Variation in bus transit service: Understanding the impacts of various improvement strategies on transit service reliability

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ABSTRACT

This article examines the impacts of various improvement strategies on running time deviation from schedule, variation in running time, and variation in running time deviation from schedules.

These strategies include implementation of a smart card fare collection system, operation of a reserved bus lane, introduction of limited-stop bus service, use of articulated buses, and operation of transit signal priority (TSP).

This study conduct this examination using data obtained from the Société de Transport de Montréal (STM)'s automatic vehicle location (AVL) and automatic passenger count (APC) systems, in Montreal, Canada, at the bus route segment level of analysis.

The introduction of a smart card fare collection system increased bus running time and service variation. Articulated buses, limited-stop bus service and reserved bus lanes have mixed effects on variation in comparison to the running time changes, while TSP did not show an impact on variations in our study.

INTRODUCTION

Boulevard Saint-Michel is a heavily used bus corridor located to the east of Montréal's central business district, in the province of Québec, Canada. STM has implemented a series of measures along the corridor. Figure 1 is a timeline showing these measures, which includes:

- On April 2nd, 2008, the implementation of a smart card system called 'OPUS' .
- On March 30th, 2009, the STM implemented a limited-stop bus service (Route 467) running parallel to the regular bus service (Route 67) along the corridor.
- On August 3rd, 2009, the STM began to operate a reserved bus lane during peak hours in order to improve the service.
- On February 1st, 2010, the STM assigned a number of articulated buses to serve Route 467.
- On September 1st, 2010, the STM equipped a few of these articulated buses with transit signal priority (TSP) systems which operates across all signalized intersections along the corridor.

METHODOLOGY

Trip segment is the paper's unit of analysis. Thus, all variables were summarized according to trip segment. After cleaning the source data, 255,000 trip segments were included in the final database. We calculated the running time deviation as following:

$$\textit{Running time deviation (\%)} = (\textit{the actual running time per trip segment} / \textit{the scheduled running time per trip segment}) * 100 \quad (1)$$

Data from the trip segments have been aggregated according to the following criteria: the implemented strategy, time of the day (e.g. am peak, pm peak..etc), type of bus (articulated or regular buses), route number, and direction (north or south). Afterwards, we calculated CV running time and running time deviation as following:

$$\textit{CV Running time (\%)} = (\textit{running time standard deviation for a group} / \textit{the group average running time}) * 100 \quad (2)$$

$$\textit{CV running time deviation (\%)} = (\textit{running time deviation standard deviation for a group} / \textit{Running time deviation average}) * 100 \quad (3)$$

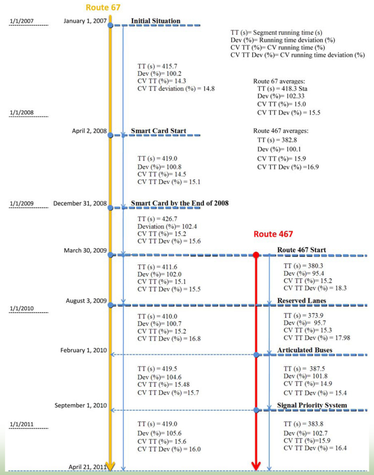

Figure 1: Time line of changes done to bus service on Boulevard Saint Michel

Four statistical models to capture and isolate the effects of the improvement strategies made by STM, have been genearted.

- The first and second models were for disaggregated trip segments, investigating the implemented strategies' effects on running time and running time deviation from schedules.
- The third and fourth models were for the aggregated grouped trip segments level, examining the implemented strategies' effects on running time variation and on variation in running time deviation from schedule.

The third model captures the effect of the implemented strategies on running time variation. The fourth model captures the difference between the trip segments' running time range of variation and the schedules' permitted level of variation after every implemented strategy by STM.

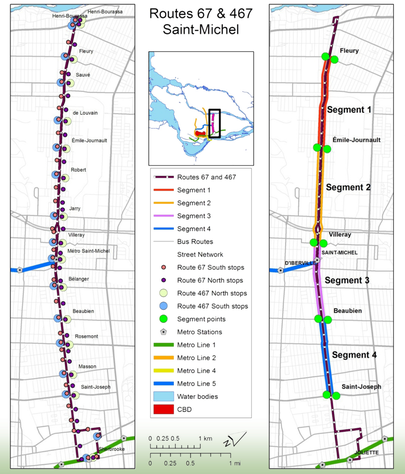

Figure 2: Study route segments

ANALYSIS

Table 3: Segment running time and segment runtime deviation (%) models

Variable	Segment running time		Running time deviation (%)	
	Coefficients	*t*-stat	Coefficients	*t*-stat
(Constant)	**361.23** ***	**405.12**	**73.43** ***	**279.76**
Actual stops	**10.53** ***	**79.71**	**3.48** ***	**89.57**
Segment passenger activity	**1.62** ***	**183.39**	**0.31** ***	**119.88**
Articulated rear door activity	**-3.17** ***	**-48.87**	**0.36** ***	**18.96**
Precip (mm)	**0.14** ***	**7.82**	**0.02** ***	**4.39**
Snow (cm)	**0.37** ***	**21.05**	**0.12** ***	**23.88**
Route 467	**-12.40** ***	**-20.94**	**6.39** ***	**36.66**
Northbound	**-14.59** ***	**-60.17**	**-2.72** ***	**-38.16**
Delay at the start (s)	**-0.07** ***	**-72.65**	**-0.02** ***	**-71.50**
AM Peak	**-8.22** ***	**-23.66**	**-0.76** ***	**-7.39**
PM Peak	**15.10** ***	**43.71**	**-3.36** ***	**-33.00**
Night	**-22.97** ***	**-64.75**	**-1.45** ***	**-13.86**
Midnight and early morning	**-48.21** ***	**-90.22**	**-0.27** *	**-1.72**
Smart card start	**3.14** ***	**7.41**	**0.83** ***	**6.61**
Smart card by the end of 2008	**12.96** ***	**30.57**	**3.10** ***	**24.88**
Reserved lane	**-11.43** ***	**-29.58**	**-4.37** ***	**-38.45**
After articulated buses date	**9.10** ***	**22.37**	**5.33** ***	**44.52**
Articulated buses	**12.97** ***	**19.24**	**-0.90** ***	**-4.52**
After TSP date	**-1.37** **	**-3.62**	**0.51** ***	**4.59**
TSP buses	**-1.40** ***	**-2.40**	-0.05	-0.29
Segment 1	**-41.64** ***	**-122.65**	**-6.98** ***	**-69.87**
Segment 3	**-72.60** ***	**-175.44**	**-0.67** ***	**-5.51**
Segment 4	**-91.67** ***	**-264.93**	**-1.29** ***	**-12.69**
N	255,000		255,000	
R^2	0.47		0.21	
F statistic (22, 254977)	10057.0		3087.3	
F significance (Prob > F)	0.00		0.00	

Bold indicate statistical significance
*** Significant at 99% ** Significant at 95% * Significant at 90%

Table 4: CV segment running time and CV segment running time deviation (%) models

Variable	CV running time (%)		CV running time deviation (%)	
	Coefficients	***t*-stat**	**Coefficients**	***t*-stat**
(Constant)	**10.354** ***	**9.58**	**9.332** ***	**6.42**
CV actual stops	**0.063** **	**2.32**	**0.126** ***	**3.43**
CV passenger activity	**0.042** **	**2.15**	0.037	1.40
CV articulated passenger activity	**0.054** **	**2.24**	**0.061** *	**1.86**
CV precip	-0.006	-1.49	-0.003	-0.60
CV snow	**0.002** ***	**2.56**	**0.003** **	**2.50**
Route 467	0.257	0.75	**1.809** ***	**3.91**
Northbound	**0.444** ***	**2.79**	-0.187	-0.87
CV delay at the start	0.001	1.25	0.001	1.60
AM Peak	-0.189	-0.89	**-0.479** *	**-1.69**
PM Peak	0.336	1.41	0.480	1.50
Night	-0.292	-1.12	**-0.664** *	**-1.89**
Midnight and early morning	**-0.561** *	**-1.68**	-0.205	-0.46
Smart card start	-0.018	-0.04	-0.107	-0.20
Smart card by the end of 2008	**0.670** **	**1.97**	**1.185** **	**2.53**
Reserved lane	**0.486** **	**2.46**	0.198	0.75
After articulated buses date	0.048	0.19	**-0.997** ***	**-2.94**
Articulated buses	**-2.752** **	**-2.18**	**-3.475** **	**-2.05**
After TSP date	**0.453** **	**1.97**	**0.583** *	**1.89**
TSP buses	0.236	0.87	0.295	0.80
Segment 1	**1.183** ***	**5.58**	**1.716** ***	**6.02**
Segment 3	**3.377** ***	**14.82**	**3.403** ***	**11.11**
Segment 4	**1.178** ***	**5.50**	**1.684** ***	**5.86**
N	478		478	
R^2	0.45		0.35	
F statistic (22, 455)	16.91		11.11	
F significance (Prob > F)	0.00		0.00	

Bold indicate statistical significance
*** Significant at 99% ** Significant at 95% * Significant at 90%

SMART CARD FARE COLLECTION SYSTEM

The introduction of a smart card fare collection system increased bus running time by 16.1 seconds (or by 3.8%), increased running time deviation from scheduled by 3.9%, increased running time variation by 0.7%, and increased variation in running time deviation from schedule by 1.1%. This indicates an unanticipated problem in relation to the implementation of smart cards.

RESERVED BUS LANES

The operation of an exclusive bus lane saved an average of 11 seconds (2.7%) for buses utilizing these lanes and decreased running time deviation from schedules by 4.3%. These buses experience more variance in their travel time by 0.5% . This can be interpreted to the effects of the cue of cars in front of the bus since Montreal has no turn on red policy.

LIMITED-STOP BUS SERVICE

The limited-stop bus service (Route 467) is faster by 12.4 seconds (3.0%) and with no significant difference in running time variation compared to the regular service (Route 67). However, Route 467 buses exhibit 6.4% higher running time deviation from schedules, as well as 1.8% higher variance in running time deviation from schedules.

This indicates that while the use of limited stop service is recommended due to running time saving and little impacts on running time variation, schedule revisions are needed to add more recovery time for Route 467 similar to the amount of recovery time that exist for Route 67.

ARTICULATED BUSES

The articulated buses saw an increase in running time by 13 seconds (3.1%) on average per segment accompanied by an increase in running time deviation from schedule of 6.6%.

Articulated buses were subjected to a decrease in running time variation by 0.9% compared to other buses, and a decrease in variation in running time deviation from schedule by 2.5%. This indicates that articulated buses are more consistently slower and behind schedule than other buses.

Therefore, transit agencies planning to use articulated buses in general are required to provide more running time and less recovery time compared to other bus types.

The presence of articulated buses in the corridor had a negative impact on running time for other buses increasing it by 9 seconds (2.2%) per trip segment, as well as increasing their deviation from schedules by 5.3%.

This increase is suggested to be stable since the CV of running time deviation from schedules has decreased by 0.99%, with no significant effect on running time variation.

TRANSIT SIGNAL PRIORITY (TSP)

The TSP equipped buses are faster than other buses by 1.4 seconds (0.3%) per trip segments compared to other buses after the introduction TSP; however, they have no significant effect on running time deviation from schedule, running time variation, and variation in running time deviation from schedules.

The presence of TSP equipped buses along the corridor had an impact on all other non-TSP equipped buses where running time declined for all buses by 1.37 seconds (0.3%) per trip segment. However, these buses suffered a increase in their running time variance.

The mixing between TSP equipped and non-TSP equipped in a route is not recommended at high frequency routes due to the impact on running time variation; as such variation will cause a decline in the reliability of service and will require additions in recovery time, diminishing their running time savings.

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