mi) network distance of a rail station. The median number of intersections within 1 km (0.62 mi) of a station is 58 (Table 6).

The median service population is 76,138. The service population is calculated by multiplying the value from an equation derived from a distance decay curve by the population residing around the station on the basis of their network distance from a station. This measure provides a more accurate representation of demand around stations (*15*). The service population assumes that not all people in a transit service area are as likely to use the rail station because of distance, so the number of people being served is discounted accordingly. Figure 2 shows a distance decay curve representing driving distances to commuter rail stations. The curve is generated by using maximum likelihood estimation. The decay function derived from Figure 2 is multiplied by the population of census tracts that were less than 16.7 km (10.38 mi) away from the station (i.e., the 85th percentile threshold of driving distances). Finally, the total service population is derived as the sum of all service populations (discounted by distance) around a station.

Station characteristics varied significantly by train line. The Deux-Montagnes train line has the highest train frequency, parking capacity, service population, and morning peak boarding (Figure 3).

Model Results

A multivariate regression is used to compare passenger boardings during morning peak hours with station characteristics, such as service population, street connectivity around the station, parking capacity, and train line characteristics (Table 7).

The results from the station model concur with transit research theory. In the model, train line dummies were used, because many characteristics of train lines, such as frequency and connection to metro stations, were highly correlated. Also, the sample size is small and only a few variables could be tested. It is not possible to increase the sample size because the main unit of analysis is train station, which is limited in number. The model shows that all train lines have fewer morning peak passenger boardings than the Deux-Montagnes train line. Additionally, the coefficient on the service population is negative, which means that more people board in areas with smaller service populations. This is understandable, because commuter rail serves large catchment areas with small populations, so a negative relationship would exist between boardings and service population (*25*). The number of parking spots is also significant. For every parking spot, passenger boardings increase by 1.12 passengers. The street connectivity variable indicates that for each additional intersection (an indicator of pedestrian-friendly urban form) around a rail station, 2.81 more passengers will board at the station. This captures the influence of those passengers who walk or cycle to rail stations. The station model can be used either for estimating demand for a planned station or for estimating the effect of service interventions (e.g., parking spots) on boardings at existing stations.

DISCUSSION OF RESULTS

The purpose of the study described in this paper was to apply techniques developed in the analysis of pedestrian-accessed transit demand to the park-and-ride context. The results of the two models

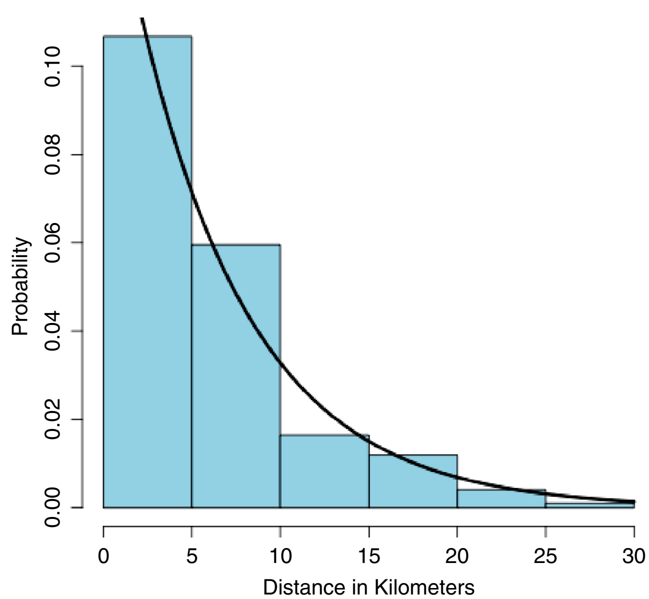

FIGURE 2 Distance decay of station service population ($p = 0.157e^{0.157x}$).

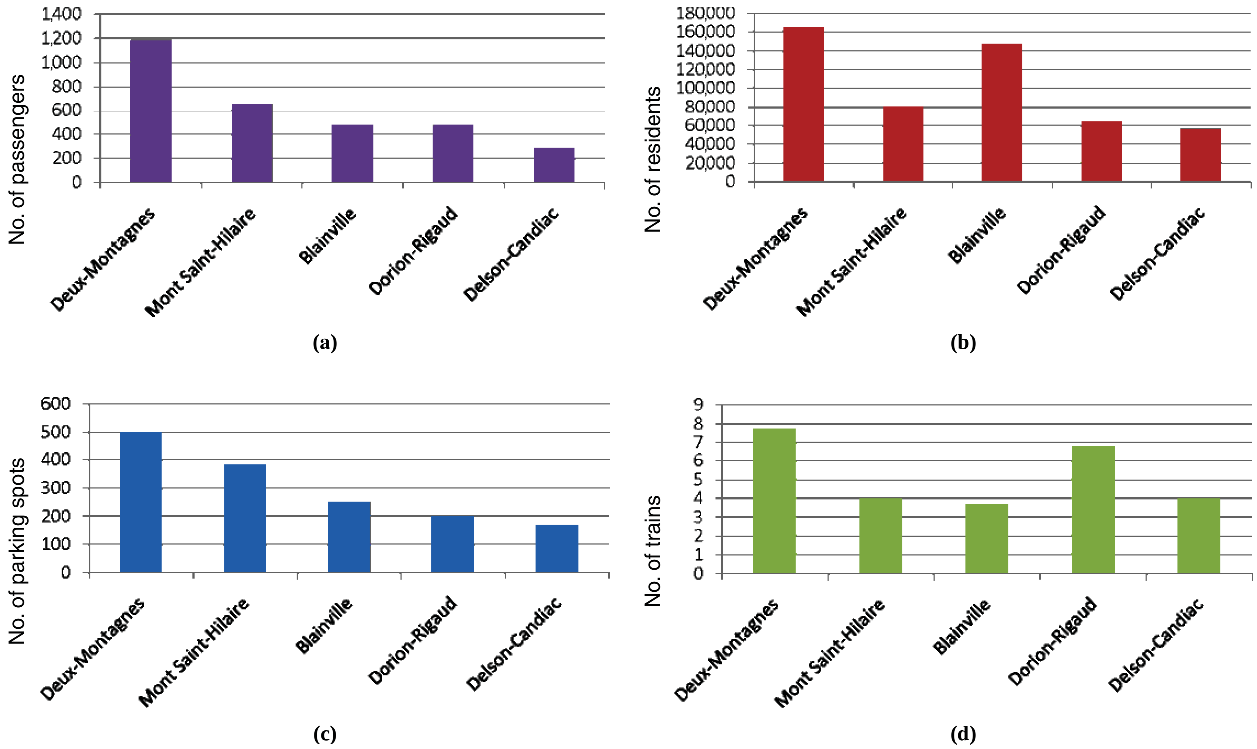

FIGURE 3 Train line characteristics: (*a*) a.m. peak boarding, (*b*) service populations, (*c*) parking capacity, and (*d*) a.m. peak inbound trains.

presented here show that the transfer is feasible, and therefore, the models provide new tools for planners of commuter rail lines and stations. Moreover, some key results of the models themselves are worth highlighting and suggest areas for further research.

Driving to Rail Stations

For the distance to station model, both parking and train frequency have significant positive effects on driving distance, although parking capacity only marginally increases driving distance. This is perhaps because capacity is not constrained at some stations. At stations where capacity is constrained, increased parking would attract more users. It is noteworthy that parking utilization was not present for this analysis. A better model could have been generated if such information was available. Train frequency, on the other hand, has a larger effect on driving distances. On-time performance could be included in future research to see whether train frequency or service reliability has a larger effect on driving distance. Bowman and Turnquist found that passengers are more sensitive to service reliability than frequency of service (*11*). For example, an unreliable high-frequency train line might not attract as many users as a line with less frequent but more reliable service. Another notable determinant of distance driven to commuter rail is the total length of the trip from origin to destination. The longer that the distance to the destination is, the more that people are willing to drive to rail. This observation could be a result of living in less dense areas rather than reflecting modal preferences. However, an important service improvement would be reducing travel time by train, which could increase the number of people driving to rail instead of driving directly to their destinations in the inner ring and CBD.

TABLE 7 Passenger Boardings by Station Model

Variable	Coefficient	*t*-Value	Significance
Rigaud Line dummy	–462.762	–2.680	0.011
Blainville Line dummy	–412.178	–2.730	0.010
Mont-Saint Hilaire Line dummy	–421.625	–2.250	0.030
Delson-Candiac Line dummy	–590.481	–2.690	0.011
Service population	–0.006	–2.260	0.030
Parking	1.120	5.730	0.000
Street connectivity	2.812	1.750	0.088
Constant	651.495	2.940	0.006

NOTE: Dependent variable: a.m. peak boardings; $N = 46$; R-squared = .733; adj. R-squared = .684.

Passenger Boardings by Station Model

In the passenger boardings model, a distance decay curve was developed to estimate transit service populations by applying an exponential decay curve to survey data. In doing so, the authors were able to build on the distance decay functions in the study of Kimpel et al. (*15*) and produce an improved passenger boardings model, which used actual driving distances to estimate a service population. The present results, which found a negative relationship between service population and boardings, parallel the findings of Peng et al. (*25*). Transit serving low-density areas will have similar relationships, because most people are boarding during the morning peak in areas with low populations and alighting in high-employments areas with larger populations. An interesting additional model would look at the relationship between evening peak boardings and service populations to observe whether the opposite relationship occurs. Parking at stations did have an effect on the total number of boardings. Each parking spot attracts approximately 1.2 users, which means that most park-and-ride users are arriving in single-occupancy vehicles. Providing priority parking for carpoolers might help decrease the number of single-occupancy drivers. As it was mentioned for the first model, information on parking utilization was not available, which could add more explanatory power to the boarding at station model.

It was not possible to include multiple service variables, because train frequency was highly correlated with other train line characteristics that could influence passenger demand at the station level. Also, information on service reliability was not available. That information might have revealed more about station demand than train frequency. Train line dummies allow capture of some of the influences of line-specific characteristics. However, it does not identify which characteristics are significant determinants of passenger demand. A larger sample size of train stations would have allowed the inclusion of more variables in the model.

CONCLUSION

This study used O-D survey and boarding data to understand the factors influencing driving distance to commuter rail stations and demand in the Montreal region. Analysis of the driving distance to rail stations showed that people drive farther to commuter rail stations with an increase of overall trip length, thus suggesting that competitive train service can reduce the number of cars entering the CBD. Higher train frequencies also attract people to drive longer distances. Parking capacity has a small but significant effect on driving distance. Station boarding is affected by station and train line characteristics. Every additional parking spot attracts 1.12 passengers, and increased street connectivity around the station influences demand at rail stations as well.

Further research that uses a larger sample of commuter rail stations is recommended to test the effects of multiple train line characteristics, such as frequency and on-time reliability. This can be achieved only by conducting parallel studies with data from other cities that have similar services. Operational characteristics such as train frequency are shown to be important determinants for both pedestrian and driving access. The results show that methods for measuring pedestrian access to transit services can easily be transferred to estimating commuter access to transit and the effects of park-and-ride lots on passenger demand and travel behavior.

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