Bus Transit Service:

The Impact of Schedule Media Type on Users' Waiting Time

Supervised Research Project Report

submitted in partial fulfillment of the Masters of Urban Planning degree

May 4, 2015

Submitted by: Vincent Poirier
Supervised by: Ahmed El-Geneidy

School of Urban Planning
McGill University

ACKNOWLEDGEMENTS

Through this project, Prof. Ahmed El-Geneidy was a great resource. His concern that the project was of interest to me and advancing to my pace was greatly appreciated. As my supervisor, I would like to thank him foremost for his availability when I needed assistance. I would also like to highlight the contribution of Ehab Diab in this research. As my second reader, he has been an invaluable resource for the realization of this study.

ABSTRACT

Passengers' satisfaction is an important feature for a public transit agency as it contributes to its attractiveness. Waiting time at a bus stop is an attribute that impacts on passengers' satisfaction. The purpose of this study is to look at the impact of the schedule media (e.g.: printed schedule, smartphone apps, etc.) on transit riders' waiting time, using Montreal as a case study. The research uses data collected from a survey conducted among bus users and from field observations at various bus stops in order to determine passengers' actual waiting time. The analysis relies on descriptive statistics and a regression model. The results show that the schedule media, when related to the bus headway, explain some variation in the actual waiting time. Indeed, for each additional minute in the headway, riders who know the schedule or use the online schedules can expect to wait respectively 0.29 and 0.26 minute less than riders who simply look at the schedule posted at the stop. Moreover, a sensitivity analysis details how the waiting time varies according to the bus headways for each schedule media used by bus riders. These findings may be of interest to transport engineers and planners who are concerned with reducing the burden of waiting for public transport users and increasing the levels of satisfaction among them.

RÉSUMÉ

La satisfaction des passagers est un élément important pour une agence de transport puisqu'elle contribue à l'attractivité de son service. Le temps d'attente à l'arrêt d'autobus est un exemple d'un facteur qui influence la satisfaction des passagers. Ainsi, le but de cette étude est de déterminer l'impact que peuvent avoir les types d'horaire (ex: horaire imprimé, application mobile, etc.) sur le temps d'attente des usagers du transport en commun à Montréal. L'étude utilise des données récoltées lors de sondages conduits auprès d'utilisateurs d'autobus, ainsi que des observations faites aux arrêts d'autobus permettant de déterminer le temps réel d'attente des usagers. L'analyse repose sur des statistiques descriptives de même que sur des modèles de régression linéaire. Les résultats démontrent que les types d'horaire, mis en relation avec la fréquence des autobus, expliquent une variation dans le temps réel d'attente. En effet, pour chaque minute additionnelle à la fréquence du service, les utilisateurs connaissant l'horaire ou utilisant les horaires en ligne peuvent attendre respectivement 0.29 et 0.26 minute de moins que les utilisateurs ayant seulement consulté l'horaire à l'arrêt d'autobus. Par ailleurs, une analyse de sensibilité démontre la relation entre le temps d'attente et la fréquence du service selon les différents types d'horaire. Ces conclusions sont d'un intérêt pour les ingénieurs et planificateurs en transport qui désirent aider les usagers à réduire leur temps d'attente.

Table of Contents

List of Figures

List of Tables

INTRODUCTION

Public transit attractiveness has often been measured with passengers' perception and satisfaction of their experience with the service provided, forcing transit agencies to continuously ensure efficient and comfortable service to its users *(Eboli & Mazzulla, 2007)*. Several attributes may be considered to measure passengers' satisfaction, which goes well beyond the on-board experience. The time spent waiting at the stop is an element that impacts on passengers' satisfaction as riders tend to overestimate their waiting time at the stop when no service information is provided (*Watkins et al., 2011; Mishalani et al, 2006)*. Time spent waiting at the bus stop is more valuable to transit users than the in-vehicle time as the time spent moving towards a destination passes faster *(Reed, 1995)*. Therefore, access to schedule information and service status affects the overall satisfaction by increasing the accuracy of waiting time.

Most transit agencies provide various tools, or media, to communicate schedules to passengers, which may include printed schedules, online schedules, or at-bus stop schedules. Some agencies go as far as providing smartphone applications linked to real-time information systems. For the purpose of this study, *schedule media* will be employed to refer to any format in which a bus schedule can be communicated, such as, and not limited to, printed schedule, online schedule, online trip planners or smartphone applications. The goal of this research is to understand the impact of the different schedule media on passengers' actual waiting time at the bus stop by answering the following research question: Do schedule media impact bus user's waiting time and to what extent? The alternative hypothesis is that the schedule media do affect bus riders' waiting time at the bus stop.

The case study conducted in this paper takes place in Montreal, the second biggest city in Canada. The *Société de Transport de Montréal* (STM), the city's transit agency, operates four metro lines and over 200 bus lines and 4 metro lines. According to the 2011 National Household Survey, 264,000 residents (36%) of the island of Montreal commuted to work using public transit *(Ville de Montréal, 2014).* For the following analysis, only the bus system will be taken into consideration and the existing schedule media provided by the STM will constitute the list of schedule media to be studied.

This paper starts with a literature review of previous works related to passengers' satisfaction and waiting time. The following sections explain the methodology as well as the data used to conduct this analysis. Then, the model results are presented and discussed, and the paper concludes by making recommendations for future works.

LITERATURE REVIEW

The literature about the relationship between schedule media and waiting time contains some interesting studies that are relevant to this research. Many studies focus on the service attributes that may influence riders' satisfaction, such as waiting time *(Eboli & Mazzulla, 2007).* Researchers identify two categories of waiting time, perceived and actual waiting time, and find that users tend to overestimate the time they spend waiting (*Mishalani, 2006; Psaros et al 2011*). While several attributes may affect the waiting time, studies comparing the influence of real-time information systems on both perceived and actual waiting time conclude that riders using real-time information systems saw reductions to both (*Dziekan, 2006; Watkins 2011).* Other researchers found that waiting time varied according to the bus service frequency, as users tend to reduce their time spent waiting (*Holroyd & Scraggs, 1966; Osuna & Newell, 1972).*

The satisfaction of transit users is affected by several features that can be determinant in whether one will decide to use transit or not. Several attributes, grouped in broader categories, were found to have an impact on riders' satisfaction *(Eboli & Mazzulla, 2007)*. Among the categories, the authors identified service planning and reliability as having a significant impact on the level of satisfaction. That category includes service reliability, information provided (such as the schedule) as well as service frequency. Wait time at the stop and travel time have also shown to be significantly important elements for riders when it comes to their satisfaction with the service. Some authors have found that the time spent outside of the bus was more onerous than the travel time itself *(Ben-Akiva & Lerman, 1985)*. The more one traveler can be certain about the next arrival, the less he would mind waiting *(Reed, 1995)*. These findings further justify the interest of identifying the features that may impact on waiting time, such as the schedule media.

Prior studies also predominantly compared the difference between *perceived* and *actual* waiting time. While the former is concerned by how long passengers perceive their waiting time to be when waiting at a bus stop, the latter examines the real waiting time. Researchers comparing perceived and actual waiting time found that users typically overestimate their waiting time (*Daskalakis & Stathopoulos, 2008; Mishalani, 2006)*. Mishalani (2006), in a case study based in Seattle, found that riders overestimated their waiting time by 0.84 minute. Some attributes, such as age, trip purpose and trip time period, may explain the increase in perceived waiting time. For example, increases in perceived waiting time have been associated with older individuals, as well as work and school-related trips, while it decreases for trips made during morning periods (*Psarros et al, 2011*).

Additional studies have been conducted in a context where real-time information systems had been implemented *(Dziekan et al., 2006; Mishalani et al, 2006).* Researchers have compared traditional schedule media to real-time information media in evaluating their impact on perceived and actual waiting time. Results show that riders using real-time information media as opposed to traditional media estimated both their perceived and actual waiting times to be shorter by up to 13% *(Watkins et al., 2011)*. Similarly, another study found that real-time information media contributed to a 20% reduction in perceived waiting time *(Dziekan et al., 2006).* Moreover, it has been shown that real-time information systems, mostly through smartphone applications, positively impacted riders' satisfaction by increasing the accuracy of the next arrival *(Gooze et al, 2013; Chen, 2012; Ferris, 2011)* while having mixed impact on ridership *(Tang et Thakuriah, 2012; Ferris et al., 2010; Vonderschmitt, 2014).* Indeed, real-time information systems allow transit users to accurately plan their commute and to reduce the time spent waiting at the stop. In regard to ridership, the studies indicated that this is not so much affected by the presence of real-time information systems. Although some increase can be noticed, this type of system usually benefits current transit users and contributes to customer retention.

Finally, one theory that is widely accepted by researchers and transportation planners is that passengers will wait half the headway when the service is frequent, and as the headway increases beyond fifteen minutes, riders will adjust their arrival time consequently with the schedule in order to reduce their waiting time *(Holroyd & Scraggs, 1966; Osuna & Newell, 1972).* Supporting this, some authors found a headway threshold that marks a transition between random and non-random passengers arriving at a bus stop. Random passengers - that is, passengers who have not scheduled their arrival time - are most common within an eleven minute threshold (*Fan & Machemehl, 2009)*. As such, schedule media increases in importance as headway also increases.

Most recent studies have only compared perceived waiting time to actual waiting time (*Daskalakis & Stathopoulos, 2008; Mishalani, 2006).* Therefore, the current study differs from previous works in two main points: first, only the actual waiting time is taken into consideration, as the purpose of this research is to identify the impact of the schedule media on waiting time, according to the scheduled headway. Additionally, this study focuses on the impact of the different schedule media on waiting time.

METHODOLOGY

Montreal, Canada, serves a case study in this research. The city's transit agency operates over 200 bus lines that are categorized into different service types. Six bus routes were considered in the analysis. Routes 45, 67, 161 and 165 are part of the local service and have a 10-minute frequency during some periods of the day, while routes 435 and 467 are part of the express service, meaning that they are serving only every other stop. In selecting the bus routes for this analysis, efforts were focused on some of the city's busiest bus lines running on main arteries. These bus lines were also selected because no major changes were made to these routes in the recent years. Figure 1 shows the bus lines under study. This selection made it possible to capture both inbound and outbound

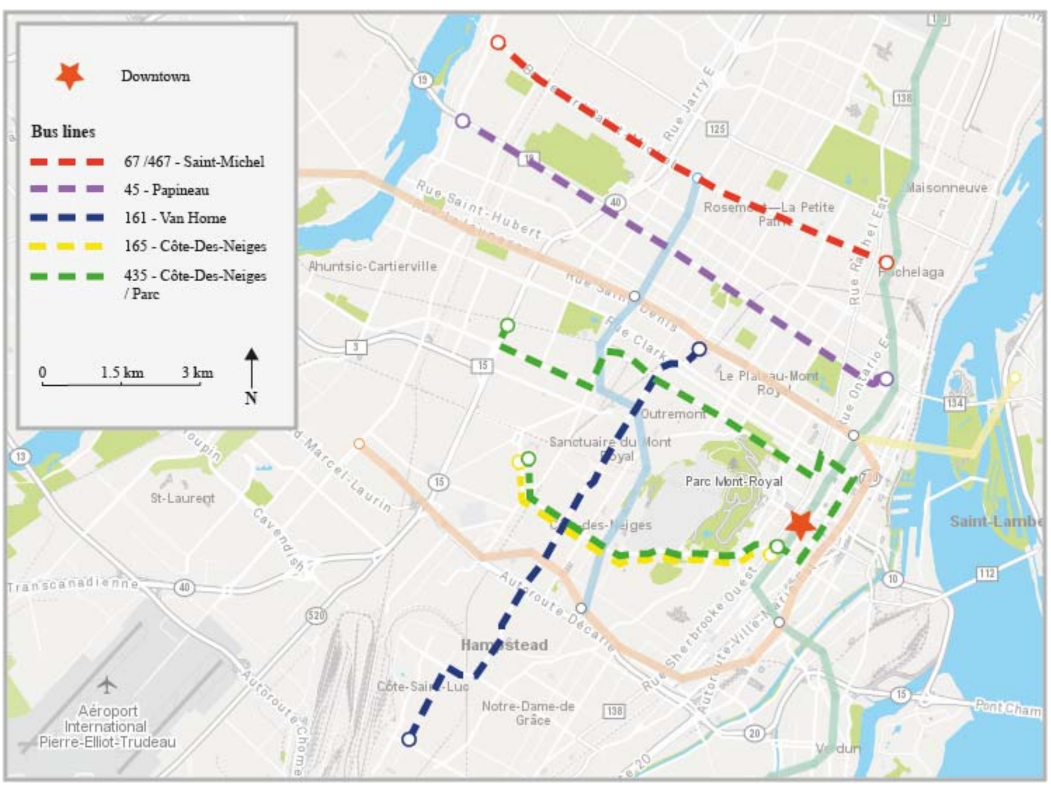

Figure 1 Selected bus lines Source : STM website

passenge ... and commercial areas to major employment areas, such as downtown. Table 1 displays the average scheduled headways for the selected bus lines according to the weekday, day time and direction. It is possible to see that some bus lines have a rather constant headway throughout the day (e.g.: bus line 67) while others vary according to the day time and direction (e.g.: 45).

Table 1 : Average Scheduled Headways (minutes), According to the Weekday, day time and Direction

Bus line	Day time	Weekday		Saturday		Sunday	
		North	South	North	South	North	South
45	AM peak (6:30 am - 9:30 pm)	14	10	30	30	14	10
	Midday (9:30 am - 3:30 pm)	18	11	23	19	18	11
	PM peak (3:30 pm - 6:30 pm)	10	21	15	30	10	21
	Night (after 6:30 pm)	13	30	29	28	13	30
		North	South	North	South	North	South
67	AM peak (6:30 am - 9:30 pm)	10	9	23	16	10	9
	Midday (9:30 am - 3:30 pm)	10	10	9	8	10	10
	PM peak (3:30 pm - 6:30 pm)	10	10	8	10	10	10
	Night (after 6:30 pm)	11	14	17	21	11	14
		North	South	North	South	North	South
165	AM peak (6:30 am - 9:30 pm)	6	7	20	23	6	7
	Midday (9:30 am - 3:30 pm)	4	5	5	6	4	5
	PM peak (3:30 pm - 6:30 pm)	5	8	4	6	5	8
	Night (after 6:30 pm)	6	12	9	18	6	12
		North	South	North	South	North	South
435	AM peak (6:30 am - 9:30 pm)	10	4	No service		No service	
	Midday (9:30 am - 3:30 pm)	32	8				
	PM peak (3:30 pm - 6:30 pm)	12	11				
	Night (after 6:30 pm)	22	20				
		East	West	East	West	East	West
161	AM peak (6:30 am - 9:30 pm)	9	8	29	21	9	8
	Midday (9:30 am - 3:30 pm)	10	10	13	12	10	10
	PM peak (3:30 pm - 6:30 pm)	9	8	11	10	9	8
	Night (after 6:30 pm)	14	16	24	24	14	16
		North	South	North	South	North	South
467	AM peak (6:30 am - 9:30 pm)	12	9	No service		No service	
	Midday (9:30 am - 3:30 pm)	26	12				
	PM peak (3:30 pm - 6:30 pm)	9	15				
	Night (after 6:30 pm)	22	26				

Data Collection Procedure

The first step of the research consisted of collecting field data through a short survey and direct observation. This survey, available in both French and English (see appendix 1), was meant to capture socio-demographic data and commuting habits of bus riders. A total of 543 surveys were conducted at 21 different stops along the bus lines identified above between September 15, 2014 and September 27, 2014. Data were collected at different moments of the day: morning peak, midday, afternoon peak and evening. This selection method allowed to capture of a wide sample of riders.

Respondents were selected at random while they were waiting at the bus stop. They were asked to identify the bus route they were waiting for and how often they use this service. They were also asked whether their current trip involved a transfer, either before or after using the bus service in question. Additionally, the survey enquired which schedule media the respondents used in order to plan the trip. Possible answers included: STM mobile application, other smartphone application, STM or other trip planner websites, printed copy of the schedule, at-bus stop schedules, ''I already know the schedule'' and ''I don't look at the schedule''. As surveys were conducted at the bus stops, some respondents could not answer all the questions because the bus arrived. As a result, some of the surveys were not completed, affecting the response rate for some of the last questions, including purpose of the trip, age, car ownership and destination.

While the surveyors were conducting the interviews, another team member would record, using a camera or personal observation, the arrival times of the passengers and the buses. Using these videos, it was possible to determine the actual waiting time of every surveyed passenger by filling up a field observation sheet (see appendix 2), which was used during the entire study. While surveyors were conducting the interviews, a research assistant would fill up the observation sheet. This sheet contains the passenger time stamp, which is the minute at which each passenger arrived at the stop, based on the last bus departure. Other information collected on this sheet includes the arrival and departure times of each bus, as well as the number of boarding and alighting passengers. The actual waiting time was then calculated using the following formula:

$$W = Ba - P - Bd, \quad \text{where}$$

W = waiting time (minutes)
Ba = bus arrival time (hh-mm-ss)
P = passenger time stamp, based on the previous bus departure time (minutes)
Bd = previous bus departure time (hh-mm-ss)

After the surveys were conducted, the next step consisted in creating two databases: the first one containing the answers from the interviews and the second one with the information about passengers and buses arrival and departure times.

Data Cleaning

Based on the date, time, stop ID and surveys ID, the two datasets were merged together in order to link the answers from one respondent to its actual waiting time. Through the cleaning process, several data entries were removed due to incomplete information or the impossibility to match the surveys to the passenger waiting time. Most of the incomplete surveys were caused by the lack of time for waiting passengers to fully answer the questions before the next bus arrived. Additionally, only passengers with a waiting time of at least one minute and less than twice the headway were considered. The final dataset contains 543 entries with which the analyses were conducted.

Variable Definition

In determining what attributes impact on passengers' waiting time at the bus stop, this study identifies two key variables: the dependent variable, *waiting time* (W); and the independent variable, *schedule media* used by the passengers in order to plan their trip. Several media combinations were tested to identify their high level of correlation. The final categories are as follows:

- *Online schedule* includes any smartphone applications, STM website or online trip planners (e.g. Google maps)
- *Printed schedule* refers to any printed copy of the schedule
- *At-stop schedule* refers to users that looked only at the schedule found at the bus stop
- *Known schedule* refers to users that either don't look at the schedule, or simply know the schedule
- *Various media* refers to users that indicated using more than one schedule media

Table 2 displays all the variables included in the analysis. The *headway* variable captures the influence of the bus scheduled headways on the waiting time. The information for the headways is based on the STM schedule rather than on the actual bus arrival as passengers plan their trip according to the schedule. The variable $headway^2$ was also included in order to understand the non-linear relationship between the waiting time and the headway. Furthermore, to control for potential service delays, the *bus delays* dummy variable identifies buses that were late according to the scheduled headway. A delay occurred when a passenger waited longer than 1 minute over the scheduled headway, given that the time unit is in minutes. The *bus stop at metro station* variable indicates whether waiting at a bus stop located at a metro station affects the waiting time of the user.

Table 2: Variable Definition

Variable name	**Description**
W	Waiting time in minutes **(Dependent Variable)**
Bus delays	A dummy variable that equals 1 for late bus arrivals (according to scheduled)
Bus stop at metro station	A dummy variable that equals 1 if the bus stop is located by a metro station
Age between 18 and 30 years old	A dummy variable that equals 1 if the respondent is between 18 and 30 years old
Age between 31 and 45 years old	A dummy variable that equals 1 if the respondent is between 31 and 45 years old
Age between 46 and 65 years old	A dummy variable that equals 1 if the respondent is between 46 and 65 years old
Age over 65 years old	A dummy variable that equals 1 if the respondent is over 65 years old
Trip during the week	A dummy variable that equals 1 if the trip happens during the week
Trip during the weekend	A dummy variable that equals 1 if the trip happens during the weekend
Trip during AM peak	A dummy variable that equals 1 if the trip happens during the AM peak (6:30 AM - 9:30 PM)
Trip during midday	A dummy variable that equals 1 if the trip happens during the midday (9:30 AM - 3:30 PM)
Trip during PM peak	A dummy variable that equals 1 if the trip happens during the PM peak (3:30 PM - 6:30 PM)
Trip at night	A dummy variable that equals 1 if the trip happens at night (after 6:30 PM)
Headway	The scheduled headway (minutes)
$Headway^2$	The value of the headway squared
Online schedule	A dummy variable that equals 1 if the respondent uses either a smartphone app or a website
Printed schedule	A dummy variable that equals 1 if the respondent uses a printed copy of the schedule
At-stop schedule	A dummy variable that equals 1 if the respondent uses the schedule posted at the bus stop
Various media	A dummy variable that equals 1 if the respondent uses any combination of the other media
Known	A dummy variable that equals 1 if the respondent either knows or did not look at the schedule
Headway X online schedule	Interaction between Headways and online schedule
Headway X printed schedule	Interaction between Headways and printed schedule
Headway X at-stop schedule	Interaction between Headways and at-stop schedule
Headway X known schedule	Interaction between Headways and known schedule
Headway X various media	Interaction between Headways and various media

Other variables were included to control for the time of the day and day of the week at which the trip was made: AM peak, midday, PM peak and at night, as well as either during the week or the weekend. Additional variables were tested but were removed from the analysis because they did not show statistical significance in the models. These variables include: gender, car ownership, frequency of use, trip transfers, satisfaction about the service, the purpose of the trip and perceived trip length.

ANALYSIS

Descriptive statistics

As shown in Table 3, the average waiting time for bus passengers, all schedule media included, is 5.84 minutes. Two schedule media are particularly used by the passengers. Half of the respondents (50%) indicated knowing/not looking at the schedule and 35% indicated using the online schedule, for a total of 85%. Additionally, among the five categories, only the known category shows an average waiting time lower than the overall mean.

A majority of respondents indicated using the bus five days a week, mainly for the purpose of work (45%). Close to 42% of the respondents indicated having a transfer before the bus they were waiting for and had a less than average wait time. On the other hand, 44% said they would make a transfer to another route and had an average wait time higher than the mean. Most of the surveys were conducted during the PM peak, AM peak and midday. The average waiting time for midday and PM peak trips are similar to the overall mean.

Table 3: Summary Statistics

		n	%	Average Waiting Time (min)
Schedule Media				
	Online schedule	191	35%	6.1
	Printed schedule	16	3%	6.6
	Known schedule	274	50%	5.4
	At-stop schedule	41	8%	6.4
	Various media	21	4%	7.9
Frequency of use				
	1 day/week	81	15%	5.9
	2-4 days/week	119	22%	5.9
	5 days/week	327	60%	5.8
	Weekends	16	3%	5.8
10 min. max service				
	10 min. max	253	47%	6.0
	Not 10 min. max	290	53%	5.7
Transfers				
	Before	226	42%	5.8
	After	237	44%	6.0
Day period				
	AM peak	159	29%	6.0
	Midday	134	25%	5.6
	PM peak	211	39%	5.8
	Evening	39	7%	6.1
Gender				
	Male	192	35%	5.6
	Female	328	65%	6.1
Purpose				
	Work	231	45%	6.1
	School	127	25%	5.6
	Shopping	58	11%	6.2
	Other	92	18%	6.0
Age				
	18 - 30	217	47%	5.7
	31 - 45	138	30%	5.7
	46 - 65	85	18%	7.0
	66 and above	25	5%	6.8
Total		**543**	**100%**	**5.8**

In regard to rider demographics, 35% are men and 65% are women. Close to 77% of the sample is under the age of 46 years old. Figure 2 shows the percentage of users per media according to the scheduled headway. The first outcome that can be observed from this figure is that four schedule media out of five indicate a peak in the number of users when the headway is every ten minutes. Only people who know or do not look at the schedule have a peak when the headways are every 5 minutes, and after the 10-minute headway the percentage decreases noticeably. This suggests that riders tend to know the schedule for shorter headways, and are more likely to look at the schedule for longer headways. There is also a higher percentage of riders using printed schedules for headways of 10 minutes and over. Inversely, there are more passengers use the at-stop schedule for headway of less than 10 minutes, suggesting that they simply show up at the stop as the service is more frequent. These passengers could be qualified as random users (*Fan & Machemehl, 2009)*.

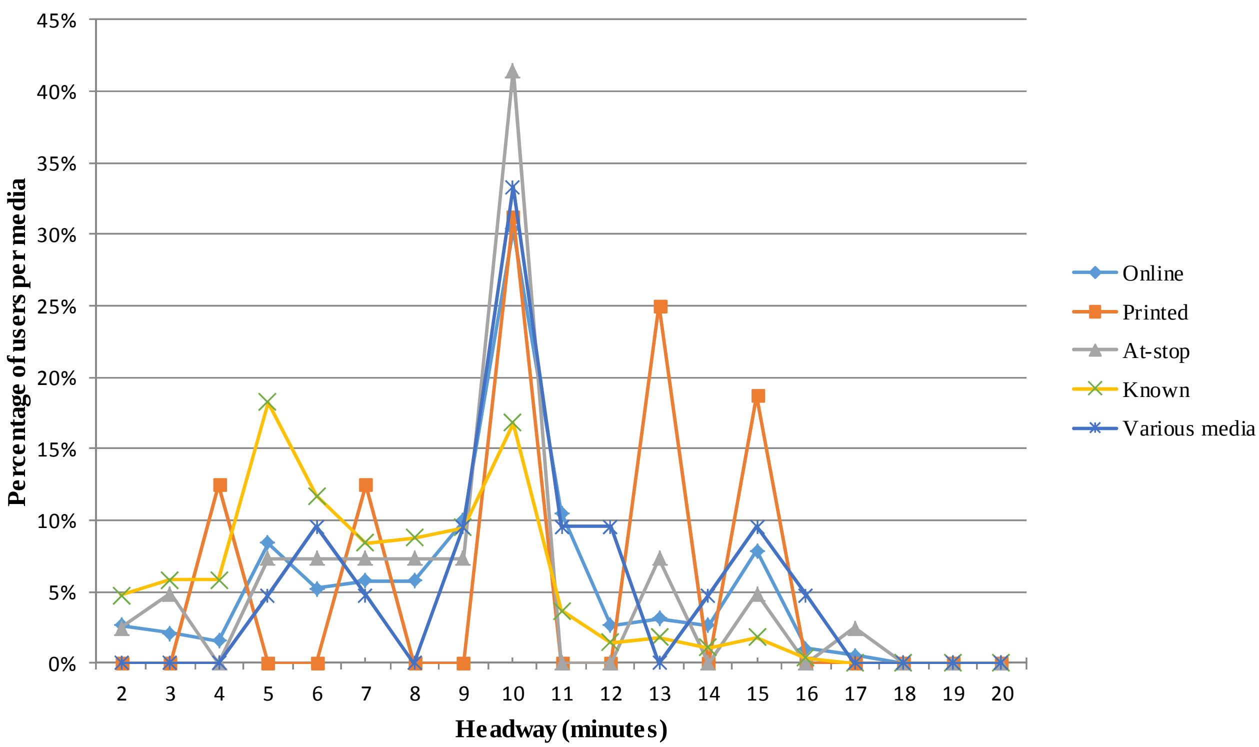

Figure 2 Most used schedule media according to the headway

Actual Waiting Time Models

Three different models are computed to describe the impact of the different variables on the waiting time. The first model included variables that were expected to have an impact on the waiting time, such as service delays and time of the day. In the second model, the headway variable was incorporated, and lastly, the third model considered the impact of the five different schedule media. By doing so, it is possible to compare different sets of variables.

It is important to mention that for all three models, the F-test results show that the F significance is almost equal to zero. Therefore, the null hypothesis can be rejected with the extremely high confidence above 99.99%, meaning that the independent variables have a relationship with the dependent variable.

Model 1

The variables contained in the first model were delays in bus service, location of the bus stop near a metro station, the age of the passengers as well as the time of the day and of the week during which the passengers traveled. The results are presented in Table 4 and have an R^2 of 0.32.

Table 4: Model 1

	Unstandardized Coefficients B		Standardized Coefficients Beta	t
(Constant)	**5.41**			**18.10**
Bus delays	**4.87**	***	**0.56**	**13.83**
Bus stop at metro station	**-2.04**	***	**-0.27**	**-6.24**
Age between 31 and 45 years old	0.13		0.02	0.41
Age between 46 and 65 years old	**1.04**	***	**0.12**	**2.83**
Age over 65 years old	**1.05**	*	**0.07**	**1.70**
Trip during the weekend	**-1.13**	***	**-0.14**	**-2.90**
Trip during midday	0.32		0.04	0.78
Trip during PM peak	0.20		0.03	0.58
Trip at night	**1.08**	**	**0.08**	**1.94**
N	464.00			
R^2	0.32			

Dependent Variable: Waiting time (min)

Bold indicates statistical significance

*** Significant at 99%   ** Significant at 95%   * Significant at 90%

The data demonstrate that when a bus is late, passengers wait approximately 4.87 minutes longer. Additionally, people over 46 years old tend to wait a little over 1 minute longer than people that are between 18 and 30 years old. This is consistent with what Psarros et al. (2011) found. Riders traveling at night wait about 1 minute more than riders traveling during the AM peak. This difference is likely attributed to the higher service frequency in the morning, which will be confirmed in the later models.

Along with these results, passengers waiting at a bus stop located at a metro station wait about 2 minutes less than passengers waiting at another bus stop on the route. Inversely, on the weekends, passengers wait on average about 1.13 minutes less than on a weekday. This can be attributed to the fact that due to longer headways during the weekends, passengers may be more concerned about potential wait times and therefore check the schedule before leaving.

Model 2

The second model differs slightly from the previous one in that the time of the day and the weekday variables were replaced by the headway variable. Instead of only including a moment of the day, the headway variable takes into consideration variations in the service frequency. The results in Table 5 show an R^2 of 0.50, a 56% increase from the previous model.

Table 5: Model 2

	Unstandardized Coefficients		Standardized Coefficients	t
	B		Beta	
(Constant)	**-1.49**	**		**-2.23**
Bus delays	**6.09**	***	**0.70**	**19.65**
Bus stop at metro station	**-0.50**	*	**-0.07**	**-1.87**
Age between 31 and 45 years old	-0.23		-0.03	-0.87
Age between 46 and 65 years old	**0.66**	**	**0.07**	**2.13**
Age over 65 years old	0.50		0.03	0.99
Headway2	**-0.03**	***	**-0.60**	**-4.28**
Headway	**1.09**	***	**1.07**	**7.45**
N	464.00			
R^2	0.50			

Dependent Variable: Waiting time (min)

Bold indicates statistical significance

*** Significant at 99% ** Significant at 95% * Significant at 90%

Similarly to the first model, late buses impact the waiting time of the passengers by adding close to 6 minutes, and people between 46 and 65 years old can expect to wait more than the users between 18 and 30 years old. In this model, however, passengers waiting at a bus stop located at a metro station can expect a decrease in their waiting time by only half a minute. This change in the results may be explained by the fact that the headway gives a better picture of the data than the time of the day and the weekday, since it considers the headway as related to passenger waiting time rather than moment of the day (e.g.: AM peak).

The impact of the headway variable in this model is clear and the results are similar to those of the effect of the moment of the day and the weekday variables. For each additional minute to the headway, a passenger may expect to wait about 1 minute. The significant value of the $headway^2$ indicates a non-linear relationship between the headway and the waiting time. When looking deeper into the dataset, the impact of short and long headways on the waiting time can be noted. This relationship will be discussed more in the sensitivity analysis section later in this paper.

Model 3

In this last model, the age variable was removed in order to increase the sample size, since not all respondents answered this question. Therefore, the dataset increased by 79 surveys for a total of 543 entries with an R^2 of 0.50, similar to model 2. The bus delays variable is once more significant with an expected additional 6 minutes of wait time for late buses. In the surveys, 36 respondents commented on the service reliability. Of this group, 23 indicated service delay and reliability as a problem.

Users waiting at a bus stop located by a metro station may reduce their waiting time by 0.50 minute. The new variable included in this model is the product of the dummy variable schedule media with the bus headway. This indicator informs on the relationship between these two variables. The results are shown in Table 6.

Table 6 Model 3

	Unstandardized Coefficients		Standardized Coefficients	t
	B		Beta	
(Constant)	**-3.74**	*****		**-2.86**
Bus delays	**6.07**	*****	**0.70**	**21.25**
Bus stop at metro station	**-0.50**	****	**-0.07**	**-2.03**
Headway²	**-0.04**	*****	**-0.63**	**-4.46**
Headway	**1.37**	*****	**1.35**	**7.12**
Printed Schedule	2.48		0.12	1.13
Online schedule	**2.22**	***	**0.32**	**1.79**
Known schedule	**2.41**	****	**0.36**	**2.01**
Various media	1.27		0.07	0.57
Headway X online schedule	**-0.26**	****	**-0.37**	**-2.00**
Headway X known schedule	**-0.29**	****	**-0.37**	**-2.28**
Headway X printed schedule	-0.30		-0.17	-1.48
Headway X various media	-0.06		-0.04	-0.28
N	543.00			
R^2	0.50			

Dependent Variable: Waiting time (min)

Bold indicates statistical significance

*** Significant at 99%   ** Significant at 95%   * Significant at 90%

The outcome differs from the previous model in regards to the schedule media. While the various media category was initially significant, online and known schedules are now significant, indicating that bus riders using these media can expect to wait respectively 2.22 and 2.41 minutes more than people looking at the schedule posted at the bus stop. This could be attributed to the fact that, regardless of the headway, people looking at the schedule plan to arrive early at the stop. When looking at the *headway x media* variable, the same two media are significant but show different expected waiting times. Indeed, these results show that for each additional minute in the headway, passengers using the online schedule or who know the schedule may expect to wait respectively 0.26 and 0.29 minute less than passengers using the at-stop schedule. These results point out the importance of the interaction between the headway and the media types.

The small variations in the waiting times induced by the different schedule media can be attributed to the fact that all media display the same constant schedule. Even though the STM is able to know whether some lines are running late, it is not yet able to communicate the new expected arrival times to its users through its current schedule media.

Sensitivity analysis

As mentioned previously, waiting time at the bus stops varies according to the headways and the schedule media used. A sensitivity analysis is conducted in order to point out the differences in the waiting times using the coefficients from the third model, and to understand the non-linear relationship between the headway and the waiting time. Two graphs were made to show the difference in the expected waiting time for a service where no delays occurred, and for users waiting at a metro stop. Figure 3 shows the expected waiting time of bus riders according to the media used where no service delays occurred.

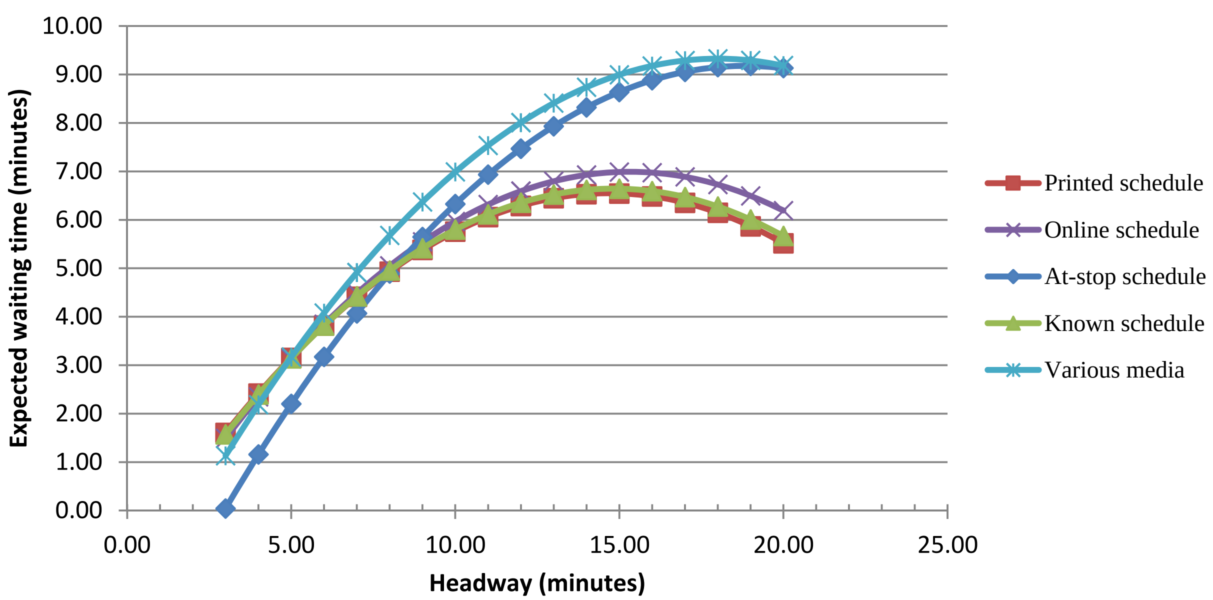

Figure 3 Bus passengers' expected waiting times according to the schedule media used, where no service delays occurred

A similar trend is observed for all five media. The curves show that waiting time increases as the headway gets longer until a peak is reached, after which the waiting time starts to decrease. This is consistent with existing research that suggests passengers will wait half the headway, but will plan their arrival in order to reduce their waiting time as the headway increases *(Holroyd & Scraggs, 1966; Osuna & Newell, 1972)*.

The curve showing the waiting time for riders using the at-stop schedule indicates the lowest expected waiting time. For example, at five-minute headways, this group's waiting time will be approximately 2.2 minutes while people using other media will wait around 3 minutes. Previous studies have made a distinction between non-random and random arrivals. Non-random arrivals are defined as passengers who plan their trip by looking at the schedule before arriving at the stop, whereas random arrivals are passengers who do not plan their trip *(Fan & Machemehl, 2009)*. Random arrivals are more likely to have lower average wait times compared to non-random arrivals when service is frequent. This may be explained by people who planned their trip using online or printed schedule media including a buffer period in their estimation, so as to guarantee not missing a bus that arrives earlier than scheduled. The inverse could also be true: that non-random passengers narrowly missed a scheduled bus and decided to wait for the following bus. Looking at each schedule media individually, Figure 3 demonstrates that passengers using the at-stop schedule or various media are the ones that can expect to wait the longest after headways of 8 and 4 minutes respectively. The peaks for these two schedule media are reached for headways of 19 and 18 minutes, meaning that these people do not manage to reduce their waiting time for longer headways. The peak for the three other media occurs at headways of 15 minutes. Past that peak, passengers seem to wait less, which suggests that they tend to plan their commute accordingly as they are more concerned about the time spent waiting. Thus, waiting time for headways between 15 and 20 minutes ranges between 7 and 5.5 minutes.

Figure 4 shows the expected wait time for passengers waiting at a stop located at a metro station.

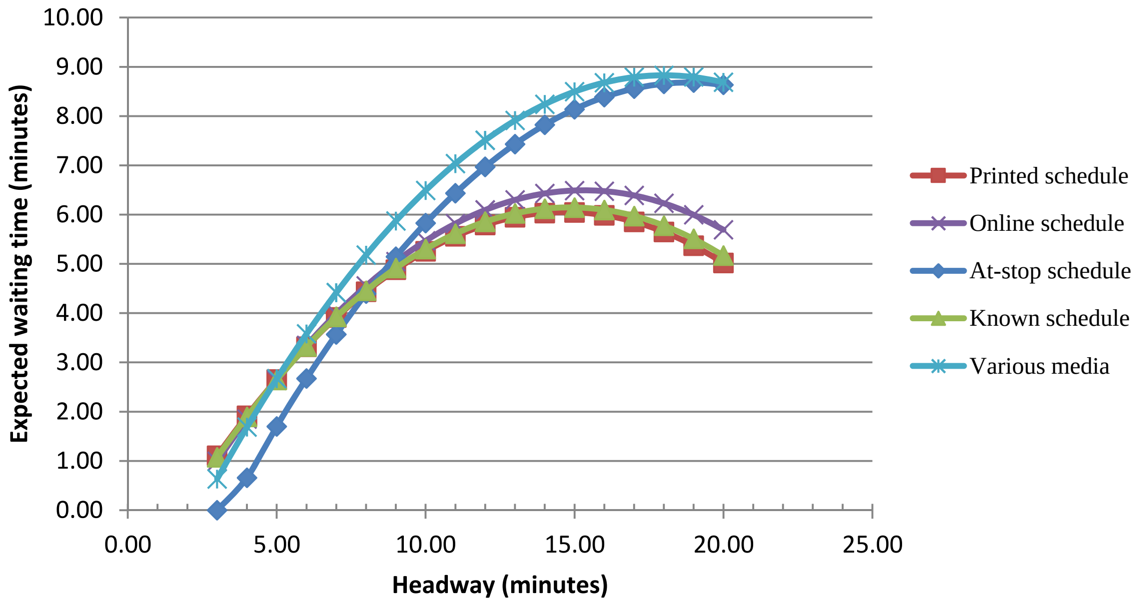

Figure 4 Bus passengers' expected waiting times, according to the schedule media, when waiting at a stop located at a metro station

The pattern is similar to Figure 3 for each schedule media. The main difference is that passengers may expect to reduce their waiting time when waiting at a bus stop located at a metro station. While the longest expected waiting time for riders using at-stop and various schedules was just above 9 minutes, this new graph shows that this group can expect to wait 0.50 minute less, bringing the waiting time just below 9 minutes. Similar outcomes can be applied for the three other media. Waiting time has decreased by half a minute, reducing the expected waiting between 6 and 6.50 minutes.

It is important to note that all estimates made in here are related to scheduled headways, so actual waiting time is expected to be longer if delays are present along an existing route. The findings from this graph can be used in the future to calculate the additional waiting time that each media user encounter during a trip associated with service delays.

CONCLUSION

The results from this study explain how some attributes affect bus passengers' waiting time at bus stops in Montreal. Bus delays and headways are shown to be consistently significant throughout the models. Findings related to the type of schedule media were correlated with wait times and headway. Notably, as headways increase, the schedule media becomes more important. Two media types, online and known schedules, obtain significant results, indicating that passengers using these media are more likely to wait longer than the people who simply look at the schedule at the bus stop. This outcome suggest that riders using a schedule may plan to arrive early at the stop not to miss the bus. On the other hand, when these two same schedule media are related to the bus headway, results slightly differ and indicate that riders can expect to wait less with longer headways. Passengers using online and known schedules can expect to wait respectively 0.26 and 0.29 minute less than people using the at-stop schedules. A sensitivity analysis was conducted to better understand the interaction between the waiting time and the headways for each schedule media. A clear distinction is noticeable between the users of online and known schedules and the riders that simply read the at-stop schedule. The former tend to wait less and reduce their waiting time for headways of more than 15 minutes while the latter can expect to wait more. This indicates that passengers are likely to adjust their arrival time, especially for headways of 15 minutes and above. These findings support previous research findings related to wait times and headway thresholds *(Holroyd & Scraggs, 1966; Osuna & Newell, 1972; Fan & Machemehl, 2009).* Additionally, this analysis shows that people waiting for the bus at a stop located at a metro station can decrease their waiting time by 0.50 minute since metro stops are usually placed in the schedules as time points.

The current study builds on previous research by supplying additional findings that could motivate transit agencies to encourage riders to use online schedules, as they have shown to reduce the waiting time for longer headways. The following recommendations can be made to transit agencies to improve riders' experience with the service based on the results of this study. Easy-to-remember schedules at major bus stop can facilitate memorization of the schedule, which is important as half of the study group indicated knowing or not looking at a schedule prior to arriving at a bus stop, especially for the high frequency routes. For those using online media, the second highest media share of the study group, providing real-time information is important in the near future to cut down the waiting time, which is an important cause of dissatisfaction among all users. This will improve perception of service reliability as well as facilitate reduced actual wait times at bus stops through more accurate trip planning.

Further research on a similar topic could include additional questions about how long in advance do people using schedules plan to arrive at the stop. This could help understanding the degree to which bus users plan an extended wait time in anticipation of early bus arrivals. Moreover, as the STM is currently developing a real-time information system for its bus service, the iBus, a similar study should be conducted in Montreal after the implementation of this system to compare whether users have adapted the way they plan their trip in order to reduce the waiting time.

REFERENCES

Ben-Akiva, M. E., & Lerman, S. R. (1985). Discrete choice analysis: theory and application to travel demand (Vol. 9). MIT press.

Chen, D. J. (2012). Measuring the Passenger's Benefit of Providing the Real Time Information System of the Bus Transit. In Transportation Research Board 91st Annual Meeting (No. 12-4000).

Daskalakis, N., & Stathopoulos, A. (2008). Users' perceptive evaluation of bus arrival time deviations in stochastic networks. *Journal of Public Transportation*,*11*(4), 25-38

Diab, Ehab I., and Ahmed M. El-Geneidy. (2014) "Transitory optimism: Changes in passenger perception following bus service improvement over time." *Transportation Research Record: Journal of the Transportation Research Board* 2415.1: 97-106.

Dziekan, K., & Vermeulen, A. (2006). Psychological effects of and design preferences for real-time information displays. *Journal of Public Transportation*,*9*(1), 1.

Eboli, L., and G. Mazzulla. (2007). Service Quality Attributes Affecting Customer Satisfaction for Bus Transit. Journal of Public Transportation, Vol. 10, No. 3, pp. 21-34. http://nctr.usf.edu/jpt/pdf/JPT%2010-3.pdf#page=26. Accessed Jan. 2015

Fan, W. D., & Machemehl, R. B. (2009). Do transit users just wait for buses or wait with strategies?. *Transportation Research Record: Journal of the Transportation Research Board*, *2111*(1), 169-176.

Ferris, B. (2011). *OneBusAway: Improving the Usability of Public Transit*(Doctoral dissertation, University of Washington). http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.230. 7222&rep=rep1&type=pdf.

Ferris, B., Watkins, K., & Borning, A. (2010). OneBusAway: results from providing real-time arrival information for public transit. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1807-1816). ACM.

Gooze, A., Watkins, K. E. & Borning A. (2013). Benefits of Real-Time Transit Information and the Impacts of Data Accuracy on the Rider Experience. Online: http://docs.trb.org/prp/13-0785.pd.

Holroyd E. M. and Scraggs D. A. (1966) ìWaiting Times for Buses in Central Londonî, Traffic Engineering and Control, Vol.8, No.3, 158-160.

Mishalani, R. G., McCord, M. M., & Wirtz, J. (2006). Passengers' wait time perceptions at bus stops: Empirical results and impact on evaluating real-time bus arrival information. Journal of Public Transportation, 9(2), 89.

Osuna E. E. and Newell G. F. (1972) ìControl Strategies for an Idealized Public Transportation Systemî, Transportation Science Vol.6, No.1, 57-72.

Psarros, I., Kepaptsoglou, K., & Karlaftis, M. G. (2011). An empirical investigation of passenger wait time perceptions using hazard-based duration models. *Journal of Public Transportation*, *14*(3), 109-122.

Reed, T. B. (1995) Reduction in the Burden of Waiting for Public Transit Due to Real-Time Schedule Information. Proceedings of Vehicle Navigation and Information Systems Conference, pp. 83-89. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=518822&tag=1

Société de Transport de Montréal. (2015) 5 ways for viewing bus schedules. April 2015. http://www.stm.info/en/info/advice/5-ways-view-bus-schedules .

Tang, L., and P. Thakuriah. (2012) Ridership effects of real-time bus information system: A case study in the City of Chicago. *Transportation Research Part C: Emerging Technologies*, Vol. 22, pp. 146-161. http://www.sciencedirect.com/science/article/pii/S0968090X12000022

Ville de Montréal. (2014). Profil Sociodémographique. Online document. http://ville.montreal.qc.ca/pls/portal/docs/PAGE/MTL_STATS_FR/MEDIA/DOCUMENTS/PROFIL_SOCIOD%C9MO_VILLE_DE_MONTREAL.PDF

Vonderschmitt, K. (2014). Riding in Real-Time: Estimating Ridership Effects of the Adoption of Mobile Real-Time Transit Tracking Applications. http://uknowledge.uky.edu/mpampp_etds/27/

Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., & Layton, D. (2011). Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. Transportation Research Part A: Policy and Practice, 45(8), 839-848.

Welding P. I. (1957) The Instability of a Close-Interval Service, Operational Research Quarterly, Vol.8, No.3, 133-148.

APPENDICES

Appendix 1: Survey

McGill 2014 (M M - J J) - H H : M M, **Arrêt :** ____________ ☐ N ☐ S **Route:** TRAM

Sondage – Utilisation des horaires de bus/ Using Bus Schedules – Survey

FRANÇAIS

1. Quelle ligne d'autobus **attendez-vous**? ______
2. Depuis **combien de temps** utilisez-vous cette ligne ?
   ____
3. À quelle **fréquence** utilisez-vous cette ligne d'autobus ?
   ☐ 1 jour par semaine ou moins
   ☐ 2 à 4 jours par semaine
   ☐ 5 jours par semaine ou plus
   ☐ Seulement la fin de semaine
4. Consultez-vous habituellement l'horaire de cette ligne d'autobus avant de l'utiliser?
   ☐ Oui, je consulte l'application STM sur mon cellulaire
   ☐ Oui, je consulte une autre application, ex. :______
   ☐ Oui, je consulte Google Maps ou le site de la STM
   ☐ Oui, je consulte une copie imprimée de l'horaire
   ☐ Oui, je consulte l'horaire fourni à l'arrêt d'autobus
   ☐ Non, je sais déjà à quelle heure l'autobus arrive
   ☐ Non, je ne porte pas attention à l'horaire
5. **Avant** d'arriver à cet arrêt, avez-vous fait un **transfert**?
   ☐ Oui, d'un autre trajet d'autobus ☐ Oui, d'une ligne de Métro ☐ Non, aucun transfert
6. Planifiez-vous faire **un transfert à la sortie** de cet autobus?
   ☐ Oui, vers une autre ligne d'autobus ☐ Oui, vers une ligne de Métro ☐ Non, aucun transfert
7. Sur une échelle de 1 à 5, indiquez votre **satisfaction** avec :

	Insatisfait →				Très satisfait
L'ensemble du déplacement :	1	2	3	4	5
Le temps d'attente :	1	2	3	4	5
La durée du déplacement :	1	2	3	4	5
L'expérience à bord :	1	2	3	4	5
Le coût du déplacement :	1	2	3	4	5

8. Recommanderiez-vous cette ligne d'autobus à votre famille, vos collègues de travail ou amis ? ☐ Oui ☐ Non
9. À quel arrêt allez-vous descendre ?
   ____
10. Lorsque vous utilisez cette ligne d'autobus, quel est le **motif principal** du déplacement? *(Encercler une seule réponse)*
    ☐ Travail ☐ Études ☐ Magasinage ☐ Autre
11. **Sexe** : M F **Âge** : ______ ans
12. Avez-vous accès à une voiture ? ☐ Oui ☐ Non
13. Pour combien de mois ou d'années avez-vous l'intention d'utiliser les services de cette ligne d'autobus ? __________
14. Quel est votre code postal? _________
15. SVP, veuillez inscrire **tout autre commentaire** ici. *(Utilisez le verso pour plus d'espace)*
    ____

ENGLISH

1. Which bus route are you **waiting for now** ? ______
2. For **how long** have you been using this route?
   ____
3. How **often** do you use this route?
   ☐ 1 day a week or less ☐ 2 to 4 days a week
   ☐ 5 days a week or more ☐ Only weekends
4. Do you usually check the bus schedules before using this route?
   ☐ Yes, I check the STM phone App
   ☐ Yes, I check another smartphone App, e.g.______
   ☐ Yes, I check online, Google Maps or STM website
   ☐ Yes, I check a printed copy of the schedule
   ☐ Yes, I check the schedule at the bus stop
   ☐ No, I already knows when my bus comes
   ☐ No, I do not pay attention to bus schedules
5. Did you **transfer before** reaching this bus stop
   ☐ Yes, from another bus route ☐ Yes, from Metro line
   ☐ No transfer needed
6. Do you plan to **transfer after** getting off the bus.
   ☐ Yes, to another bus route ☐ Yes, to a Metro line
   ☐ No transfer needed
7. On a scale from one to five, indicate **how satisfied** you are with your:

	Unsatisfied →				Very satisfied
Overall trip :	1	2	3	4	5
Waiting time :	1	2	3	4	5
Travel time :	1	2	3	4	5
Experience on board:	1	2	3	4	5
Cost of trip :	1	2	3	4	5

8. Would you recommend the bus service to a family co-worker or friend? ☐ Yes ☐ No
9. At which stop will you **get off?**
   ____
10. What is the **primary** purpose of your trip when you use this route? ***(select only one)***
    ☐ Working ☐ Studying ☐ Shopping ☐ Other
11. **Gender**: M F **Age**: ______ years old
12. Do you have access to a car? ☐ Yes ☐ No
13. For how many months or years do you intend to use this bus service? _________
14. What is your home postal code _________
15. Please write any **other comments** you would like to add. *(Use the back side for more room)*
    ____

Merci beaucoup et bonne journée! Thank you so much and have a nice day!
www.mcgill.ca/urbanplanning www.tram.mcgill.ca

* École d'urbanisme : 815, rue Sherbrooke O., Pavillon Macdonald-Harrington, Bureau 400, Montréal, QC, H3A 2K6 T: 514 398-4075
** School of Urban Planning: 815 Sherbrooke St. W., Macdonald-Harrington Building, Suite 400, Montréal, QC, H3A 2K6 T: 514 398-4075

Appendix 2: Field observation sheet

Stop_Code	Stop name	Month	Day

		Surveyor name		
		1	2	3
minutes	Passenger count			
Left behind				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28+				

Bus route: **Type:** **Bus seq:**
Door open time:
End of passenger activity time:
Door close time:
Departure time:
Door 1 boarding: **Door 1 alighting:**
Door 2 alighting:
Door 3 alighting:

Another route trip (1 min): **Type:** **Bus seq:**
Door open time:
End of passenger activity time:
Door close time:
Departure time:
Door 1 boarding: **Door 1 alighting:**
Door 2 alighting:
Door 3 alighting:

Stop_Code	Stop name	Month	Day

		Surveyor name		
		1	2	3
minutes	Passenger count			
Left behind				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28+				

Bus route: **Type:** **Bus seq:**
Door open time:
End of passenger activity time:
Door close time:
Departure time:
Door 1 boarding: **Door 1 alighting:**
Door 2 alighting:
Door 3 alighting:

Another route trip (1 min): **Type:** **Bus seq:**
Door open time:
End of passenger activity time:
Door close time:
Departure time:
Door 1 boarding: **Door 1 alighting:**
Door 2 alighting:
Door 3 alighting: