USING MOBILE APPLICATION DATA, POPULATION SIZE, ACCESSIBILITY, AND VALUE JUDGMENTS IN PUBLIC TRANSIT IMPROVEMENTS

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Acknowledgements

Thanks to Dr. Paul Thomassin for his support and encouragement. Thanks to Sam Vermette at Transit App, without whom this article would not exist. Finally, thanks to Alexandre Grégoire for technical assistance.

Abstract

In order to maintain transit systems, information about them is needed. This article provides information regarding the absence of correlation between transit use, population density, and accessibility. To this end, mobile application data is used. The data is from an application called Transit App that enables easy navigation within transit systems.

In North America, the transportation mode share of the automobile is very high. One consequence of the North American population's high automobile dependency is high auto travel demand on roads. Concurrently, the ability to build additional infrastructure is limited and, in some cases, impossible. As a result, traffic congestion levels have increased significantly, particularly in the past decade. (Schrank, Eisele, and Lomax 2012). Traffic congestion negatively affects transportation efficiency and also creates negative environmental externalities. As Vukan Vuchic stated in *Transportation for Livable Cities*: "Unrestricted individual behaviour collides with socially optimal behavior" (1999). One solution to the problem of traffic congestion is to increase the mode share of public transportation. But what can induce urban North American populations to trade their automobiles in favor of public transit? What are the qualities a public transit system must have for a significant proportion of the population to frequent it?

One of the ways to approach this question is to investigate where people do and do not use it. In this article, public transit in all 19 boroughs of Montreal is considered. Population density is compared to transit use to determine whether transit use is homogenous in all Montreal boroughs. The results are then discussed within the context of other public transit research. The results will hopefully disambiguate some of the factors that influence public transit use in Montreal. This knowledge may facilitate the creation of coherent goals and purposes for public transit in general and the Société de Transport de Montréal in particular.

Context and Literature Review

Montreal is Canada's second-largest city with a population of 1,649,519, and with 3,779 persons per km^2, it has a high population density (Statistics Canada 2013). By North American standards, Montreal has a relatively extensive transit network (Eluru, Chakour, and El-Geneidy 2012).

Empirical data regarding transit users are collected by public transit organizations through studies like the Agence Métropolitaine de Transport (AMT)'s Enquête Origine-Destination 2008. The Enquête Origine-Destination has collected statistics through telephone surveys on the population of greater Montreal approximately every five years since 1970. The findings cover demographics, modal choice, trip frequency, and locations. The next report is expected to be published in 2015. The current report, published in 2008, states that at the time of the study on an average day Montreal residents made 3,831,280 trips (2.18 trips per person). Of these trips, 52 percent were done by car, 31.2 percent by public transit, and the remaining trips happened through other means such as bicycles, walking, or other motorized vehicles (AMT et al. 2008).

Data collection on public transit users is done by several organizations besides the AMT. Transportation Research at McGill (TRAM) conducted commuter surveys in 2011 and 2013. The subsequent reports highlighted possible opportunities for McGill University to foster the use of active and public transportation to and from its campuses in downtown Montreal and in Ste-Anne-de-Bellevue (Shaw et al. 2013). In other words, the report attempts to answer the question "If someone wants to make a trip to or from this campus, what will make them choose something other than an automobile to do it?"

In Québec City, students at the Centre de Recherche en Économie de l'Environnement, de l'Agroalimentaire, des Transports et de l'Énergie (CREATE) recently conducted a study to evaluate the potential for reducing the commuting mode share of cars at Université Laval using stated preference data (Barla et al. 2013). They found that policies that aim to reduce automobile dependency by changing attitudes are not effective while direct transit incentives as well as automobile disincentives are only moderately effective. However, they found that a combination of several policy interventions is highly effective—more than the effects of each individual intervention would have suggested.

A note on transportation research: while some universities have created transportation-focused institutions, such as the Chaire en Mobilité at Université de Montréal's École Polytechnique and TRAM at McGill's School of Urban Planning, there is no such thing as a degree in transportation let alone a degree in public transit. As a result, research on public transit is done in a variety of academic fields.

The notion of accessibility is often conflated with the concept of mobility. While they are often both discussed in the same works, it is important define each because they are different concepts (Godin 2012). Mobility is measured in vehicle-km or person-km and is used to describe the ease or speed with which distance can be covered (Vuchic 1999). Higher mobility means a higher number of kilometers traveled in the same time period. Accessibility, however, is calculated in opportunities. Higher accessibility means a higher number of possible departure times as well as a higher number of possible destinations. There are many ways to calculate accessibility (Godin 2012; Geurs and Krizek 2012). A number of possible accessibility indicators are described in Audrey Godin's 2012 thesis *L'accessibilité en Transport—Méthodes et*

Indicateurs. In this paper, the accessibility indicator will be cumulative trip-stops, but there are many others.

Finally, a note on mobile application data. Transportation research using this kind of data could not be found at the time of writing. This determination is not surprising given that smartphones are a relatively new technology and that the data had not only to exist, but also be in a format that could be loaded into a relational database.

Hypothesis

In Montreal, the variation in public transit use between boroughs is not directly proportional to the variation in population size, but it is proportional to accessibility. Public transit in all 19 boroughs of Montreal will be considered. Transit use will be compared to population density to determine whether it is homogenous in all Montreal boroughs. It will then be compared to accessibility in each borough. Do passengers (or potential passengers) make more trips or fewer trips depending on the neighborhood? Does the frequency of transit use vary in proportion with population size? Does it vary in proportion with accessibility?

Method

First, two values are compared: the magnitude of public transit use and population. For the former, data from a mobile application, the Transit App, are used. For the latter, Statistics Canada data are used.

Following this comparison, the magnitude of public transit use is again compared, this time to accessibility. As previously stated the accessibility indicator will be the sum of all transit opportunities in each borough.

A clarification regarding the transit data: the Transit App is a mobile application that provides transit information to its users. When the application is launched, it makes use of the location services of iOS or Android devices to find the location of its user. The device then sends its location to the Transit App servers so that the app may show the user the public transit opportunities within a reasonable radius (see Figure 1). The Transit App servers also keep a log of all such requests (see Figure 2). This log is the source of the data used in this article.

It is important to note that each data point represents a user considering or intending to use public transit; it does not show what the person actually did. Additionally, each data point corresponds to the location of the user at the time they planned their trip, as opposed to the point of entry into a bus, metro, or train. Consequently, the data points can be considered representative of the locations of users who are considering public transit as a means of travel. Another consequence is that this data does not include persons who do not use mobile devices. For this article, the data points are for one day, specifically Wednesday, November 13, 2013, from midnight to midnight. A Wednesday was deliberately chosen as being less likely to be disrupted by any particular event such as a concert, sporting event, or festival in the city.

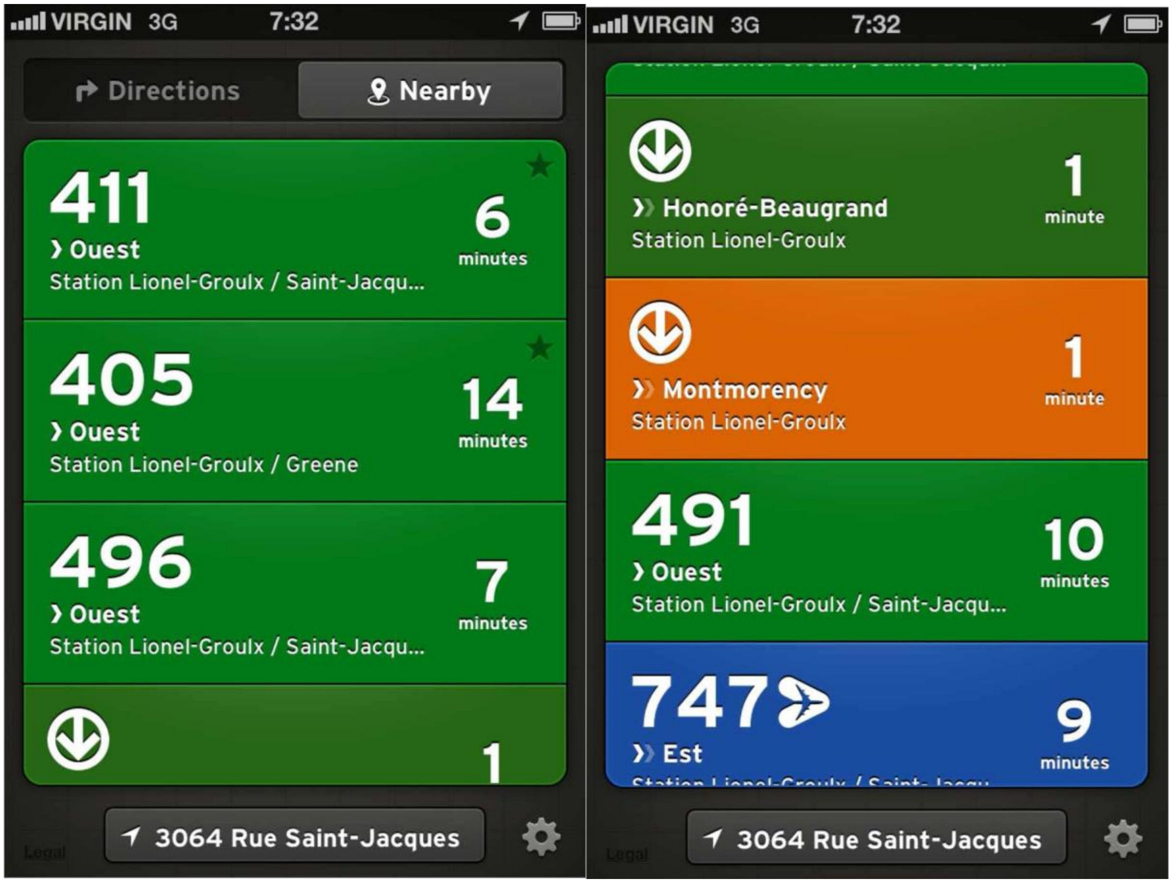

Figure 1. A sample display of public transit opportunities.

There are 42,925 data points for the entire Greater Montreal Area. The data was loaded into a relational database with a Geographical Information System (GIS) extension. In the database, each borough in the Greater Montreal Area is defined as a polygon with a specific set of geographical points.[1] A script was written to read every line of the Transit datasets and find longitudes and latitudes.[2] The script queried the database to identify the polygon containing that point. Thus, each data point was assigned to a borough. It was then possible to determine a count for each borough, and within Montreal 21,702 data points were found (see Table 1).

The data were weighed by population size and a chi-square test was performed to determine statistical significance (see Table 2). The test statistic was found to be 12,917.6471, which is far above the chi-square critical value, 28.8693. The weighed data was then compared to the expected count by borough. The expected count is the value which would have been found if the count for each borough were always proportional to population size. (see Table 2).

[1] Shapefiles for the boroughs were created by Roberto Rocha, data journalist for *The Gazette* (2012).
[2] Script written and executed by Alexandre Grégoire, M.A.

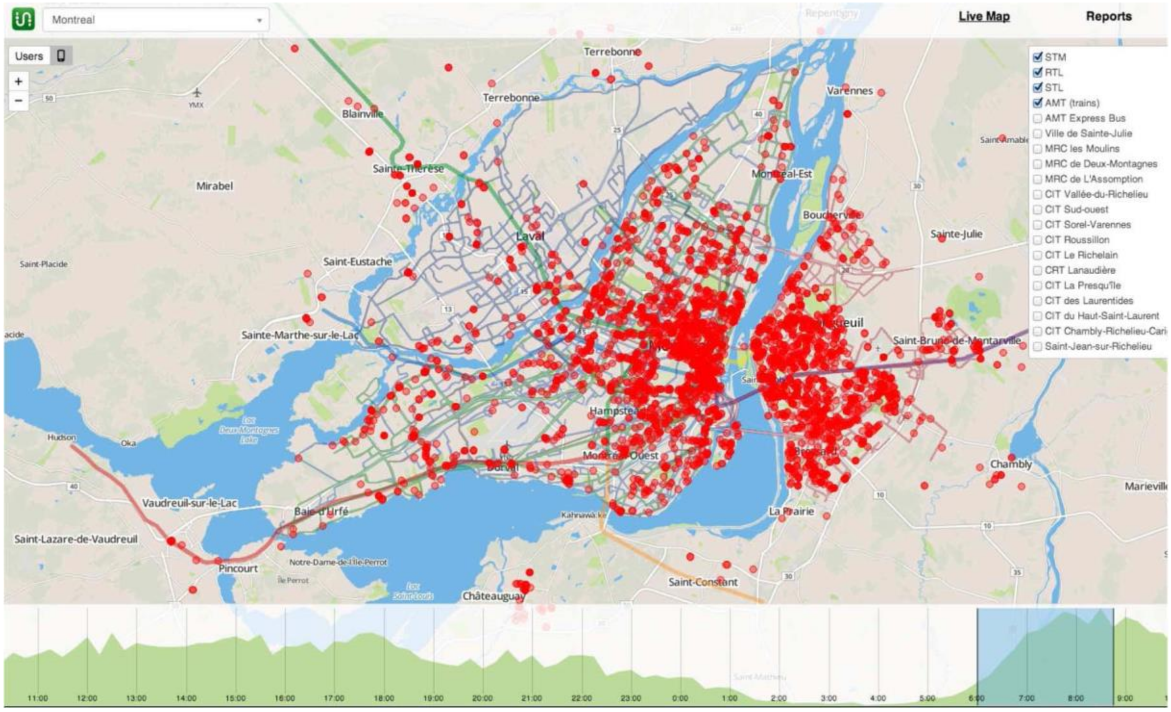

Figure 2. A sample visualization of Transit App log requests.
Notes: Each dot is a request; the above is for a window of approximately two hours on December 3, 2013.

Following this calculation, the transit data was compared to an accessibility indicator. The accessibility indicator used here is cumulative trip-stops, or the total number of stops made by buses or trains in a given time period in a given space. It is a rudimentary accessibility measure, defined as:

(1) $$Trip\text{–}stops_{ij} = \sum_i^j trip(stop_1) + \sum_i^j trip(stop_2) + \ldots \sum_i^j trip(stop_n)$$

and made with the General Transit Feed Specifications (GTFS) for Société de Transport de Montréal.

To obtain the indicator, a relational database with a GIS extension was used once more. The zipped GTFS data were obtained from the STM web site (Société de Transport de Montréal 2014). Three files, trips.txt, stops.txt, and stop_times.txt, were loaded into the database and a script was made to export the stop times for each stop corresponding to a typical weekday, which would have the same service type as November 13, 2013, to match the mobile app data points. The GTFS data includes the latitude and longitude of each bus and metro stop making it then possible to assign each trip-stop to a specific borough. The data for each borough was then summed using Microsoft Excel.

Table 1. Data count for each borough.

Borough	Data count
Ville Marie	4,227
Côte des Neiges -Notre Dame de Grâce	2,478
Plateau Mont Royal	2,401
Rosement -La Petite Patrie	1,635
Ahuntsic -Cartierville	1,544
Sud-Ouest	1,319
Saint-Laurent	1,294
Mercier -Hochelaga -Maisonneuve	1,213
Vileray -St-Michel -Parc Extension	1,160
Verdun	935
LaSalle	728
Pierrefonds-Roxboro	612
Montréal Nord	580
Lachine	546
Pointe-aux-Trembles / Rivière-des-Prairies	413
Saint-Léonard	385
Outremont	184
L'île Bizard / Sainte-Geneviève	48
Anjou	0

The accessibility indicator thus obtained, it was then used to weight the transit use data and a chi-square test was performed to determine statistical significance between accessibility and transit use (see Table 3). The test statistic was found to be 8,845.4942, which, like the previous test, is far above the chi-square critical value of 28.8693.

Results and Discussion

This research was done with the expectation that the variation in public transit use between boroughs would not be proportional to the variation in population size, but that it would be proportional to accessibility. The results support half of the hypothesis. In fact, in Montreal transit use is proportional to neither. Some boroughs, like Ville-Marie and Plateau-Mont-Royal, have much higher transit use relative to the expected counts while others, such as Pointe-aux-Trembles/Rivière-des-Prairies, show very low use (see Tables 4 and 5). There is no correlation to population size or accessibility.

Previous research tends to support the notion that accessibility has a significant impact on transit use (Eluru, Chakour, and El-Geneidy 2012; Cerda 2009). However, apparently in Montreal this significant impact does not translate to correlation.

Table 2. Data for a chi-square test, with each borough weighted for populated density.

Borough	Data count	Population	Population proportion	Expected count	Test statistic
Ville Marie	4,227	79,572	0.049	1,064.840	9390.381
Côte des Neiges-Notre Dame de Grâce	2,478	164,931	0.102	2,207.123	33.244
Plateau Mont Royal	2,401	99,386	0.061	1,329.993	862.453
Rosemont-La Petite Patrie	1,635	135,760	0.084	1,816.753	18.183
Ahuntsic-Cartierville	1,544	126,696	0.078	1,695.458	13.530
Sud-Ouest	1,319	69,472	0.043	929.681	163.034
St. Laurent	1,294	84,795	0.052	1,134.735	22.354
Mercier-Hochelaga-Maisonneuve	1,213	129,940	0.080	1,738.870	159.034
Villeray-St. Michel-Park Extension	1,160	140,395	0.087	1,878.779	274.989
Verdun	935	65,959	0.041	882.670	3.102
LaSalle	728	75,467	0.047	1,009.907	78.692
Pierrefonds-Roxboro	612	65,718	0.041	879.445	81.332
Montreal North	580	83,884	0.052	1,122.544	262.220
Lachine	546	40,904	0.025	547.381	0.003
Pointe-aux-Trembles-Rivieres-des-Prairies	413	105,396	0.065	1,410.419	705.354
St. Leonard	385	71,944	0.044	962.762	346.720
Outremont	184	22,830	0.014	305.513	48.330
L'Île Bizard-St. Geneviève	48	17,590	0.011	235.391	149.179
Anjou	0	41,080	0.025	305.513	305.513
Total	21,702	1,621,719	1.000		12,917.647

Conclusion

Why is it that some neighborhoods contain several metro stops, commuter trains, and dozens of bus lanes while others do not? Had a correlation been found, we might have assumed that service was being apportioned in response to population size or to the observed pattern of demand. Since that is not the case, the differences in the transit service from one neighborhood to the next must be due to something else.

In his 2012 book *Human Transit*, Jarrett Walker writes that transit agencies are often focused on *how* to do their job and spend perhaps too little time defining *what* that job is. For example, a transit agency may be spending a significant amount of time discussing which bus models to purchase and very little time discussing whether the bus service should cover all areas of the city equally, whether there should be twice as many buses running in neighborhoods with twice the population, or whether the buses should go to the neighborhoods where the demand is already high.

Table 3. Data for a chi-square test, with each borough weighted for accessibility.

Borough	Data count	Accessibility count	Accessibility count proportion	Expected count	Test statistic
Ville Marie	4,227	49,067	0.0774	1,680.6695	3,857.8667
Côte des Neiges-Notre Dame de Grâce	2,478	59,154	0.0934	2,026 1749	100.7543
Plateau Mont Royal	2,401	31,985	0.0505	1,095 5676	1,555.4986
Rosemont-La Petite Patrie	1,635	42,689	0.0674	1,462 2068	20.4195
Ahuntsic-Cartierville	1,544	54,472	0.0860	1,865.8045	55.5032
Sud-Ouest	1,319	23,758	0.0375	813.7719	313.6695
St. Laurent	1,294	53,568	0.0845	1,834.8402	159.4189
Mercier-Hochelaga-Maisonneuve	1,213	49,699	0.0784	1,702 3171	140.6502
Villeray-St. Michel-Park Extension	1,160	43,458	0.0686	1,488 5470	72.5158
Verdun	935	17,189	0.0271	588.7670	203.6074
LaSalle	728	32,716	0.0516	1,120.6062	137.5502
Pierrefonds-Roxboro	612	18,434	0.0291	631.4114	0.5968
Montreal North	580	33,692	0.0532	1,154.0367	285.5352
Lachine	546	20,497	0.0324	702.0744	34.6961
Pointe-aux-Trembles-Rivieres-des-Prairies	413	47,241	0.0746	1,618 1244	897.5359
St. Leonard	385	25,635	0.0405	878.0639	276.8728
Outremont	184	7,462	0.0118	255 5925	20.0533
L'Île Bizard-St. Geneviève	48	2,656	0.0042	90.9748	20.3005
Anjou	0	20,216	0.0319	692.4494	692.4494
Total	21,702	633,588	1.0000		8845.4942

Decisions regarding public transit must be made in order to address the issues of congestion, air pollution, and dependence on non-renewable energy sources (Vuchic 1999; Johnson 1993; Schrank, Eisele, and Lomax 2012). Discussions regarding public transit may also touch on drunk driving, livability of cities, mobility of persons with disabilities, and mobility of low-income persons (Manaugh and El-Geneidy 2012; Paré, Frohn, and Laurin 2004).

Any amount of data collection and quantitative analysis will not tell transit agencies what to do. Walker tells us that this question can only be answered with “the purest of value judgments. [...] There is no right or wrong answer. It depends on why a city is running public transit at all” (2012).

Table 4. Difference, for each borough, between the data count and the expected data count in terms of population density.

Borough	Difference between data count and expected count
Ville Marie	3,162
Plateau Mont Royal	1,071
Sud-Ouest	389
Côte des Neiges-Notre Dame de Grâce	270
St. Laurent	159
Verdun	52
Lachine	-1
Outremont	-121
Ahuntsic-Cartierville	-151
Rosemont-La Petite Patrie	-181
L'Île Bizard-St. Geneviève	-187
Pierrefonds-Roxboro	-267
LaSalle	-281
Anjou	-305
Mercier-Hochelaga-Maisonneuve	-525
Montreal North	-542
St. Leonard	-577
Villeray-St. Michel-Park Extension	-718
Pointe-aux-Trembles-Rivieres-des-Prairies	-998

In the course of this research, I determined that some data is easy to find. It was very easy to find information about the number of passengers, the number of trips, the distance and destination, and the modal choice. It was much harder to find data (or indicators, for that matter) about the availability of transit for persons with disabilities, about the relative pleasantness or enjoyment of transit, about communication with transit agencies, or about the reliability of public transit. It might be that these aspects of public transit, difficult to quantify though they may be, have an impact on usage. Further research on these topics is certainly warranted, and mobile application data may play a significant role in that research. “Urban transportation in many ways reflects the general problems of advanced societies, such as the dichotomy between individual and social interests, the external impacts of a system’s operation, and the relationship between market conditions and public service” (Vuchic 1999).

Table 5. Difference by borough between the data count and the expected data count in terms of accessibility.

Borough	Difference between data count and expected count
Ville Marie	2,546
Plateau Mont Royal	1,305
Sud-Ouest	505
Côte des Neiges-Notre Dame de Grâce	452
Verdun	346
Rosemont-La Petite Patrie	173
Pierrefonds-Roxboro	-19
L'Île Bizard-St. Geneviève	-43
Outremont	-72
Lachine	-156
Ahuntsic-Cartierville	-322
Villeray-St. Michel-Park Extension	-329
LaSalle	-393
Mercier-Hochelaga-Maisonneuve	-489
St. Leonard	-493
St. Laurent	-541
Montreal North	-574
Anjou	-692
Pointe-aux-Trembles-Rivieres-des-Prairies	-1,205

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