VANCOUVER, BRITISH COLUMBIA’S HIGH TECH BUS RAPID TRANSIT ACHIEVES MODE SHIFT FROM PRIVATE VEHICLES SURPASSING RAPID RAIL TRANSIT

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1. Service Code: 3. Multi Modal 3-2 Public Transit
2. Technology Code D-2 Fleet Management and Logistics
F-3 Markets and Business
G Human Factors and Behaviour

ABSTRACT

Bus Rapid Transit (BRT) services were first introduced in Greater Vancouver in 1996 as a forerunner to rapid rail transit. Using high capacity articulated buses on high volume corridors, BRT services can achieve travel speeds competitive with auto travel, through limited stops, ITS technology, direct routes and bus priority measures.

The 98 B-Line BRT introduced in August 7, 2001, features state-of-the-art Intelligent Transportation Systems (ITS) unique to the 98 B-Line, including automatic vehicle location, traffic signal priority, automatic stop announcements and LED read-outs onboard, and distinctive stations with real-time passenger information.

This paper will demonstrate that consumer-oriented technology enabled the 98 B-Line to achieve a mode shift from private vehicles surpassing rapid rail transit, and customer satisfaction ratings surpassing BRT services without this technology. A $3 million annual capital and operating cost savings was achieved, together with a large increase in ridership.

Soon after its introduction, 98 B-Line’s achieved a mode shift of 23 percent from private vehicles, resulting in a reduction of 8 million vehicle-kms of driving each year. The
resulting improvements to air quality and environmental benefits enhanced the livability of a great city. By 2003, 98 B-Line’s mode shift from private vehicles had increased to 48 percent, surpassing Vancouver’s rapid rail transit system.

**INTRODUCTION**

**A Livable Region Strategic Plan to Manage Rapid Growth**

Greater Vancouver has experienced a period of rapid population growth, from 950,000 in 1967 to over 2 million in 2004, projected to increase by another million people by 2031. In the five-year period between 1996 and 2001 while Canada’s population grew by 4 percent, the population of Greater Vancouver increased by 8.5 percent.

Growth has been characterized by low density sprawl, interspersed with pockets of higher density, the gradual loss of farmland and green space, reduced air quality, increasing distances between home and work, and increasing reliance on the automobile. The impact of this growth is evident on every commuting day with traffic congestion and delays in the network.

To maintain Greater Vancouver’s high quality of life, a Livable Region Strategic Plan was adopted in 1996 by the Greater Vancouver Regional District to guide the future growth of the 22 municipalities that comprise the District. The Plan was designed around four principles:

1. **Protect the Green Zone** of agricultural land and parks
2. **Build Complete Communities** where people can live, work and play
3. **Achieve a Compact Metropolitan Region** by concentrating population growth in selected areas
4. **Increase Transportation Choices** to reduce reliance on the car, protect the Green Zone, create complete communities and a compact metropolitan region.

The Greater Vancouver Transportation Authority, publicly known as TransLink, was formed in 1999 to bring together planning for major roads and bridges, transit, and transportation demand management in the 22 municipalities and to increase transportation choices consistent with the principles of the Livable Region Strategy.

**Bus Rapid Transit and the Development of the 98 B-Line**

The Bus Rapid Transit services were conceived to relieve traffic congestion on the region’s busiest corridors and improve the environment by attracting large numbers of people from private vehicle travel with cost effective bus services. In 1996, Greater Vancouver introduced 99 B-Line, the first of three Bus Rapid Transit services, incorporating high capacity express service, along the Broadway-Lougheed corridor. This route extends from the University of British Columbia at the western end to Lougheed Mall at the eastern terminus. The 99 B-Line was followed by the introduction
of 98 B-Line between Richmond and Vancouver in August 2001 and the 97 B-Line between Simon Fraser University and Coquitlam in September 2002. Greater Vancouver’s three B-Line routes now carry 50,000 daily passengers, or 10 percent of bus passengers in Greater Vancouver.

**Rapid Transit Network (2002)**

B-Line services are high frequency limited stop express bus services on high volume corridors that typically carry between 1,000 and 3,000 passengers per peak hour in each direction. They use high capacity 60-foot articulated buses with distinctive B-Line branding, colour scheme and livery. Due to its efficiency and capacity, B-Line services carry more people at a lower cost per person than traditional bus services achieving a “rapid transit economy of scale” as compared with local bus services.

The 98 B-Line incorporates state-of-the-art Intelligent Transportation Systems features not found in the other two B-Line services. These included automatic vehicle location (AVL) and traffic signal priority (TSP), and distinctive stations with real-time passenger information. The 98 B-Line is considered to be one of the most technologically advanced transit systems in North America, operating 7 days a week with a dedicated fleet of 28 low floor articulated 60-foot buses.
The 98 B-Line runs as frequently as every 5 to 6 minutes during peak hours, along a 16-km route between Richmond City Centre, Vancouver International Airport and Downtown Vancouver. The corridor is anchored by high-density commercial and office development at each end, with low density to high density residential and commercial development in between, as well as Vancouver International Airport in Richmond. The 98 B-Line stops at a transit exchange near the two Airport terminals, which have frequent shuttle service connecting to the exchange.

Along much of the route, transit priority measures allow buses to bypass traffic congestion and maintain their schedules, achieving travel times competitive with private vehicles. These priority measures include a 3 km. median busway on No. 3 Road in Richmond, queue jumpers that allow the bus to move in a separate lane ahead of other traffic entering a corridor, bus only lanes and traffic signal priority at designated intersections which allow a green light to be extended or a red phase to be truncated based on schedule adherence.

Transit Management on 98 B-Line is provided through the Siemens’ Transit Master system. Each 98 B-Line bus is equipped with on-board Global Positioning System (GPS) units, linked to a PC-based vehicle logic unit (VLU) that collects and processes the data, checks schedule adherence and facilitates communication with the central operating system at the Surrey Transit Centre (STC). A mobile data terminal allows drivers to view their current status and permits command and control of the system on board. The buses are polled very 18 seconds and their locations are transmitted via a dedicated radio channel to the STC where their locations are differentially corrected. The arrival times of each bus at upcoming stations are predicted and transmitted to LED customer information signs at the stations.
At bus stations, these message signs indicate when the next two 98 B-Line buses will arrive. The locations are also relayed back to the buses and based on schedule adherence, the VLU requests traffic signal priority (TSP) via a transponder located on the side of the bus. The transponder uses Dedicated Short Range Communications (DSRC) to send a TSP request to wayside receivers located at designated intersections on the corridor. The TSP requests are relayed from a "check-in" receiver to the traffic controller. A "check-out" receiver sends a request to the traffic controller to end the TSP sequence.

This AVL system allows facilitates better fleet management to address issues such as bunching and overlapping of vehicles. The AVL system also supports automated voice and digital displays providing “next stop” announcements to on-board passengers.

Distinctive, architecturally designed 98 B-Line stations provide high quality passenger amenities consistent with the rapid transit experience. Shelters are well lit, with glass walls for good visibility and security, as well as being designed for low maintenance. Stations were sized to accommodate passengers based on forecast boardings at each station, plus an allowance for benches, trash cans, newspaper vending machines, and ticket vending machines for on-street ticketing and all door loading.
Assessment of Market Potential and Customer Needs

Prior to the introduction of the 98 B-Line, extensive consumer research was conducted, to test the potential for the alternative routings and trip times as well as new ITS features to attract ridership from private vehicles.

A market survey was conducted of a random representative sample of 900 regular travellers on each of the corridors between Richmond and Vancouver where the 98 B-Line service could potentially run in order to develop trip volume estimates for each corridor.

In addition, interviews were conducted on-board a prototype rapid bus parked in Downtown Vancouver with 225 regular travellers on the Richmond-Vancouver corridor, and people with disabilities who were pre-recruited to establish consumer preferences for on-board information, ease of boarding and alighting, seating types and configurations, colour schemes and materials.

Research was designed to meet the following objectives:

1. Profile current travel, by mode of transportation, time of travel and corridor travelled
2. Evaluate the B-Line service concept of high frequency limited stop express service using high capacity buses among present travellers of each of the corridors
3. Estimate total annual one-way trip volumes, separately for each corridor, for a B-Line service with a total trip time of 35 minutes and an alternative service with a total trip time of 40 minutes
4. Identify potential usage of stops at selected locations
5. Identify potential origin-destination patterns
6. Estimate mode shift from private vehicles
7. Understand target market priorities with regard to possible features and benefits of the service, including automated on-board announcements of stops, LED signage at stops, emergency telephones
8. Evaluate proposed branding and livery, interior colour scheme, seat configuration, luggage storage, on-board information, vertical poles versus straps, the need for reading lights and air circulation

Implementation of Consumer Research Findings

Consumer research was one of many data inputs that were used to design a service that best met the needs of potential riders as well as shaping the urban environment consistent with Greater Vancouver’s Livable Region Strategy. Throughout the planning and engineering process leading up to the introduction of B-Line services, there was heavy reliance on planning and engineering guidelines, transportation modelling and traffic counts together with consumer research data.
Two Versions of the Bus Rapid Transit Service Concept Tested

In the large-scale study of 900 Greater Vancouver residents who travelled the Richmond-Vancouver corridors on a regular basis, a split sample approach was applied to the presentation of the 98 B-Line concept. One-half of respondents were presented with a concept description with a travel time of 35 minutes, and the other half were presented with a description with a 40-minute travel time, on a random rotated basis with respondents randomly assigned to each version.

Respondents were asked about their likelihood of use of the new service and the estimated number of one-way trips they would take in an average week, month or year. A one-way trip was defined as a trip to a single destination, not counting any transfers along the way; thus a trip from home to work and back home again would be two one-way trips.

A standard marketing research formula was used to down weight respondent estimates of their use of the proposed service, based on experience with the extent to which consumers overestimate likelihood of use of new product and service concepts, gained from validation of estimates with actual experience when a new service is introduced. Overestimation derives from several factors, including the desire to please the interviewer, the fact that when a service is introduced there is never 100 percent awareness of the service as there is in a market survey, and the fact that the service is never totally without defects as it is in the idealized survey environment.

The research found no significant difference in likelihood of using the 35-minute trip service as compared to the 40-minute trip service; that is, consumers did not distinguish between a 35-minute and a 40-minute B-Line trip between Richmond and Vancouver in estimating their likelihood of using the service. Thus some of the resources that would have been necessary to deliver a faster B-Line trip were re-allocated to provide parallel express bus services originating from a tourist area of Richmond, and going direct to Downtown Vancouver. These services had been tentatively slated for elimination to provide service hours for a faster B-Line trip.

Origin-Destination, Time of Travel and Potential Usage of Stops

A list of proposed stops was reviewed by the target market of 900 Richmond-Vancouver corridor users. Respondents identified at which stops they would be most likely to board and at which they would most likely disembark if they were to use the proposed new 98 B-Line. Respondents were also asked their preferences regarding a number of alternative routings.

Research findings regarding estimated usage of proposed stops was one of the data inputs used to establish stop location. The original stop configuration was altered, with some stops added, while potentially very low volume stops were eliminated. Station locations were selected to maximize user access and minimize user travel time. Stations were generally located at cross street bus routes, but at a minimum spacing of 400 meters in
high density downtown Vancouver and Richmond, and up to 2 km apart in lower density areas. In addition, the routing within Richmond was adjusted. Research showed strong support for routing the service along Number 3 Road.

Pre-B-Line travel patterns along the routes between Richmond and Vancouver, including the inbound and outbound time of travel by various modes, were identified. This information was cross checked against traffic counts to enable the development of estimated boardings that would occur during various times of day in both directions. In addition, an estimate of volumes of passengers who would be making connections to other transit modes at specified stops further assisted in scheduling connecting buses.

**BRT Features and Benefits Sought by Target Market**

A list of 17 possible features of the proposed 98 B-Line service was evaluated by the target market of present travellers along the Vancouver-Richmond routes. These items related to on-time reliability, proposed headways, proposed service hours, overcrowding and seating availability, covered stations, security while waiting, on-board and station information, travel time compared to the car, storage, seating, air conditioning, and even driver attitude. Features related to the proposed new technology received high ratings.

Automated voice announcements of the next stop was rated 7.3/10, on-board electronic display of the next stop received a 6.7/10 rating, on street ticketing (6.9/10). In the separate study on-board the prototype bus in downtown Vancouver, “digital sign display with a computer voice announcement of the next stop” was rated important by two-thirds of the target group, who gave this feature a 7.7/10 importance rating.

The on-board traffic management system including a global positioning system and the ability to delay lights to enable the bus to stay on schedule was not evaluated by consumers prior to introduction of BRT service. The plan was to monitor customer ratings after implementation to determine whether Intelligent Transportation Systems had an impact on perceived on-time reliability and frequency of service.

**Enhanced Livability through BRT Technology**

In 2003, Transport Canada through their ITS Deployment and Integration Plan, TransLink and a consultant team led by IBI Group jointly funded a project to evaluate the system performance of the 98 B-Line. The goals of the 98 B-Line service that were evaluated included:

1. Reduction in bus travel times on the corridor
2. Providing improved customer service through reliability and convenience
3. Increasing transit ridership
4. Operating an efficient transit service relative to traditional bus routes.

The report provided a comprehensive evaluation of the before-and-after performance of the service, a summary of “lessons learned” and also developed guidelines for future
BRT deployments within and outside the region. These guidelines could then be used by TransLink and other agencies that were contemplating BRT implementation. The results of the evaluation are provided in this paper as a framework to consider BRT success and to gauge the impacts of customer related features in future projects.

**Reduction in Bus Travel Times on the Corridor**

Less frequent stops, dedicated bus lanes and queue jumper lanes together collectively resulted in reduced travel times on the 98 B-Line compared to conventional bus services on the same route. Current round-trip travel time on the 98 B-Line is 84 minutes on average, whereas local bus travel times were approximately 100 minutes on the same route.

The purpose of traffic signal priority is to keep buses on schedule rather than to reduce travel time. More reliable schedule adherence permits lower layover time to be incorporated into the schedule and is estimated to save 4 minutes round trip, or 5 percent of route travel over the entire route, which equates one vehicle of the fleet of 24.

**Improved Customer Service**

The Greater Vancouver Transportation Authority conducts ongoing daily tracking of customer satisfaction with all transit services in the Greater Vancouver area as well as ongoing tracking of mode shift from private vehicles to transit. An analysis of four quarters of customer satisfaction data gathered from riders on the 98 B-Line bus rapid transit with AVL, real time information at the station and traffic signal priority, is followed by the same data from 99 B-Line that does not have these technological advances:

![98 B-Line Customer Satisfaction Ratings Trends](image)

*SOURCE: System-Wide Customer Satisfaction Survey: Bus, SeaBus, SkyTrain*
The 98 B-Line has consistently higher overall satisfaction ratings, on-time reliability ratings, perceived frequency of service and safety at the stop ratings when compared to the 99 B-Line. Although customers are generally unaware of the ability of the 98 B-Line service to use AVL systems to delay traffic signals and keep the bus on schedule, their ratings demonstrate that they register a difference.

In recent quarters, 98 B-Line has been a victim of its own success, with all customer satisfaction ratings being negatively impacted by overcrowding (rating not shown here).

The 98 B-Line significantly outperforms SkyTrain on the dimension of Safety at the Stop, and matches SkyTrain overall satisfaction for two out of four quarters shown.
Increasing Transit Ridership and Mode Shift from Private Vehicles

In its first year of service, ridership on the 98 B-Line reached 14,000 boardings per day; by 2002 ridership had increased to 18,000 daily boardings, and by 2003, ridership increased to 19,900 daily boardings. Early survey work found that 23 percent of B-Line riders previously used a private vehicle to make the trip they were currently making on 98 B-Line. During the four quarters of 2003, the 98 B-Line, with its added technological features, has achieved a mode shift of 48% from private vehicles, surpassing both 99 B-Line and SkyTrain.

Respondents were asked: “In the past, before you started taking the 98 B-Line for this trip, what main mode of transportation did you use to reach this destination?”

<table>
<thead>
<tr>
<th>Previously Used a Private Vehicle for the Same Trip</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>99 B-Line</td>
<td>41%</td>
</tr>
<tr>
<td>98 B-Line</td>
<td>48%</td>
</tr>
<tr>
<td>SkyTrain</td>
<td>45%</td>
</tr>
</tbody>
</table>

Added to the 48 percent from private vehicles, are 9% who previously walked, 3% who previously cycled, 1% who took the taxi, and 2% who previously used a variety of other modes for the trip who now make their travel on 98 B-Line representing a significant mode shift which provides benefits to the operator, users and the community. This results in an increase in ridership translating into additional revenues.

Impact on Traffic

In the early months of operation of the 98 B-Line Traffic Signal Priority was not installed in the 68 signalized intersections along the route. When TSP was fully installed, 59 intersections had the capability to provide priority to 98 B-Line vehicles on request. TSP systems were not installed at 9 signalized intersections where cross-street general purpose and/or bus traffic volumes are high, and TSP could possibly cause excessive delay to this traffic.

Comparisons of travel times before and after the implementation of the Transit Priority System concluded that there was a significant reduction in variability of travel times of the 98 B-Line after TPS was operational. The TSP system uses dedicated short range communications to transmit priority requests from vehicles to roadside traffic signal controllers when buses are running behind schedule.

In order to minimize the impact on cross street traffic, a “check in/check out” system for signal priority was devised to precisely locate the bus in the vicinity of the intersection. This system permits the priority call to be released as soon as the bus enters the intersection, rather than maintain the priority call for a full 15 seconds. This feature has convinced many traffic engineers that providing priority to transit vehicles does not
necessarily seriously impact general purpose traffic.

**Reduced Vehicle Emissions**

An additional benefit of a shift in mode from auto to transit is reduced vehicle emissions. Based on an average vehicle trip length of 8 km in this corridor and 1.2 persons per vehicle, the shift from auto to transit associated with the 98 B-Line represents a reduction of a million vehicle kilometres per year by private automobile. Deducting the annual bus kilometres of travel to carry this increased ridership, a conservative estimate of the net reduction in emissions attributable to the shift in mode from private automobile to public transit is:

1. 1,192 tonnes per year of CO2
2. 0.01 tonnes per year of PM
3. 4.9 tonnes per year of Nox
4. 59.36 tonnes per year of CO
5. 5.09 tonnes per year of HC

**Capital and Operating Cost Savings**

The 98 B-Line has reduced costs to the owner for both capital expenditure for vehicles and annual vehicle operating costs.

Vehicle capital cost reduction associated with reduced travel times is estimated to be 20% of the 98 B-Line vehicle fleet or approximate 5 vehicles, equating $3.2 million. This saving would be realized over the life of the vehicles of approximately 17 years.

The vehicle capital cost saving resulting from reduced layover time associated with the AVL and TSP system is estimated to be approximately 1 vehicle or an annual saving of $650,000 over the life of the vehicles.

Operating cost savings as a result of the reduced travel times are substantial. Based on 4,000 annual hours of operation per vehicle, a travel time saving of 20%, a fleet size of 28 vehicles and operating costs of $80 per vehicle hour, the annual operating cost saving is estimated to be approximately $1.8 million per year. This is attributed to the less frequent stops, the bus lanes and queue jumps. An additional $360,000 per year operating cost saving is attributed to the AVL and TSP systems.

Annualized benefits exceed annualized costs of the 98 B-line by approximately $3 million per year. The owner/operator benefits from the higher speed and more reliable travel time of the 98 B-Line translate into a requirement for fewer vehicles and fewer vehicle hours; this benefit is combined with higher transit revenue from increased ridership.

**CONCLUSION**

98 B-Line has demonstrated that the addition of state-of-the art ITS technology to a bus
rapid transit service enhances society’s livability by producing:

- Large increases in transit ridership and decreases in use of private vehicles
- Significant positive impacts on the environment
- Better service to transit riders, including a faster trip and enhanced safety at the stop
- Significant cost savings to the owner/operator