Assessing operation and customer perception characteristics of high frequency local and limited-stop bus service in Vancouver, Canada

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ABSTRACT

Public transport agencies implement different strategies aimed at improving the operation of transit service and to increase satisfaction among its riders. One service strategy employed by transit agencies is a limited-stop bus service that runs parallel to a heavily used route to decrease travel times for existing riders and to reduce pressure on the local route. Using bus operations data obtained from automatic vehicle location (AVL) and automatic passenger counter (APC) systems and customer satisfaction data collected in Vancouver, Canada, the present study evaluates levels of satisfaction among users of a local and limited-stop bus service while controlling for the service characteristics these users have experienced in the past seven days. Our results reveal that after controlling for characteristics related to the conditions of the service experienced by users, namely passenger activity levels, patrons of the express route service were more likely to be satisfied with the transit service compared to users of the local service. This finding indicates that the operational characteristics of a limited-stop service, including in-vehicle time savings and higher route frequency, are highly valued by its users. Results of this study demonstrate how operations data can provide greater context for customer satisfaction analyses. Finally, this study provides transit planners and policy makers with a better understanding of how customers perceive local and limited-stop service.

Keywords: Bus service, limited-stop bus service, AVL/APC data, customer satisfaction

INTRODUCTION

The success of a public transport agency largely depends on the number of satisfied passengers using the system and who will continue to use it in the future. Operational improvements, namely reductions in travel time and advances in service reliability, increase the operational efficiency for a public transport provider (Diab, Badami, & El-Geneidy, 2015). However, these improvements may also increase riders' satisfaction (Hensher, Stopher, & Bullock, 2003; Mouwen, 2015) and result in the growth of patronage (Bates, Polak, Jones, & Cook, 2001; Noland & Polak, 2002), which is an important measure of success for a public transport provider. One of the most effective strategies to reduce the running time of a bus route is the implementation of a limited-stop bus service along public transit corridors with high passenger demand.

Limited-stop bus or express service is a special service that serves a limited number of stops along a bus route where high passenger activity is present (Tétreault & El-Geneidy, 2010), while usually a parallel route serves all stops along the same corridor. While limited-stop service provides passengers with lower travel times, network design must be carefully considered to ease passenger transfers (Ibarra-Rojas, Delgado, Giesen, & Muñoz, 2015). Spacing of stops along a limited-stop bus service should be several times greater than a local service (Vuchic, 2005) and located at high passenger activity stops and transfer points to maximize the benefits from this kind of service. More specifically, Nielsen et al. (2005) recommends that every third or fourth local stop will be served by an express bus. Whilst there appears to be little in the way of standards for the implementation of a limited-stop bus service, Ercolano (1984) stated that time savings of a limited-stop route must be at least 5 minutes in order for users to perceive the operational improvements. At bus stops served by both local and express bus service, it is assumed that passengers will normally take the first bus departure for short journeys, but are likely to wait for the express bus departure if the distance travelled by this route is in excess of 10 km (Nielsen et al., 2005).

There are two main objectives of this study, first is to predict overall satisfaction levels of users of two concurrent bus routes, a local and limited-stop bus service, while controlling for operational characteristics of the service these users experienced. The second objective is to expand our understanding of how operations data, collected from automatic vehicle location (AVL) and automatic passenger counter (APC) systems, can be used to better understand how customers perceive transit service. Using AVL/APC data and customer satisfaction data collected for a local and limited-stop bus route in Vancouver, Canada, logistic regression modeling is employed to understand how service characteristics influence overall satisfaction levels of local and limited-stop route users. Results of this article provide further insight on how customers perceive the quality of limited-stop bus service and contribute to the limited knowledge in the literature regarding how operational data can be used to provide a complete picture of satisfaction levels, particularly how experience with transit service affects passenger satisfaction levels.

This study commences with a review of relevant literature on customer satisfaction and operational benefits of limited-stop and local bus service, which is followed by a description of the study context. The next section provides a detailed description of the operations data and customer satisfaction data used in this study, which is followed by a detailed explanation of how we merged the operations data to each survey respondent. Next, we present the satisfaction data used in this study and model results of overall satisfaction levels with bus operations data. Finally, the results are discussed and conclusions from this paper are drawn.

LITERATURE REVIEW

The implementation of a limited-stop bus service and the various benefits resulting from this operational strategy have been studied from many different approaches. Broadly, the literature can be categorized into studies that evaluated the operational benefits of this new service strategy (Diab & El-Geneidy, 2012; Parbo, Nielsen, & Prato, 2018; Surprenant-Legault & El-Geneidy, 2011; Tétreault & El-Geneidy, 2010), how customers perceived the new service (Conlon, Foote, O'Malley, & Stuart, 2001), studies evaluating best practices for the design of such routes (Chen, Liu, Zhu, & Wang, 2015; Chiraphadhanakul & Barnhart, 2013; Leiva, Muñoz, Giesen, & Larrain, 2010; Soto, Larrain, & Muñoz, 2017) and others recommending planning approaches for designing the service (Tétreault & El-Geneidy, 2010). More recently, some researchers have tried to understand the conditions that make express bus service an attractive alternative, and have found that a key condition driving demand for express service is high demand for long trips that share similar origin-destination pairs in a corridor (Hart, 2016; Larrain & Muñoz, 2016; Yi, Choi, & Lee, 2016).

El-Geneidy and Surprenant-Legault (2010) observed bus run time savings of a newly implemented limited-stop bus service in Montreal, and found a decrease in the running time of 13% during peak hours. Similarly, running time savings of 10.8% were observed by Diab and El-Geneidy (2012) while evaluating changes in run time along the same route evaluated as the previously mentioned study, after a combination of operational service strategies were implemented along this bus corridor in Montreal. Declines in running time between 10.8% and 13% can lead to substantial savings in operations. Both studies were conducted on an express bus service which operates parallel to a local bus service that serves all bus stops including the limited and intermediate stops. In terms of the local bus service, time savings are also expected on this route because a proportion of the passenger activity of this route will shift to the new limited-stop service (Tétreault & El-Geneidy, 2010). The operational time savings associated with limited-stop bus service have also been shown to reduce emissions of pollutants (i.e., CO2, HC, CO, NOx, PM2.5) (Tang, Ceder, & Ge, 2018).

In addition to studying the operational benefits associated with limited-stop bus service, a few studies have in parallel evaluated how customers perceived the implementation of a limited-stop service. Conlon et al. (2001) studied the implementation of a new limited-stop route in Chicago, and found significant increases in satisfaction among the users of the new service. Furthermore, the authors reported that this new service attracted new riders to the route, increased the share of infrequent riders along the route, and drew riders from other bus routes. Following the implementation of a new limited-stop line in Montreal, El-Geneidy and Surprenant-Legault (2010) surveyed users on their perception of travel time savings, and observed that among users that reported switching to the limited-stop bus service, 66% of riders reported a decrease in their travel time and on average these users reported time savings within the range of 6.9 to 11.9 minutes, although real time savings were on average 1.5 minutes per trip. A similar result was observed by Diab and El-Geneidy (2012), who found that 55% of users reported a decrease in their travel time, and riders overestimated their travel time savings within a range of 2.5 to 6 minutes. Also, the authors noted that riders were walking longer distances to use the faster limited-stop service. Accordingly, passengers have a positive attitude towards service improvements, and generally overestimate travel time savings compared to reality, which was also observed by El-Geneidy et al. (2017) after determining that users overestimated the time savings associated with an all-door boarding pilot project. Reasons for the overestimation of the benefits associated with a newly implemented service strategy such as limited-stop service remain unclear, and how these perceptions change over time is unknown (Diab et al., 2015).

Archived data collected through AVL and APC systems provide transit agencies with a rich and extensive database that can be analyzed in transit research for planning and operational improvements (Dueker, Kimpel, Strathman, & Callas, 2004; EI-Geneidy, Strathman, Kimpel, & Crout, 2006). However, the use of operations data in combination with perception variables to understand what influences users' satisfaction levels has been rarely demonstrated in the literature. Reducing the attrition of existing riders requires an understanding of the customer's needs and perspectives of service quality, both for the overall service and for attribute-specific items (i.e. reliability and safety). For that reason, several public transit agencies have adopted marketing strategies, such as regularly surveying customer satisfaction levels, to elicit knowledge on overall and attribute-specific satisfaction levels and to identify the relative influence of these service attributes on a users' overall service assessment. While satisfaction measures obtained from passengers are frequently incorporated in performance-based contracts due to the presumed link to the overall performance of a provider, few studies have actually examined the link between customer satisfaction data and objective performance measures in public transit (Friman & Fellesson, 2009), although this research agenda is being pursued recently by several authors including van Lierop and El-Geneidy (2017), Carrel, Lau, Mishalani, Sengupta, and Walker (2015), and Carrel, Mishalani, Sengupta, and Walker (2016). Davis and Heineke (1998) argue that satisfaction surveys are most valuable if a link can be made between satisfaction and service performance measures. Otherwise, an analyst might know that customers are dissatisfied with a particular service aspect, but will not understand the sensitivity of satisfaction ratings with respect to the delivered service. For example, linking satisfaction with crowding and objective measures of crowding would provide feedback to agencies regarding how sensitive overall satisfaction ratings are to experienced levels of crowding, and presumably how crowding measures impact people differently. With that being said, this study aims to expand our knowledge of the link between satisfaction and operations data. Specifically, we aim to determine how different factors, in particular operation characteristics, are related to overall satisfaction levels of local and limited-stop bus users. Also, while previous research was designed to evaluate customers' perceptions of a newly implemented limited-stop service (Diab & El-Geneidy, 2012; Surprenant-Legault & El-Geneidy, 2011), the objective of this study is to evaluate satisfaction levels among limited-stop bus route users of a mature service that has been running parallel to a local route in Vancouver for several years at a high level of frequency.

STUDY CONTEXT

The location of this study is Vancouver, which is the third-largest metropolitan area in Canada. In 2016 the Metro Vancouver area had a population of approximately 2.5 million people. Public transit service in the Metro Vancouver region is provided by TransLink, which is a publicly owned transport authority. The two bus routes studied, route 99 B-Line and route 9, are operated by TransLink's Coast Mountain Bus Company, which operates bus service in Metro Vancouver. TransLink was created in 1998 and is governed by a council of mayors representing the 21 municipalities in Metro Vancouver and a Board of Directors. The two bus routes serve a major east-west arterial in Vancouver, Broadway, which provides connections to and from several of Vancouver's busiest hubs. Furthermore, these routes connect to the rapid transit lines in Vancouver as displayed in Figure 1. Note, the same fare system and cost applies to both bus routes, and during peak hours the curb lanes along this corridor are exclusively reserved for bus traffic.

The main operational differences between these routes are that route 99 B-Line is a limited-stop service, the route exclusively operates low-floor articulated buses, allows passengers with a prepaid fare to board at all doors of the bus, and the alignments of the two routes differ slightly at the eastern and western ends. The western terminus of route 99 is located at the University of British Columbia (UBC), whereas route 9 ends around 4 km prior to UBC, whilst it provides occasional service to the university (between September and April). From the eastern side, route 9 commences around 3 km east of route 99 at Boundary Loop, then it is joined by the 99 B-Line at Commercial Drive to run in parallel along Broadway street until it intersects with Alma street in the west where route 9 usually ends. The alignments of both routes are displayed in Figure 1. The 99 B-Line has an average one-way route length of 13.9 km, and on average the travel time is 40 minutes[1]. The passenger demand along this corridor is so strong that both local and limited-stop services can be operated with very high frequency. Average daily weekday boardings on Route 99 B-Line have increased between 2014 (55,420 passengers) and 2018 (55,900 passengers), and this route is the busiest bus route in the TransLink network (Translink, 2019). During peak hours customers using the 99 B-Line service experience a headway of 3.5 minutes or less between buses. The average one-way length of the local bus service (route 9) is 10.4 km, and has an average trip duration of 63 minutes. During peak hours, the headway of route 9 is 5 minutes. The passenger demand along route 9 was highest in 2014 (25,090 passengers) and has since declined to a total of 22,940 average daily weekday boardings in 2018 (Translink, 2019).

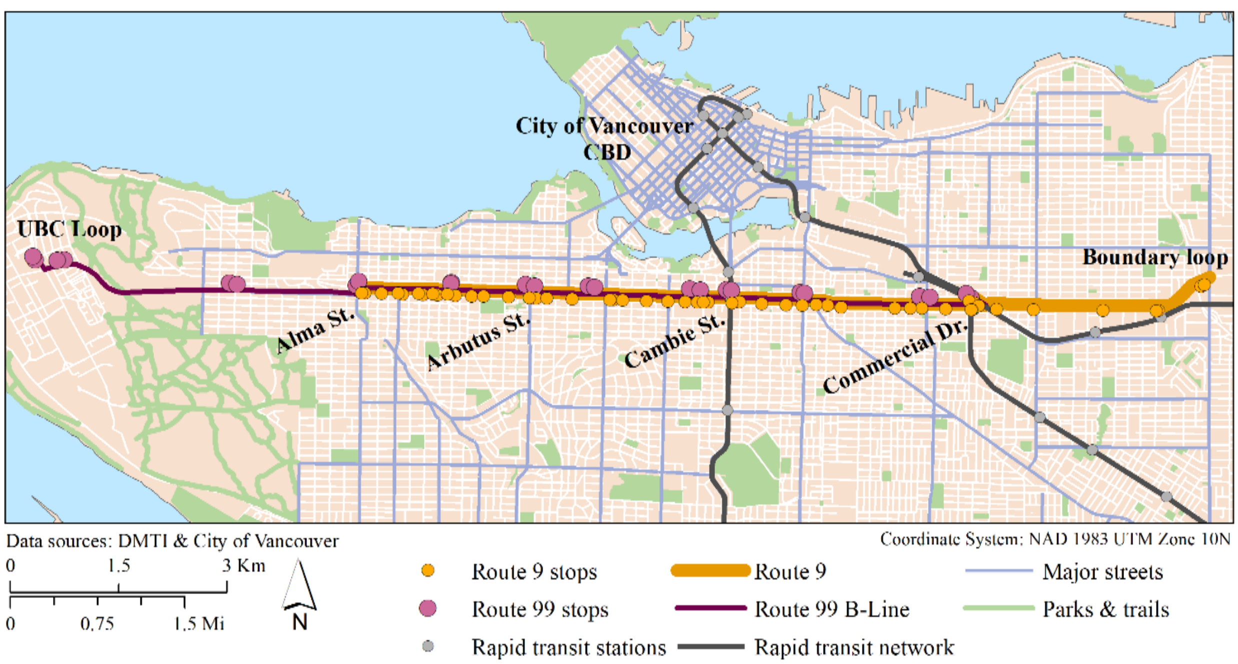

FIGURE 1 Context map for routes 99 B-Line and 9 in Vancouver, Canada.

Two sources of data were obtained from TransLink: (1) AVL/APC operations data, and (2) customer satisfaction survey data. In our analysis we use only data collected between January 1,

[1] Note, the operating conditions described here reflect the service that was present during data collection.

2011 and December 31, 2013 from both sources. The analysis of this study commences with a descriptive analysis of operational differences between both routes and differences in perception of service quality among route 99 B-Line and 9 riders. This is followed by an analysis of customer perceptions of service quality among express and local bus users, which controls for the actual service these customers experienced (operations data).

ANALYSIS

Operations Data

The operations data (AVL/APC data) employed in this study was provided by TransLink. The AVL system records the arrival and departure time at each stop, and is commonly used to evaluate efficiency and reliability of service. APC data is the primary source of data used to measure route-level passenger activity (boardings and alightings), as bus passengers are not required to tap-out upon exit with their smart fare card and some passengers pay with cash. For routes 99 and 9, these data are collected at the stop-level and include scheduled and actual trip start time, scheduled and actual stop arrival and departure times, details regarding the use of the wheelchair ramp or bicycle rack, the number of boardings and alightings (averaged across all doors), and the passenger load departure. Table 1 presents summary statistics of operations data, to differentiate operational characteristics of both the express bus service (route 99) and local bus service (route 9). We cleaned the source data by removing incomplete trips and trips on the weekend and holidays.

The summary table of operational characteristics of both bus routes indicates that the express service experiences on average twice the number of passenger boardings and alightings as the local bus service. The average passenger load of a bus along route 99 is 34.9 passengers, which is significantly higher than the average load at stops along route 9 (13.4 passengers). It is important to note that route 99 B-Line is exclusively served by articulated buses with a capacity of 85 passengers, whereas route 9 is operated by standard sized buses that have a capacity of 55 passengers. Despite the operation of higher capacity vehicles along route 99, 19% of trips along route 99 from our study sample experienced extreme crowding levels at one or more stops along the trip, and this number increases to 30% of trips during the evening peak. Along trips operated by route 9, however, only 4% of trips achieved extreme levels of crowding along a trip.

TABLE 1 Descriptive statistics of operational characteristics of both routes

Variable Name	Description	99 B-Line Limited-stop service		Route 9 Local service	
		Peak[1]	**Off-peak**	**Peak**	**Off-peak**
On-time performance	The percentage of stops where a bus arrived more than 5 minutes late.	10%	13%	5%	8%
Passenger activity	The number of passenger boardings and alightings at all doors during a trip.	256	219	144	137
Stop-level passenger activity	The number of passenger boardings and alightings at stops during a trip.	18	16	8	7
Passenger load	The number of passengers on a bus at the departure of a stop.	38	32	14	14
Crowding	Percentage of trips with one or more stops that had a passenger load that exceeded the capacity of the bus.	28%	10%	5%	2%
Bicycle rack usage	Percentage of trips where the bicycle rack was used.	40%	40%	11%	9%
Wheelchair ramp usage	Percentage of trips where the wheelchair ramp was activated.	18%	26%	12%	21%

[1] Peak hours began at the start of transit service in the morning until 09:30 and from 15:00 until 18:30 Monday to Friday

Customer Satisfaction Data

As of 2015, routes 99 and 9 were ranked the first and fourth busiest bus routes, respectively, in the TransLink network. There are key operational differences between these routes, namely route 99 only serves select stops, which reduces the run time by approximately 23 minutes compared to route 9 that serves both the limited stops and all intermediate stops. Also, route 99 allows passengers to board at any door of the bus as long as they have prepaid fares. Accordingly, we wanted to assess how passengers perceived these differences in operational characteristics, by evaluating satisfaction levels among respondents whose most recent trip was on either one of these two routes, while controlling for the performance of these two routes using the AVL/APC data introduced above.

The customer satisfaction surveys are conducted quarterly, and are collected with the purpose of evaluating how existing customers (specifically participants who reported taking a trip in the past 30 days) perceive the quality of service provided by TransLink. Surveys are conducted by telephone, and are voluntary, which can result in non-response bias. The survey begins broadly by asking customers to rate their overall experience with the transit system in the Metro Vancouver within the past seven days. Then, the survey asks respondents to name the mode(s) and route number they have used during their last or second to last trip and follows that with questions about their perception of service quality during that trip. The survey questions cover a range of service characteristics, including their perception of crowding, trip duration, and the on-time performance of their most recent trip. At the end of the survey, participants are asked a series of questions related to their socio-demographic and household characteristics and their usage of transit.

For the purpose of our study, we selected respondents who reported using the bus on their last trip, but removed users who reported using more than one bus or mode, to avoid any bias that may impact their perception of the service on route 9 or 99. This yielded a total of 679 respondents in our final sample, 485 99 B-Line users and 194 users of Route 9. We focused on questions related to the customers' perception of the performance of these two routes, for example the level of crowding and how one would rate the trip for providing punctual service. Table 2 presents summary statistics of the differences in socio-demographics between the limited-stop (route 99) and local (route 9) riders, and mean levels of satisfaction related to service performance variables. A *t*-test was used to compare mean values of riders on route 99 and 9, to assess statistically significant differences of user-reported perceptions of service characteristics as well as differences in socio-demographic characteristics and usage levels of the two groups of users.

As indicated in Table 2, users of route 99 are younger, are more likely to be students and have higher levels of income compared to route 9 users. Regarding their satisfaction levels, differences are observed, however, the most noteworthy difference among these riders is their perception of crowding. Namely route 99 users are very dissatisfied with crowding levels (mean of 5.3 out of 10), which is logical given the high passenger activity and extreme crowding levels observed from the operations summary statistics. Regarding satisfaction levels with the users' most recent trip on either route 99 or route 9, the summary statistics indicate that riders on route 9 were more satisfied with their last trip (mean of 8 out of 10) compared route 99 users (mean of 7.5 out of 10). Additionally, route 9 users reported marginally higher levels of satisfaction with the overall transit service provided by TransLink (mean of 7.9 out of 10) compared to route 99 users (mean of 7.7 out of 10).

TABLE 2 Summary Statistics of Survey Variables Comparing Route 99 and 9 Users

	99 B-Line Limited-stop service N = 485	**Route 9** Local service N = 194	
Personal Variables			
Age 16-34	25%	15%	***
Age 35-54	39%	39%	
Age 55 plus	36%	46%	**
Household Income level			
Under $25,000	12%	19%	**
$25,000 – 55,000	23%	30%	**
$55,000 – 85,000	27%	30%	
$85,000 and over	38%	21%	***
Employed full time	49%	45%	
Student	11%	5%	***
Transit Usage			
Irregular riders	10%	10%	
Customer for over 1 year	83%	83%	
Compared to 6 months ago, are you now riding transit..			
More regularly	13%	17%	
Less regularly	11%	8%	
The same	76%	75%	
Access to a car	69%	61%	*
Likely to continue to use transit	92%	88%	
Satisfaction levels[1]			
Overall service provided by the transit system in Metro Vancouver	7.7	7.9	*
Satisfaction with previous trip on route 9/99	7.5	8.0	***
Crowding	5.3	7.5	***
On-time reliable service	7.9	7.7	
Trip duration	8.5	8.5	
Frequency of service	8.1	7.6	***

Significantly different sample mean: ***=p<0.01, **=p<0.05, *=p<0.1

[1]Satisfaction measured on a Likert scale between 1 and 10 (10 being highly satisfied)

Linking the two sources of data

The objective of this study is to examine overall satisfaction with the users' most recent trip on route 99 B-Line (express route) or 9 (local route), as a function of operational characteristics, personal characteristics, and the context of that individuals' trip. Incorporating operational characteristics in our model, which are rarely combined into satisfaction studies in practice or in the literature, was done in an effort to contextualize the service that user experienced for a better understanding of how customers react to the service they experienced.

Accordingly, we linked AVL/APC operations data collected to customer satisfaction surveys collected between January 1, 2011 and December 31, 2013. The key information available for us to match the trip of an individual to the operations data were the date of the interview, the time of day and day of week of that individual's trip (which occurred in the past seven days), and the route that they used. Unfortunately, the exact date of the trip, direction of the trip and its origin and destination were not collected in the survey, which imposes a limitation on our ability to link the satisfaction survey to the AVL/APC data associated with their trip. We linked each survey entry date with operations data of trips over the past week that occurred during the same time period (e.g. weekday morning peak). This provided us with average values of operations variables we anticipated would impact an individual's overall satisfaction levels, such as on-time performance, crowding, passenger activity (number of boardings and alightings at a stop), and leave load (number of passengers onboard the bus as it departs a stop). We also calculated the standard deviation and coefficient of variation for each variable, to control for variability in service characteristics throughout the seven days. Linking these two sources of data was done to better understand the service these users experienced and to determine how operational characteristics predict overall satisfaction levels.

Overall satisfaction model

Our goal is to understand the factors impacting the satisfaction level of users of route 99 or 9. Accordingly, a logit model was employed to predict a satisfied user or not, using the following question as our dependent variable: "Based on your own experience in the past seven days, on a scale of one to ten how would you rate the overall service provided by the transit system in Metro Vancouver?" The selection of this question as our dependent variable, rather than satisfaction with the users' last bus trip will be discussed in the final section of this paper. Satisfaction was asked on a scale between 0 and 10, so a binary variable was created, where responses of 8 and above were converted to "satisfied" and below 8 "dissatisfied". These cut offs are based on the internal threshold for which TransLink considers customers as satisfied or not. We modeled overall satisfaction as a function of operations variables we collected over the seven days, including on-time performance, passenger load, passenger activity and crowding, and characteristics of that trip, including the route used (99 or 9), and whether the trip occurred during a peak hour. We then expanded our model to include personal characteristics, including age, household car access, and their frequency of transit use.

Two logit regression models were developed using overall satisfaction with transit service in Metro Vancouver as the dependent variable, and the results are presented in Table 3. Model 1 assesses whether the operations variables describing the context of the service during the past seven days, i.e., the conditions experienced by route 99 and 9 users, influenced overall satisfaction levels. Model 2 expands on Model 1 by including personal characteristics of the user, namely their age category. Both models have a total sample size of 679.

The key policy variable in Model 1 is the route 99 dummy variable, which accounts for whether a respondents' last trip was along this route and controls for the operational characteristics that are unique to the limited-stop service. This variable showed a positive and statistically significant impact on the likelihood that a user was satisfied with the service delivered by TransLink. More specifically, the odds of an express route user being satisfied are 4 times higher than a local route user, while controlling for other variables. This suggests that route 99 users are more likely to be satisfied with service than users of route 9 when experiencing similar service characteristics, including levels of passenger activity. As expected, more heavily loaded buses and trips with higher passenger activity decrease the odds of satisfaction among riders. With consistently high passenger demand along bus routes such as route 99, passengers do not know if they will be able to board the bus or whether they will have to wait for the next bus. This results in greater variation in waiting time and travel time for customers (Tirachini, Hensher, & Rose, 2013), which may change customers' behavior, as risk-averse riders may choose a route with lower occupancy rates (Kurauchi, Bell, & Schmöcker, 2003), for assurance that they will be able to board the bus.

Variables that were tested in our model but did not reveal statistical significance include average on-time performance and the standard deviation of on-time performance. The percentage of crowded stops along a trip (stops where the bus departed a stop exceeding the capacity) also revealed no statistical significance in our model. Crowding has many effects on both the operations of bus service and passengers' well-being (Li & Hensher, 2011; Milkovits, 2008), however the impact of crowding on riders is very complex to analyze particularly in this study predicting satisfaction of users from two bus routes, as a result of the mediating effect of the travel time savings experienced by route 99 users, despite higher crowding levels. Also previous research has shown variance in satisfaction levels with crowding during the peak and off-peak which was mostly related to expectations of riders (van Lierop & El-Geneidy, 2017). In other words, riders using the route 99 were found to be satisfied with a crowded bus during the peak and not satisfied with the same level of crowdedness along a bus route operating during the off-peak.

Model 2 expands on our first model by incorporating personal characteristics of the user. We tested different variables including car access, employment status, frequency of transit use, and income level and found no statistical significance of these variables in our model. Similar operational results are found after controlling for users' age. When compared to individuals aged 55 and over, the odds of users between the ages of 16 and 34 being satisfied are 32% lower. Similarly, the odds of being satisfied for users between the ages of 35 to 54 years is 44% lower than users aged 55 and over. Lower satisfaction levels in younger cohorts have been similarly observed and explained by the greater likelihood to be employed full time and undertaking many responsibilities that include travel (van Lierop & El-Geneidy, 2017).

TABLE 3 Predicting Satisfaction with Transit Service

	Model 1: Operations data			**Model 2: Operations data and personal characteristics**		
Variable	OR	Confidence level		OR	Confidence level	
		2.5%	97.5%		2.5%	97.5%
Constant	131.11*	1.03	2.65	213.79**	1.44	39327.79
Operations Data						
Average passenger load	0.88**	0.78	0.98	0.88**	0.78	0.98
Variation in passenger load	0.17	0.00	99.35	0.17	0.00	105.86
Passenger activity	0.98*	0.96	1.00	0.98**	0.96	1.00
Passenger activity squared	1.00***	1.00	1.00	1.00***	1.00	1.00
General Trip Information						
AM peak trip	1.08	0.52	2.26	1.19	0.57	2.51
PM Peak trip	0.83	0.44	1.55	0.95	0.50	1.79
Off-peak trip	*Reference*			*Reference*		
Route 99	4.00**	1.06	15.73	4.68**	1.22	18.77
Satisfaction Variables						
Age 16 – 34 years	---	---	---	0.68*	0.43	1.06
Age 35 – 54 years	---	---	---	0.56***	0.39	0.82
Age 55 and over	---	---	---	*Reference*		
Goodness-of-fit measures	AIC: 869.55 BIC: 905.72 N = 679 Log likelihood: -426.78			AIC: 864.57 BIC: 909.77 N = 679 Log likelihood: -422.28		

***=p<0.01, **=p<0.05, *=p<0.1

DISCUSSION & CONCLUSIONS

The main objective of this article was twofold. First, to predict satisfaction levels of users of a local and limited-stop bus service, while controlling for personal and operations characteristics. Second, to expand on our knowledge on how operations data can provide a more complete understanding of passenger satisfaction levels. Operations data extracted from AVL/APC systems were employed to provide context for operational differences at the stop and trip level between the local and limited-stop bus service. Overall, we found that passenger activity levels are significantly higher on the limited-stop bus service (99 B-Line) compared to the local bus service. We next evaluated differences in satisfaction levels and personal characteristics of the local and limited-stop service users included in our study sample, to provide a base understanding of satisfaction levels of these groups of riders. Finally, we constructed two logit models to predict overall satisfaction with transit service in Metro Vancouver, as a function of passenger activity and stop observations and personal characteristics of the users studied. The model results revealed that 99 B-Line users (limited-stop bus route) are 4.7 times more likely to be satisfied with overall bus service compared to route 9 (local route) users, when keeping all other variables at their mean. In other words, under the same conditions of crowding and passenger activity, express route users are far more likely to be satisfied. This finding is important for transport policy, suggesting that if a bus corridor is suitable for the implementation of a limited-stop bus service, namely sufficient demand along a bus corridor and high demand for long trips that share similar origin-destination pairs in a corridor, satisfaction levels are expected to be positively impacted by implementation for this service. Characteristics of a limited-stop route service that are captured in the dummy variable of our model, such as the significantly lower travel time that is offered by a limited-stop service, the operation of articulated buses, and higher service frequency have an important impact on a customers' satisfaction levels among existing users.

Regular monitoring of customers' perception of service through the collection of customer satisfaction surveys is one of the most widely used and recognized tools in the industry to directly capture the customers' judgement of service quality (Davis & Heineke, 1998; Hensher et al., 2003). Accordingly, how surveys are collected and the specific questions included in questionnaires are critical to ensure that agencies are collecting high quality and meaningful data. In this study context, the survey administered by TransLink was designed to first ask customers about their rating of the quality of transit service in Metro Vancouver and then asked detailed questions regarding the last trip they took within the past seven days. By linking satisfaction data to operations data of the past five weekdays corresponding to when the respondent was interviewed, we were able to predict the respondents' overall satisfaction with transit service as a function of operations data and personal characteristics. However, we were unable to find a statistically significant relationship between these operations variables and the individuals' satisfaction with their last bus trip since the actual date was not given as well as boarding locations and direction. The average performance of trips occurring at the same time over the past week did appear to predict the users' overall satisfaction levels and their attitudes towards the service quality delivered by TransLink which they prompted to reflect on over the past seven days. Collecting more detailed information regarding an individuals' last trip in customer satisfaction surveys would significantly improve the ability to combine operations and customer satisfaction data. One way this could be done is by collecting the users' payment card information in surveys and linking their reported satisfaction with their last trip to their travel information from their payment card, assuming that users are required to tap-on and tap-off. The use of smart card data for analysis of customer perceptions of service as demonstrated in Brakewood and Watkins (2016) is emerging in the literature as a strategy to evaluate changes in transit travel.

As the summary statistics of the express and local route users revealed, on average, the local route users reported higher overall satisfaction levels, which can be misleading if analysis is limited to summary statistics. The advanced modeling approach enabled us to detangle the causes of these differences and showed that when controlling for the type of service, personal characteristics, and operating conditions, users of the express route are more satisfied with the overall service. We urge transport agencies to be cautious when evaluating summary statistics of satisfaction levels, as this analysis demonstrates that important contextual information is missing from such values. To increase overall satisfaction levels among the 99 B-Line users, requires reducing crowding levels, as our model indicated that passenger activity and passenger loads were found to negatively impact a users' satisfaction overall. Routes 99 and 9 are ranked first and fourth respectively among the most highly used bus routes in the TransLink network. To meet this passenger demand, peak hour headways are approximately 3.5 minutes and 5 minutes on routes 99 and 9. Therefore, strategies to mitigate the negative impacts of crowding on these routes are recommended, for example reductions in fares at off-peak hours, or increasing the frequency of service or the types of buses operated to have a higher carrying capacity. A total of 77,000 boardings daily along these two routes is also high enough to start discussions of converting the type of service offered along this corridor to a light rail with exclusive right of way allowing greater capacity of passengers. Serving this route with higher capacity vehicles, is critical as we see that crowding is negatively impacting satisfaction levels of the 99 B-Line users.

Customer satisfaction data and operations data are seldom analyzed together either in the literature or in practice. In most public transit agencies, these data are collected and analyzed by two different departments. However, it is essential that public transit agencies consider the needs of existing and future users in all strategic planning decisions, as customers are the most important judges of service quality. As agencies set internal targets for service performance, according to what is presumed to be suitable quality of service for customers, we need to know more about how accurately these benchmarks align with customer expectations of service. Through combining satisfaction and operations data, we have a better understanding of users experience transit and whether or not service meets their expectations. Furthermore, it is expected that customers' expectations of service quality change for different levels of service (i.e. an express bus service compared to a local bus service), among different groups of people and at different time periods. Accordingly, this is an important future area of research for both public transit planners and academics to consider.

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