Limited bus stop service: An evaluation of an implementation strategy

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Abstract

Transit agencies implement limited-stop (express) bus services as a mean to provide an attractive and competitive transportation mode when compared to the automobile. In 2008, the Société de transport de Montréal (STM), the transit agency providing service on the Island of Montréal, Québec, Canada, was considering various measures to improve bus service. These measures included implementing a limited-stop service to run parallel to route 67 Saint-Michel, a heavily used bus route located east of the CBD. The selection process regarding which stops to include in the new service involved an evaluation of several scenarios and an estimation of run time savings. In this research paper, we use archived AVL and APC data to measure changes in on-time performance and run times offered by the new service and to compare these changes to previous estimates, through a before-and-after study. In addition, an on-site survey is conducted to measure the riders' perception of time savings. Implementing a limited stop service yielded to 4.6 minutes savings in run time for the new limited service meanwhile the existing regular service experienced an increase of 0.8 minutes in mean run time, which is due to a new smart card system that was introduced as well and caused major changes in run time. The runtime savings in the limited stop service falls in the expected estimates made by the research team, which increases the trust in the methodology, used selecting the stops and estimating the savings. Finally, the study shows that riders are generally satisfied with the new service. They also over estimate the savings from implementing the new limited service by 4 to 7 minutes more than the actual savings.

Key Words: Run Time, On-time Performance, Travel Time, Limited-Stop Service, Express Service, Transit Planning, Transit Operations

INTRODUCTION

Transit agencies implement limited-stop (express) bus services as a mean to provide an attractive and competitive transportation mode when compared to the automobile. Limited-stop bus services provide riders with shorter in-vehicle time. For the initiative to be successful, travel time savings should be substantial and easily perceivable by riders [1]. In 2008, the Société de transport de Montréal (STM), the transit agency providing service on the Island of Montréal, Québec, Canada, was considering various measures to improve bus service. These measures included implementing a limited-stop service to run parallel to route 67 Saint-Michel, a heavily used bus route east of the CBD. The STM went through a selection process with our research team to select the best set of stops. Scenarios were developed for using one limited stop serving every 4 or 5 regular stops. Finally, the STM select around 40% of stops to be included in the new service (one every three stops), leading to an increase in stop spacing to an average of 615 meters (0.382 mile), which is a little lower than the recommended spacing in the transit industry for such services [2-4]. The selection process regarding which stops to include in the new service involved an evaluation of several scenarios and estimates of run time savings [5]. The first scenario kept only transfer stops. The second scenario selected stops in the first quartile of passenger activity as measured by the Automatic Passenger Counter (APC) counts. The third scenario used the Montréal origin-destination survey data for users of this route and selected the top quartile of stops with the most activity [6]. The fourth and final scenario incorporated all the above criteria in selecting the limited stop service. Run time models were then generated using archived Automatic Vehicle Location (AVL) and APC to estimate savings along both the new and the existing service. The run time savings for the limited stop service from scenario four was estimated to be in the range between 11 and 38 percent with a realistic estimate of 20 percent. The use of AVL and APC data in estimating savings and changes in the existing services is common in the transit research field [7-9].

The STM implemented route 467 Express Saint-Michel on March 30, 2009. This paper uses archived AVL and APC data for routes 67 and 467 Saint-Michel to quantify the run time savings, changes in on-time performance and evaluate the accuracy of the previous estimates made by the research team through a before-and-after study. In addition, an on-site survey is conducted to measure the riders' satisfactions and perceptions of time savings along both routes.

The paper starts with a literature review of bus run time and limited-stop service followed by a description of the studied route and estimates from the previous study. The next section pertains to the methodology used to prepare and analyze the data for run time, on-time performance, and survey questions. It is then followed by a discussion of those results and finally by a conclusion section.

LITERATURE REVIEW

Transit users want to have a reliable service that arrives on-time, with a minimum in-vehicle time [10], and minimum access and egress time [11]. AVL and APC systems have been implemented by a number of transit agencies [12, 13] and analyzed by a number of researchers [14-17]. Run time models are usually used in understanding the existing service and in evaluating several transit planning and operation strategies, such as implementation of transit signal priority (TSP) or adoption of new technologies [9, 18, 19].

Run time is known as the time that takes a bus to complete a trip between two defined points along a route. Run time is affected by factors that do not fall under the control of the transit agency, such as congestion or weather, and those that can be controlled by the agency such as route design and the behavior of drivers [20]. Most researchers agree on the basic factors affecting bus run times [21-25]. Table 1 contains a summary of known factors affecting run times.

Table 1: Factors affecting transit travel times

Variables	**Description**
Distance	Segment length
Intersections	Number of signalized intersections
Bus stops	Number of bus stops
Boarding	Number of passenger boardings
Alighting	Number of passenger alightings
Time	Time period
Driver	Driver experience
Period of service	How long the driver has been on service in the study period
Departure delay	Observed departure time minus scheduled
Stop delay time	Time lost in stops based on bus configuration (low floor etc.)
Nonrecurring events	Lift usage, bridge opening etc.
Direction	Inbound or outbound service
Weather	Weather related conditions
Road	Road characteristics
Operating environment	Congestion

Reduction in run time is expected to lead to an increase in ridership [26] and will greatly increase riders satisfaction [11]. One of the most effective strategies for decreasing run time is decreasing the number of stops being served by a route. This can be done through revision of existing stop spacing and/or eliminating some of the existing stops. The savings from this strategy leads to more time savings than eliminating the effects of congestion [27]. This reduction can be achieved either by stop consolidation [8] or by offering limited or express bus service [1, 4, 26]. To our knowledge the use of archived AVL and APC data to quantify the amount of savings in run time due to implementation of limited stops services is not present in the transit literature. Only one study looked at savings due to implementation of limited stop services in Chicago [3] and they concentrated mainly on riders satisfaction after the implementation of the service. The second study, which we are evaluating in this paper, concentrated on the selection criteria and estimates of time savings [5].

Express or limited buses stop at only few stops along a route while a parallel regular route serves all of the limited and intermediate stops. One of the drawbacks of express service is that wait times tend to increase after implementation [4], therefore they should be implemented parallel to high frequency routes (routes with short headways, 8 minutes or less) and high ridership routes. Accordingly an evaluation of customer satisfaction after the implementation of such a service is a must. This evaluation can be done through an on-site survey.

CASE STUDY

Montréal, Québec, is the second most populous metropolitan area in Canada with 3.7 million inhabitants. The STM operates bus and subway services on the Island of Montréal, which is home to about half of the region's population. Four subway lines served by 759 cars and 192 bus routes served by 1,600 vehicles comprise the STM network, making over a million trips per weekday. Route 67 and 467 are located east of downtown Montréal and run north-south along a boulevard crossing through five boroughs of the City of Montréal. The routes are 9.16 km long in the northbound direction and 9.96 km southbound. Both lines 67 and 467 connect to two métro (subway) stations, one at its southern terminus and another at its midway point. The built form around the route is mostly three-storey triplexes mixed with some commercial buildings near major intersections. Table 2 includes a summary of route characteristics, while Figure 1 is a map of the studied routes.

Table 2: Physical characteristics of Route 67 and 467 Saint-Michel

		Route 67 regular		**Route 467 express**	
		Northbound	Southbound	Northbound	Southbound
Total	Length (kilometers)	9.16	9.96	9.16	9.96
	Traffic signals	40	43	40	43
	Number of stops	39	40	16	17
	Average stop spacing (meters)	241	255	611	623
Analysis	Length (kilometers)	8.38	8.89	8.38	8.89
	Traffic signals	36	40	36	40
	Number of stops	36	37	14	15

1 km = 0.6214 mile

The experience with APC and AVL technology at the STM dates back to 1999. AVL systems are widespread in North America [25], and the third-generation system used by the STM equips 220 buses out of 1,600 in the fleet. Buses with APC and AVL are assigned to different routes to obtain a sample of bus operational information. Data are recorded at both the stop and the trip levels by the system, mainly in order to revise schedules and generate performance measures such as schedule adherence. Route 467 operates between 6:00 and 19:00 with maximal headways of 10 minutes [28]. Due to real or de facto layover points, and to the need to compare routes 67 and 467 at the same stops, the defined route was shortened by four stops northbound and by three stops southbound.

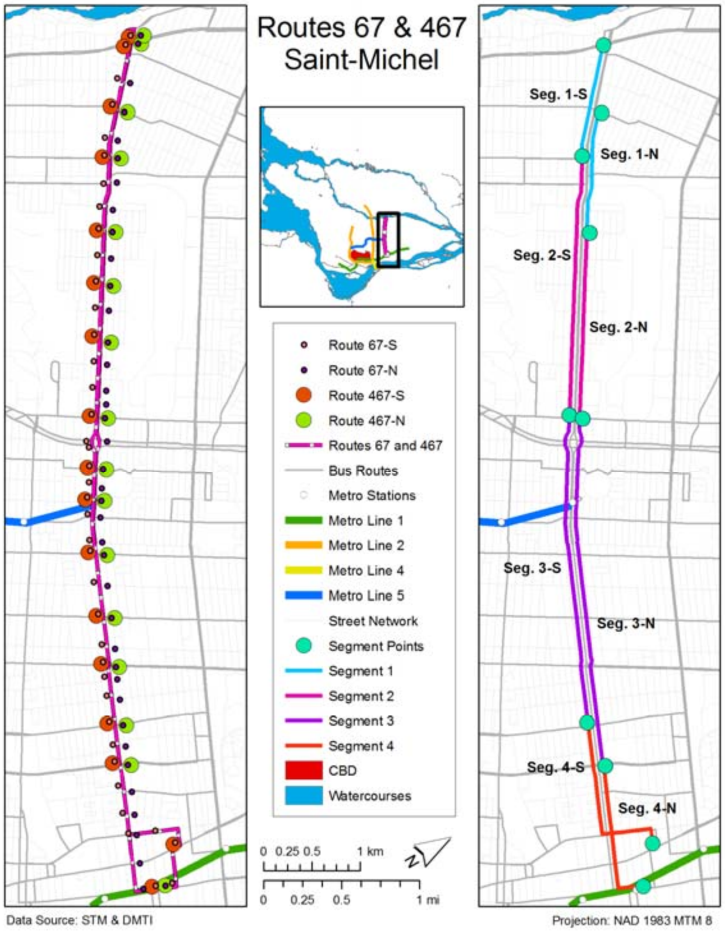

Figure 1: Study routes and segments

METHODOLOGY

The objective of this paper is to evaluate the selection criteria proposed by the research team for a limited-stop bus service and to measure the accuracy of the run time estimates introduced in the previous study by Tétreault and El-Geneidy [5]. An analysis of archived AVL and APC data collected before and after the implementation of a limited-stop service is performed. AVL and APC data is obtained from a sample of trips serving route 67 during the before period, and routes 67 and 467 during the after period. Over 240,000 individual stop records were obtained from the STM data archival system. Entries include bus arrival and departure times at each stop along the route, as well as information on passenger activity. The before data was collected between April 7 and July 4, 2008, while the after data was collected between April 6 and July 3, 2009. The records were cleaned in order to remove incomplete trips and recording errors.

The first step is to prepare summary tables and run time models to quantify the time savings associated with both routes after the implementation of the limited-stop bus service.

After data cleaning and eliminating short-turn runs, two databases were built. A database with all complete trips contains 2601 before trips, 2637 after trips for route 67, and 130 after trips for route 467. In December 2008, the City of Montréal upgraded the traffic signal timing along a small part of the route. Accordingly, the route is divided for the analysis into four segments northbound and four corresponding sections southbound, yielding 10,480 before segments, 10,621 after segments for route 67, and 6,481 after segments for route 467. See Figure 1 for the exact location of each segment.

The trip-level analysis excluded data from the first and last stops in both directions. In order to compare routes 67 and 467, the second to the last stops used were corresponding to the route 467 ones. For more precision, leave time from the first stop in the northbound direction was kept, but not passenger activity because of a higher risk of error for this variable at the first stop due to a layover. Besides, the second to the last stop in the northbound direction also had to be removed from the analysis because layovers are often taken at this stop rather than at the last scheduled stop. Hence, the third to the last stop is used for route 467, which corresponds to the fourth to the last stop for route 67. Table 3 is a list of variables prepared for conducting the analysis.

Table 3: Variables

Variable Name	Description
Run Time	The run time per trip or segment in seconds, from the departure of the first stop before the designated trip or segment to the departure from the last stop of the designated trip or segment
After	A dummy variable that equals to one if the trip observed is recorded in the after time period (2009)
R467	A dummy variable that equals to one if the trip observed is serving route 467 (only in the after time period)
Southbound	Dummy variable for southbound trips
Distance Segment	The distance in meters travelled per segment
TP Peak AM	Dummy variable for trips or segments scheduled between 6:30 AM and 9:30 AM
TP Midday	Dummy variable for trips or segments scheduled between 9:30 AM and 3:30 PM
TP Peak PM	Dummy variable for trips or segments scheduled between 3:30 PM and 6:30 PM
TP Evening and Night	Dummy variable for trips or segments scheduled between 6:30 PM and 3 AM
Delay Start	The delay at the start of the route in seconds (leave time – scheduled time)
Delay End	The delay at the end of the route in seconds (leave time – scheduled time)
Tweaked Traffic Lights	A dummy variable that equals to one if the traffic light cycle in the segment were adjusted to ease bus traffic (valid only for segment 2, in 2009)
Passenger Activity	The sum of boardings and alighting per trip or segment
Passenger Activity Squared	The sum of the square of boardings plus alighting at each stop per trip or segment
Maximum Load	The maximum load during a trip or segment
Proportion Stops Made	The proportion of the scheduled stops that was actually made

The run time model incorporates a number of variables relating to the time of day, delay, and passenger activity information [29]. This is in addition to a set of dummy variables to control for the before and after and the type of service (limited or regular). It is important to note that all buses serving the route during the two study periods were low floor buses. Also, weather conditions were tested as well, yet we could not find any adverse weather conditions or differences between the two study periods. Accordingly, weather conditions were not included in the analysis. Also, only weekday data is included in the analysis. The following is the model specification:

(1) Run time = f(After, R467, Southbound trip, AM peak trip, Midday trip, PM peak trip, Evening and night trip, Delay at the beginning of the trip, Passenger activity (boardings and alightings), Passenger activity squared, Proportion of stops made, Maximum load)

In this model, run time is expected to increase with passenger activity, for southbound trips, for peak hour trips, and with the delay at the beginning of the trip. The dummy variables R467 and After are expected to have a statistically significant negative effect on run time. The savings in run time will then be compared to estimates generated in the previous study by Tétreault and El-Geneidy [5]. A similar model is also generated, yet at the segment level. The specifications of the segment model are as follows:

(2) Run time = f(After, R467, Southbound trip, Segment length, Tweaked segment, AM peak trip, Midday trip, PM peak trip, Evening and night trip, Delay at the beginning of the trip, Passenger activity (boardings and alightings), Proportion of stops made, Maximum load)

The tweaked segment is expected to have a negative effect on run time. Segment length should have a positive effect and it is included in the model to account for the variance in the length of segments. The second part of this before and after study includes analyzing changes in on-time performance at several stops serving routes 67 and 467. The stops selected for the on-time performance analysis are the stops at the end of each segment. The stops are also highlighted in Figure 1. What follows is the model specification used in this analysis:

(3) Delay at a time point = f(After dummy,R467, Southbound trip, Segment length, Tweaked segment, AM peak trip, Midday trip, PM peak trip, Evening and night trip, Delay at the beginning of the trip, Passenger activity (boardings and alightings), Proportion of stops made, Maximum load)

In this model, the delay is expected to increase with passenger activity, for southbound trips, for peak hour trips, and with the delay at the beginning at the trip. It is expected that on-time performance will decline for the regular route and increase for the 467.

The third part of the analysis is to compare savings identified in the run time model and changes in delays at time points to riders' perceptions of the savings. In June 2009, the research team conducted a short on-site survey at stops serving both routes 67 and 467. 270 existing riders were surveyed on the changes that they noticed in waiting and run times since the introduction of the limited-stop service. The survey also asked the riders if they changed their usual stop to use route 467 and for how long they have been using route 67.

ANALYSIS AND DISCUSSION

The average run time along route 67 was 34.3 minutes northbound and 35 minutes southbound during the before time period. During the after time period for route 67, the average run time was 33.7 minutes northbound and 34.5 minutes southbound. Hence, improvements in run time are around 2% along route 67 in both directions since the implementation of the limited-stop service. As for route 467, it is faster by around 10% northbound and by around 11% southbound. Summary statistics are reported in Table 4.

Table 4: Average values for variables pertaining to routes 67 and 467, before and after

Variable	67N B	67S B	67N A	67S A	467N A	467S A
Run time (s)	2061	2102	2025	2071	1852	1869
Passenger Activity	166	177	136	145	128	133
Maximum Load	46	44	38	36	41	38
Actual Stops	28	30	28	29	13	14
Scheduled Stops	35	37	35	37	13	15

In terms of passenger activity, there is an average of 166 passengers using both doors per northbound trip and 177 for southbound trips during the before period, compared to an average of 136 passengers northbound and of 145 passengers southbound in the after period. For route 467, the average number of passenger activity is 128 and 133 passengers per trip in the northbound and southbound direction respectively. The decline in passenger activity explains some of the savings experienced along both routes. The mean number of actual stops in the before period is almost the same for route 67 as in the after period. Nevertheless, as all the scheduled stops do not tend to be served, five to seven stops could be consolidated. On route 467, all stops are generally made. The frequency of stopping is a reflective of high passenger activity. During the before time period, the STM was making 343 trips per day along route 67. Throughout the after period, the STM operated 198 trips per day for route 67 and 212 for route 467. This change leads to 67 more trips per day. With this increase in its service, the waiting time at stations is expected to decline. If the number of passengers using route 67 remains the same then run time for route 67 and 467 is expected to decline since the number of passengers is distributed between more trips. If the passenger activity increases, meaning new riders are attracted to the service, then the savings in run time should decline than the expected estimates. A more detailed analysis of run time can help in quantifying the exact savings along both routes and changes in on-time performance.

Run time and on-time performance models

The characteristics of the run time model are well known in transit literature [8, 18, 27]. The first step is to check the effects of the independent variables on run time and to what extent the effects of these variables follow the theory of transit planning. This step is used as our benchmark for assessing the quality of the collected data. Also, the *"After"* and *"Route 467"* variables are key variables for evaluating the changes in run time. A general multivariate linear regression model for run time (in seconds) was derived using the archived trip data and is given in Table 5. In addition, the same table includes a run time model at the segment level (in seconds), and an on-time performance model (in seconds).

Table 5: Linear regression models

Variable Name	Route Run Time Coef.	Route Run Time t	Segment Run Time Coef.	Segment Run Time t	On-Time Performance Coef.	On-Time Performance t
After	52.92*	13.38	13.83*	12.43	16.54*	13.85
Route 467	-262.87*	-18.34	-65.10*	-48.73	-30.52*	-21.28
Southbound	56.45*	13.27	-16.66*	-18.20	-20.44*	-20.81
Segment Length (m)			0.23*	281.65	-0.01*	-14.92
Tweaked Segment			-1.97	-1.49	2.96**	2.09
AM Peak	214.72*	24.23	57.45*	27.16	9.34*	4.11
Midday	258.54*	29.67	70.68*	34.83	12.23*	5.62
PM Peak	324.88*	34.78	88.25*	40.90	6.11**	2.64
Evening and Night	116.88*	14.33	33.98*	16.52	18.22*	8.25
Delay at Start (s)	-0.37*	-17.40	-0.11*	-27.22	0.87*	205.17
Passenger Activity	1.90*	15.53	1.46*	53.33	0.98*	33.14
Passenger Activity Squared	-0.01*	-2.94				
Maximum Load	-0.41	-1.61	-0.06	-1.14	0.54*	10.39
Proportion of stops made	227.73*	8.77	53.53*	18.36	43.76*	13.98
Constant	1392.53*	87.53	-134.95*	-40.61	-68.78*	-19.28
R Square	0.654		0.92		0.68	
N	5364		27577		27577	

*Indicate Statistical Significance at the 99% confidence level
**Indicate Statistical Significance at the 95% confidence level

First, the “After” variable accounts for the difference between time gains on route 67 and time losses due to changes in external factors such as implementation of new smart card system that consumes more time. The net effect is thus an increase of 53 seconds in run time on route 67 and a decrease of 210 seconds on route 467. As would be expected, passenger activity (boardings and alightings) increases run time by 1.9 seconds per passenger, but since the activity squared is negative, the time per passenger decreases as overall passenger activity increases. This finding is standard in the transit literature. Southbound trips are longer by 56 seconds, which accounts for the additional distance, intersections and traffic signals. Time of the day also has an important influence on run time. What is curious is that the coefficient associated with midday trips is greater than the AM peak trips one. Of course, trips in the AM peak would still be longer when accounting for increased passenger activity, but this might be due to waiting at time points or other factors apart from traffic conditions. PM peak trips are much longer (324 seconds), probably because of congestion. The proportion of actual stops made compared to scheduled stops increases the run time and mostly accounts for deceleration and acceleration time. 227 seconds have to be added to run time if a bus serves all the scheduled stops. Buses starting their runs late are faster than on time or ahead of schedule buses. Drivers may be adjusting their behavior based on whether they are ahead or behind schedule since run time decreases by 0.37 second for every second of delay at the beginning of the route. The model developed here is consistent with previous research and can be used for further analysis, thus establishing the robustness of the STM collection and archival system [8, 9, 17, 18, 27, 30]. The estimated changes in run time can be generated by using the coefficients from the above model to conduct a sensitivity analysis and predict the average new run time when keeping all variables constant at their mean values. The estimated numbers are shown in Table 6. It is clear that savings in run time are present for routes 67 and 467 at all directions during both peaks except for Route 67 in the PM peak going southbound. Yet the negative change is minor (4 seconds) and variables that are not controlled for in the model such as changes in traffic signal timing. Yet it is clear that run time in general went down on route 67 due to a decline in the passengers using the route. While for route 467 the decline is related to the decline in the number of stops and the number of passengers using the route per trip. It is also important to note that STM implemented a smart card system in December 2008, which is after the before time period and before the after time period. This new system requires each passenger to scan his card upon riding the bus. The switch from a waive-card system to scanning one could have added more time for every passenger activity, since the scanning requires passenger to keep their card adjacent to the card reader for a certain fraction of a second. This new smart card system is known to be time consuming and requires the smart card to be attached to the readers for at least 2 seconds. Also a new fare box system was implemented as well. Both can changes can help in explaining the increase noticed in travel time along the regular route (67) and also the reason why the time savings along route 467 is near the lower end of the estimations.

Table 6: Run times (time savings) in minutes predicted by the complete route model

	Route 67 before	Route 467 after	Route 67 after
Peak AM Southbound	35.79	30.88 (4.91)	35.41 (0.39)
Peak AM Northbound	34.93	29.98 (4.95)	34.38 (0.55)
Peak PM Southbound	38.61	33.47 (5.14)	38.69 (-0.07)
Peak PM Northbound	37.27	32.73 (4.54)	36.70 (0.56)

*Change is indicated between brackets

Regarding the run time model along the four segments, it is clear that the model follows the same signs and magnitude as the route model, except for the northbound variable. The difference may be due to the addition of the segment length variable. Accordingly, buses running northbound are in general faster when controlling for distance travelled. For the “tweaked segment” where the City of Montréal implemented several changes in the signalization program to favor transit service, no statistically significant impact on run time could be found. In the segment level the square of the passenger activity was dropped since it did not show a statistical significance at this level of analysis.

The on-time performance model is reported in Table 5, as well. On-time performance is calculated by subtracting the scheduled time from the leave time. A negative value indicates that the bus arrives early at the stop, while a positive value indicates a delay. The on-time performance has declined by 16 seconds when measured at the end of each segment during the after period. This decline in on-time performance is constant with the after variable can be related to the new smart card system as well. In the meantime, on-time performance has improved for route 467 relative to route 67. As a result, waiting time decreased by around 30 seconds for passengers using route 467. It is also important to note that buses are not allowed to depart stops early at time points. On-time performance improves with the increase in segment length. This means that the longer the segment, the higher the probability that a driver will arrive on time at the end of the studied segment. This finding is consistent with the finding from run time models where drivers try to go faster when they are delayed. The segment that was exposed to the changes in traffic signals has experienced a statistically significant decrease in on time performance by 2.9 seconds. In average buses arrives late at the end of this segment, accordingly a revision to the schedule is needed to address this change in traffic signal. Yet, the statistically significant positive coefficient associated with the amount of delay at the beginning of the segment indicates that although drivers try to go faster when they are late at the beginning of the route, they tend to fall behind schedules by 0.87 seconds for every second of delay at the beginning of the route. This variable also shows that some adjustments to schedules to add more recovery time can help in the operations of this route.

Comparing the amount of savings from implementing the limited-stop service directly to the savings estimated from the previous study as absolute numbers is not possible. The previous study was conducted in the winter time and the definition of the study route is different due to data issues. Accordingly, the comparison can only be done in terms of proportions. Table 7 presents the different scenarios developed in the previous study and the amount of expected savings compared to the observed savings derived from the above models.

Table 7: Estimates versus actual savings

	Route 467				Route 67			
Scenario	*Optimist*	*Pessimist*	*Realist*	***After***	*Optimist*	*Pessimist*	*Realist*	***After***
Peak AM Southbound	38.4%	11.3%	19.9%	**13.7%**	21.7%	0.0%	12.5%	**1.1%**
Peak AM Northbound	45.3%	12.5%	23.0%	**14.2%**	24.7%	0.0%	14.2%	**1.6%**
Peak PM Southbound	38.6%	11.4%	20.0%	**13.3%**	21.8%	0.0%	12.6%	**-0.2%**
Peak PM Northbound	39.1%	11.3%	20.4%	**12.2%**	21.8%	0.0%	12.5%	**1.5%**

Actual time savings proved to be slightly over the pessimistic ones, with up to 2.4% more time savings when compared to the before period, for both route 467 and route 67. The full trip time on route 467 in the after period during peak hour is about 13% shorter than in the previous period, while it is about 1% shorter for route 67 after the implementation of route 467. The situation described by the pessimistic scenario is one where there is no change on the variables affecting route 67, and where route 467 only benefits from time savings made by skipping stops. The proximity between the pessimistic estimates and the actual time savings could be explained by the introduction of the smart card system. The smart card adds in average 4 to 2 seconds per passenger. The time consumed by the introduction of the smart card and new fare box system could participate in offsetting time savings gained from an increase in the number of buses running on the Saint-Michel axis. All in all, the new limited-stop service route 467 is going faster than the previous route 67, and so within the estimated ranges.

Survey analysis

The final step in this study is to quantify to what extent users have perceived these savings. A survey was carried out for this research in June 2009 among 270 users of routes 67 and 467 at 8 northbound stops and 11 southbound stops for both routes, as well as at 1 northbound 67-only stop. Confidence intervals for multiple choice questions vary between 6.13% and 6.84%. The answers revealed that 62.1% of the respondents used route 467 most often compared to 37.9% for route 67, and that 67.5% did not change their usual stop to use route 467.

Around 31.9% of riders perceived a decrease in their waiting time for route 67, while 24.0% noticed an increase and 44.1%, no change. As for route 467, the perception of decrease reached 65.9%, with only 3.4% who were seeing an increase in their usual waiting time, and 30.7% who did not see any change. The decreases in waiting times match with the findings from the statistical analysis. Users of route 467 were exposed to a decline of 30 seconds in delays. Since not all the buses serving route 67 and 467 are equipped with AVL system and since information related to actual headways is not present, it is not possible to verify the changes in waiting time.

Around 72.4% of riders thought that their travel time decreased since the introduction of route 467, 23.2% did not notice a change, and 4.1% felt a longer commute. The survey also asked the riders to quantify the amount of savings in their personal trip time, as well as to identify the bus stops that they use for boarding and alighting. This information was compared for every rider to the average travel time between the two defined stops using archived AVL data. A difference in means test was used to compare perceptions to the average travel time obtained from the AVL data. For route 467 riders, a statistically significant difference exists between their estimates and the actual savings. Real travel time savings were on average 1.5 minutes per trip, while users estimated them within a range of 6.9 to 11.9 minutes. Still, there was no significant difference between the perception of change in run time along route 67 and the actual change, which was equal to 0.04 minutes (2.4 seconds).

CONCLUSION

The first objective of this research was to evaluate the estimates of Tétreault and El-Geneidy [5], who attempted to predict time savings associated with the implementation of a new limited-stop bus service running parallel to an existing route in Montréal, Québec, Canada. A before and after approach was used here in order to measure the actual changes in run times and on-time performance along route 67 and route 467 Saint-Michel. The actual values found are slightly over Tétreault and El-Geneidy's pessimistic estimates. A run time model indicated savings of nearly 5 minutes (13%) during peak hour along the limited-stop service, while savings for route 67 were minor, around 1% of run time gains. Introduction of a new smart card and fare box system is likely to have minimized run time gains for both routes. On-time performance of buses riding the different segments of routes 67 and 467 is affected by the same factors as the entire run time. It is important to note that for each second of delay at the beginning of a trip, a bus arrives 0.87 second late, meaning that the drivers do not have enough recovery time in their schedules. It is also clear that buses serving route 67 tend to serve 5 or 7 stops per trip than the scheduled stops. A stop consolidation analysis is recommended to identify the potential saving from consolidating these stops along route 67. The second objective of this article was to examine the users' perceptions of time savings of the new limited-stop bus service. As the survey reported, users perceive important time gains, both in waiting and travel time. Existing riders overestimate the average savings for their trips. For example the 1.5 minutes of time savings was estimated to be between 5.4 to 10.4 minutes, which means errors ranging between 360% and 693%. These estimates need to be taken carefully since they are based on a sample of 250 users, accordingly a more comprehensive survey is recommended with a bigger sample size. Savings in travel time are generally perceived positively, so minor changes in service can always help in increasing customer satisfaction as it is seen in this analysis.

The limited-stop service is thus providing real time savings to its users as well as important additional perceptions of time savings. The STM has taken a conservative action and kept 40% of its original stops for the limited-stop service, more than the 1 out of 3 stops rule. Further time savings for the agency and the users could be observed if longer average stop spacing than the current one of 615 meters (0.38 mi) were to be adopted. Due to STM material and financial limitations, not all buses serving the studied routes are equipped with APC and AVL systems, preventing research on key elements such as variability of service before and after the implementation. Also we could not use the data in hand to generate a reliable estimate of the change in the total passenger activity along the route. In the future, it is recommended to have the actual headway to estimate the accuracy of these estimates and the actual number of users along all the buses serving the route.

Evaluating the impact of the new smart card system on run time is one of the areas that needs more research. The smart card system used by the STM requires that the card to be approached to the reader for 2 to 4 seconds, which had a significant effect on the models. An evaluation of the smart card effects on the STM system in general is recommended. STM is planning on replacing the existing buses serving this route with articulated buses starting from October 2009, also TSP is planned as well for the same route, and an exclusive bus way. Accordingly a study is recommended to measure the effect of these changes as well on the run time of both routes.

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