Expo Line
Upgrade Strategy

Project Summary
May 7, 2012

SNC·LAVALIN

EXPO LINE UPGRADE STRATEGY
SNC-LAVALIN INC.

STUDY OBJECTIVES

The Vancouver SkyTrain's Expo Line is the backbone of Metro Vancouver's rapid transit network. The Expo Line first opened in January 1986 with an initial 21.4 kilometres of guideway and 15 stations between Waterfront Station and New Westminster Station. Its subsequent expansion to King George Station in Surrey increased the Expo Line to a 29-kilometre system with 20 stations.

Until 2009, the Expo Line operated at capacity, carrying approximately 12,000 people per hour per direction (pphpd). A fleet expansion in 2009-2010 exceeded demand on the line; however, studies revealed that the expected ridership growth over the next several years would again lead to overcrowded conditions.

Upgrading the Expo Line is in line with several of the goals outlined in TransLink's Transport 2040 Strategy. TransLink – Metro Vancouver's transportation authority – highlighted goals of reducing carbon footprints for local, regional, and national governments; improving quality of life through improved air quality, reduced stress associated with driving, and increased physical fitness achieved by walking and cycling; and improving accessibility to other transportation options for an aging population.

TransLink and the BC Ministry of Transportation and Infrastructure engaged SNC-Lavalin Inc., with its longstanding history and familiarity with Vancouver's rapid transit system, to identify the upgrades and strategy necessary to increase the Expo Line's ultimate design capacity of 19,400 pphpd to 25,700 pphpd.

SOLUTIONS AND ACHIEVEMENTS

SNC-Lavalin led a multi-disciplinary study to determine the scope and timing of the upgrades needed to increase the Expo Line capacity. The study included a comprehensive technical analysis of existing conditions and future potential improvements, and developed a business case that demonstrated the viability of the preferred upgrade alternative. The study was unique; with strategic upgrades being considered for an existing system. An alternative approach to a traditional multiple account evaluation methodology was used to evaluate benefits generated by a series of improvements.

With this approach in mind, the study team also needed to consider the most appropriate time for any given upgrade, so that system operation continued normally and service disruptions and passenger inconvenience were minimized.

SNC-Lavalin fully satisfied the objectives of the study and kept within budget and schedule. The key tasks included: confirming current passenger demand condition; forecasting future ridership over the next 30 years; assessing the existing system constraints preventing the system from achieving full potential capacity; identifying potential upgrades; and recommending an upgrade implementation strategy.

SNC-Lavalin conducted surveys that revealed a significant number of pass-ups at westbound platforms between Joyce-Collingwood and Main Street-Science World stations. Morning peak hour ridership demand was close to exceeding the line's current capacity. However, a key project challenge was that none of the available transport models indicated a base year forecast that exceeded the capacity of the line as observed by the study team.

A comparison was further made between the Expo Line growth rates from the models and historical data. The team observed much higher historic growth rates relative to the model forecasts. The difference in the growth rates suggested that Expo Line demand was not only driven by downtown employment, but also by other factors, such as regional economic activity. While the existing models took into consideration a number of these factors, the cumulative effect of these factors was having a larger effect than suggested. Re-calibrating the transport model was deemed impossible, due to the lack of a consistent set of SkyTrain passenger data observed on a station-by-station and directional basis.

Instead, to estimate the maximum hourly demand on the Expo Line, SNC-Lavalin adopted a growth-factoring ridership forecast approach that took into account the historical growth and the observed pass-ups at stations. This approach provided a good fit to the observed conditions and generated a robust estimate of future demand up to year 2041.

The study team identified two logical upgrade options: upgrade to an all 4-car Mark II fleet or upgrade to an all 5-car Mark II fleet. Based on the technical analysis, the team recommended an upgrade to an all 5-car Mark II fleet in order to provide the full capacity of the system and to serve the travel demand projected in the study.

The study clearly identified if and when station improvements would be needed so to maintain safe passenger flows, the required sub-system upgrades, and a staged upgrade plan over the course of the next 30 years with capital and operating costs.

Overall, the assignment was a comprehensive planning study where SNC-Lavalin demonstrated its ability to conduct and manage a major rapid transit system rehabilitation and upgrade planning study utilizing multidisciplinary expertise, most of which was provided by SNC-Lavalin staff.

TECHNICAL EXCELLENCE AND INNOVATION

Developing the Expo Line Upgrade Strategy was complex. SNC-Lavalin recognized that the strategy would need to consider and address the system's multi-faceted nature.

SNC-Lavalin conducted a technical analysis of all the sub-systems for their current conditions and abilities to support additional capacity, and identified the required upgrades and potential constraints.

A particularly innovative study element was the development of a method to quantitatively assess the actual practical capabilities of the system and the actual extent of congestion. Traditionally, assessments were completed subjectively. SNC-Lavalin produced an aggregate model that could be used in combination with the dynamic train and equipment data, as well as station infrastructure dimensions, in order to accurately determine capacity constraint locations. The model produced a definitive set of data for the practical capacities of the equipment currently within the SkyTrain system; it incorporated an improved factoring scale to determine the practical capacities based on manufacturer catalogue data.

A specific output spreadsheet was created for each station in response to their unique circulation elements, such as escalator availability, elevators, and entry/exit points.

ENVIRONMENTAL, ECONOMIC, AND SOCIAL SUSTAINABILITY AND AESTHETICS

Recognizing the critical and regional importance of the Expo Line, SNC-Lavalin anticipated future issues if the system was not upgraded. These issues supported the case for upgrades.

Environmental Issues

Ridership growth will result in passenger demand that meets or exceeds the near-term capacity. This may result in congestion, overcrowding, and passenger delays and inconvenience, as well as an overall decrease in transit attractiveness. Patrons may opt for less sustainable modes of travel, such as private vehicles, which would result in increased greenhouse gas emissions.

Economic Issues

The potential for transit-oriented development may decrease if existing and future capacity constraints on the system are not addressed.

Social Issues

The region's aging population is a key factor affecting the need for accessible transit. Currently, certain Expo Line stations lack up-escalators. Providing down-escalators may also improve accessibility for the elderly and persons with mobility impairments.

Design Issues

Over time, the aging Expo Line may not comply with the latest design standards and emergency evacuation requirements. An environment that diminishes security and features poor aesthetics reduces the overall transit experience for all Expo Line users.

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1.0 Introduction

The Expo Line is the backbone of Metro Vancouver's rapid transit network. Since 1986, it has served millions of customers by providing a reliable and efficient link between New Westminster, Surrey and Vancouver. The success of this system is measured by the number of passengers it has carried and the increases in demand year after year. In 1999, it carried 43.6 million passengers and in 2008 (with the Millennium Line extension), it carried approximately 73.2 million passengers, a 68 percent increase or about 6 percent increase per year.

Up until 2009, the Expo Line had been operating at capacity, carrying approximately 12,000 pphpd. A fleet expansion in 2009-2010 added 48 new MKII vehicles. Although capacity currently exceeds demand on the line, the expected ridership growth over the next several years will again result in overcrowded conditions, unless further capacity increases are implemented.

The ultimate design capacity originally envisaged for the Expo Line was 19,400 pphpd using trains consisting of 6 MKI vehicles operating at 93 second headways. With more recent design innovations the system can now increase line capacity to 25,700 pphpd based on running a fleet with 5 MKII vehicles per train, operating at 93 second headways. To achieve this new capacity target, physical upgrades to stations, subsystems and the Operations and Maintenance facility would be needed.

1.1 Overview of the Expo Line

The Expo Line first opened in January 1986 with an initial 21.4 km of guideway and 15 stations, linking Waterfront Station with New Westminster Station. Progressive extensions in 1989, 1990 and 1994 brought the line to King George Station in Surrey, establishing a total of 20 stations along 29 km of guideway.

In 2002, the SkyTrain system was further expanded with the opening of the Millennium Line. The Expo and the Millennium Lines share the same guideway and station platforms from Waterfront to Columbia Station. Beyond that, the Expo Line continues to King George Station in Surrey, whereas the Millennium Line loops back via Lougheed Highway to VCC-Clark Station in Vancouver. In addition to Columbia Station, a platform to platform interchange between the two lines is provided at Commercial-Broadway Station. The two lines also share the same vehicle fleet, controlled from a single Operating and Maintenance Centre (OMC) near Edmonds Station.

The combined Expo-Millennium Line is operated by the British Columbia Rapid Transit Company (BCRTC), a subsidiary of the South Coast British Columbia Transportation Authority (TransLink). Exhibit 1 shows the Expo Line and its coverage within the TransLink Rapid Rail Transit Network.

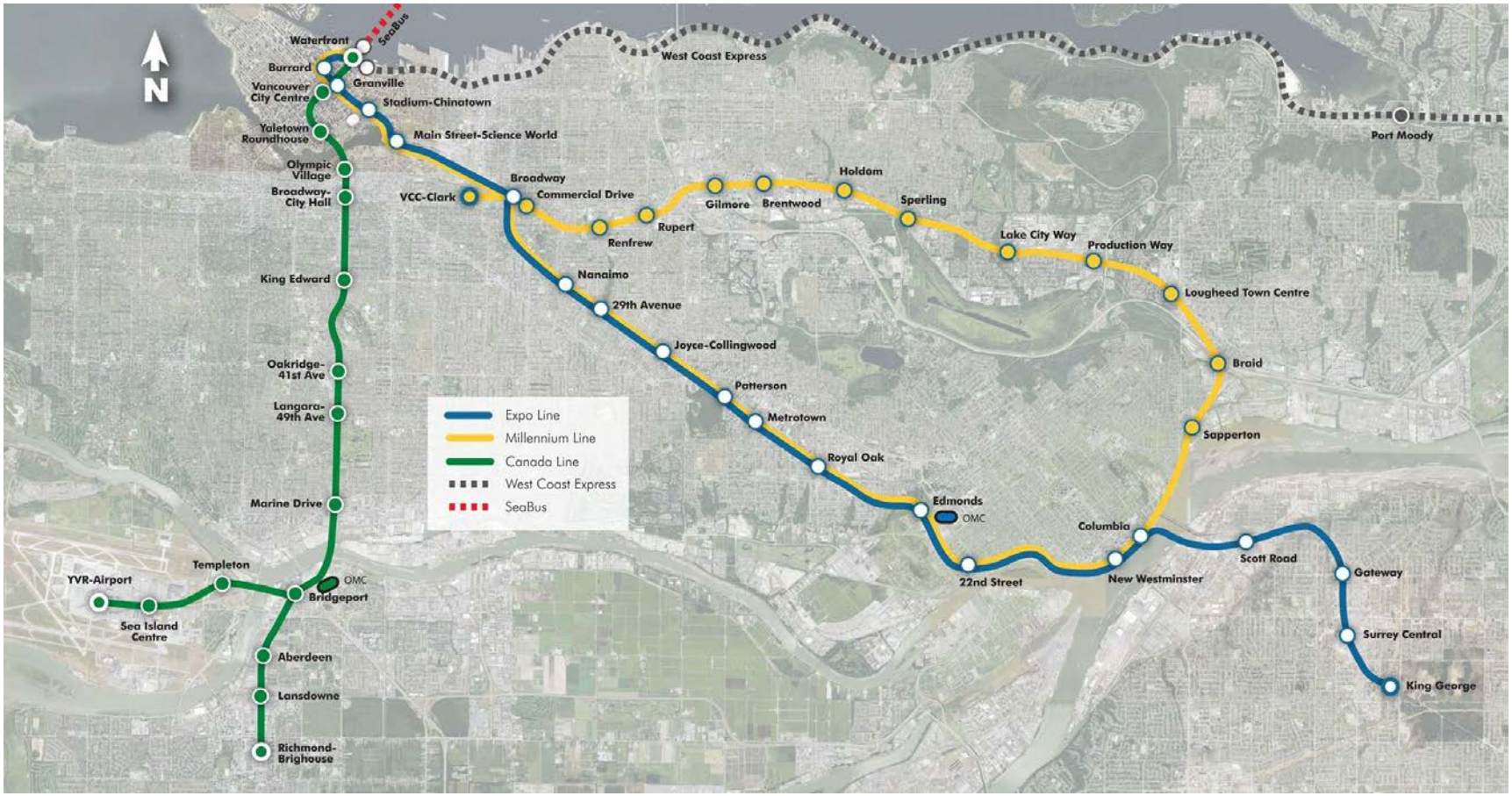


Exhibit 1: Metro Vancouver SkyTrain System (2010 Operations)

1.2 Study Context

In recent years, various factors have, by cumulative effect, contributed to the increase in ridership demand on the Expo Line:

- Strong economic activity in the region
- Increased fuel prices and parking rates
- Heightened densities and development around transit stations
- Improved bus service
- Policies supporting increased transit use
- Improved rapid transit network connectivity

In the future, demand on the Expo Line will also be influenced by changes in other parts of the regional transit network, changes in land use patterns, and changes to regional initiatives and policies. For example:

- High-density residential and employment developments have been occurring around key SkyTrain Stations. As long as transit service continues to be an attractive option, the region will continue to see growth in transit-oriented developments.
- Carbon footprint reduction targets of the local, regional and national governments will trigger initiatives and/or policies to encourage greater shift from the private vehicle to public transit.
- The Evergreen Line is expected to start operations by 2014.
- At the time of this study, TransLink and other government agencies were studying the feasibility of the UBC Line and rapid transit in Surrey. These projects and bus service expansions will attract more trips on the Expo Line.

The end result of these changes over time will be an increase in demand for further rapid transit capacity along the Expo Line corridor as it will remain the backbone of the system for the foreseeable future.

A strategy is needed to:

- Increase the Expo Line capacity to meet the growth in demand.
- Ensure that all subsystems are upgraded to handle the increase in capacity.
- Determine if and where station improvements are needed to ensure unimpeded and safe passenger flows.
- Allow for staged and gradual upgrades of the system within reasonable budgets through targeted capital investments over the next 30 years.

1.3 Objectives of this Study

The primary objectives of this study were to:

1. Confirm the existing Expo Line passenger demand;
2. Determine existing conditions such as passenger flows and crowding at stations;
3. Determine future ridership forecasts to 2041;

4. Test and evaluate the sub-system capacities and limits;
5. Confirm the system's maximum possible capacity and any related constraints;
6. Identify required upgrades;
7. Develop alternative strategies to achieve maximum capacity and evaluate them; and,
8. Propose an implementation plan.

The review process also included the following considerations in the analysis of alternatives:

- Current issues related to capacity during peak hours and accessibility
- Currently committed near-term upgrades and their impact on an overall upgrade strategy;
- Additional vehicle purchase and operating scenario optimization (such as fleet mix optimization) to match capacity to projected demand;
- Fleet expansion's effect on the existing subsystems.

1.4 Existing System Configuration

As part of the Expo Line Upgrade Strategy, upgrades to all subsystems are required to support an increase in capacity. The rationale for this arises from a high level of interdependency between the various system elements. Exhibit 2 is a schematic that illustrates this principle. As shown, the development of the Expo Line Upgrade Strategy is highly complex, as the strategy needs to consider and address the multi-faceted nature of the system.

A need to increase passenger carrying capacity on the Expo Line affects five to six different sets of elements (such as the Propulsion Power Systems, vehicle fleet and station throughput). While the design of the Expo Line originally envisaged a maximum capacity limit of around 19,400 pphpd, advances in vehicle design and other subsystems has enabled the possibility to get more capacity than originally planned.

At the same time, growth patterns along the corridor generated more trips than originally forecast at certain key stations. These now require expansion to meet these changes.

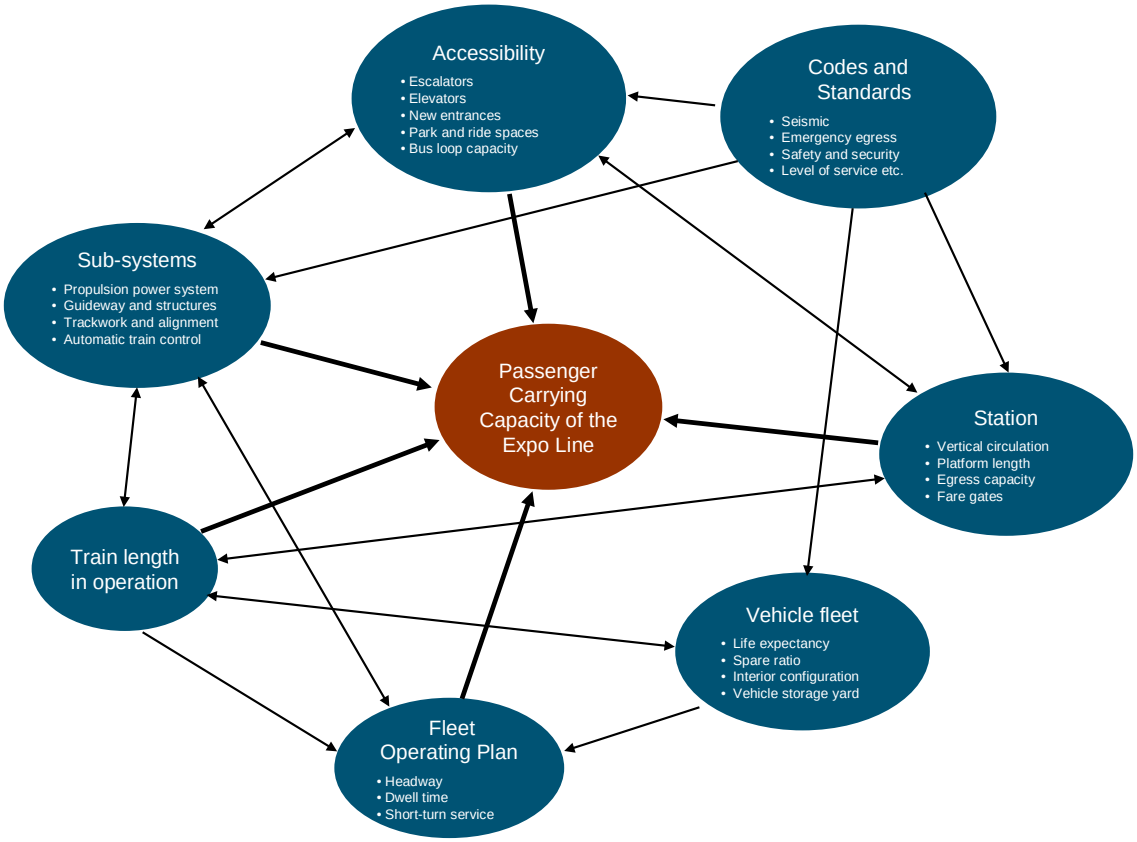


Exhibit 2: Interdependency of the Expo Line System Elements

2.0 Existing and Future Issues/Constraints

2.1 Existing Issues

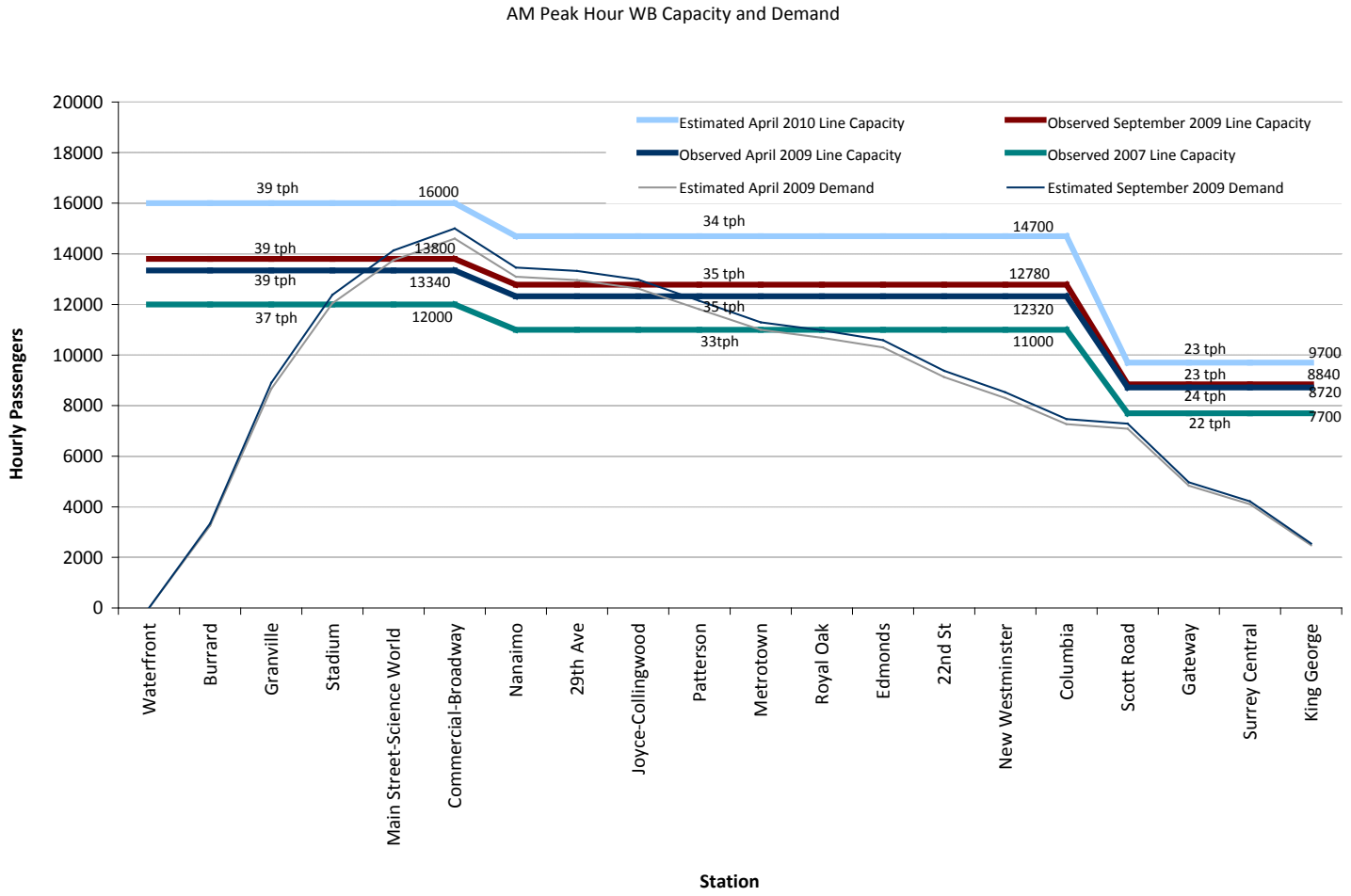
2.1.1 Line Capacity

The Expo Line suffers from a number of physical and technological constraints which prevent the system from reaching an ultimate capacity of 25,700 pphpd without targeted investments being made.

As of 2009, the peak hour demand estimated at 14,600 pphpd exceeded the system capacity of 13,300 pphpd between Broadway-Commercial Station and Main Street Station. As shown in Exhibit 3, demand in April 2009 was outstripping capacity at Commercial-Broadway Station by 9.5%. This resulted in passengers being left on platforms and waiting one or two trains before being able to board. By 2010, capacity had been increased to 16,000 pphpd with the addition of 48 MKII vehicles to the fleet.

By September 2009 with fleet expansion underway, about 1,225 passengers (or more than 2 train loads) did not board the first train as it passed through the Commercial-Broadway Station due to overcrowding.

Although capacity is now at 16,000 pphpd, occasional pass-ups still occur at the height of the peak periods.



Notes: * 39tph = 39 trains per hour

Exhibit 3: Estimated Maximum Demand versus Line Capacity

2.1.2 Station Circulation Capacity

While most stations function within acceptable parameters, specific passenger elements at certain stations are operating at close to maximum capacity, thereby lowering the overall quality of service and passenger comfort. In particular, during the April 2009 survey, stations such as Burrard, Commercial-Broadway and Metrotown experience surge-related circulation issues at peak times.


Line ups at Burrard and Metrotown Station when exiting

Issues include lengthy queues at escalators, and overcrowding on platforms due to pass-ups occurring during the 15 minute peaks. The latter occurs frequently at Scott Road, Joyce-Collingwood, 29th Avenue, Nanaimo, Commercial-Broadway, Main Street-Science World and Stadium-Chinatown Stations during the morning peak.


Pass-ups and platform crowding issues at Commercial-Broadway Station


Pass-ups at Joyce-Collingwood and Scott Road Stations

Inside MKI Car

Inside MKII Car

Photos showing pass-ups and platform crowding conditions inside Expo Line Trains (April 2009)

At Commercial-Broadway Station passenger traffic between the Millennium Line and the Expo Line platforms also causes circulation back-ups at the escalators to/from the passerelle over Broadway in the morning and afternoon peaks.

2.1.3 Train Composition Issues

Exhibit 4 shows the current Expo Line MKI train profiles. It is noted that the 2-car MKII train shown below is rarely in use as of 2010, except during the special AM peak hour service from Commercial-Broadway to Waterfront Stations. Exhibit 5 shows a typical AM peak period train composition arrival pattern at Commercial-Broadway Station in 2010.

Exhibit 4: Current Expo Line Train Profiles

4-car MKI train	 332 passengers/train
6-car MKI train	 498 passengers/train
2-car MKII train	 256 or 264* passengers/train (only used during the special AM peak hour service from Commercial-Broadway to Waterfront Stations)
4-car MKII train	 512 or 528* passengers/train

*** For the new MKII trains**

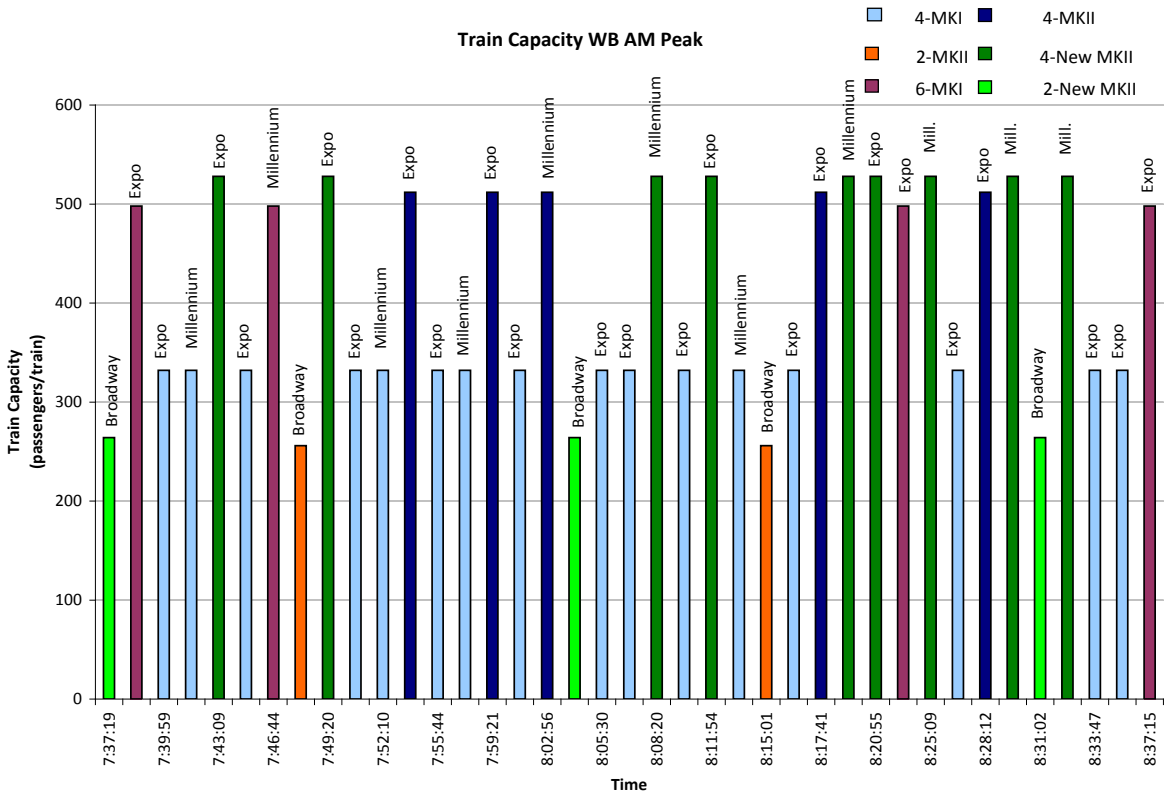


Exhibit 5: Maximum Observed AM Peak Hour Westbound Train Arrivals at Commercial-Broadway Station (April 2010)

The current operation of trains with uneven lengths results in passengers bunching near the stopping position of shorter trains. This also has the effect of uneven train loading on longer trains on longer trains, which is a further cause of downstream pass-ups.

2.1.4 Pass ups at Key Stations

The capacity issue that has become most critical in the morning peak during 2009 was pass-ups (passengers missing one or more trains) at stations between Joyce-Collingwood and Main Street- Science World. On-site surveys conducted in April 2009 and September 2009 showed that during the AM peak period, pass-ups occurred routinely at all the westbound platforms between Joyce-Collingwood and Main Street-Science World Stations.

2.2 Future Issues

As ridership on the Expo Line increases, the issues currently identified will increase in severity. Degradation of service will continue without implementing strategic upgrades. Passenger convenience and comfort will decline with the occurrence of delays and overcrowding, resulting in decreased transit attractiveness. Passengers may opt for less sustainable but more comfortable modes of travel.

2.2.1 Near- and medium-term capacity will not accommodate projected ridership demand

The near-term capacity will not accommodate the forecast ridership demand beyond 2014. At key stations like Burrard, the existing capacity will be exceeded by 2012.

Even with the addition of fleet in 2010, the issues of congestion, overcrowding and passenger delays and inconvenience will return when ridership growth results in passenger demand that meets or exceeds the near-term capacity.

Furthermore, increasing passenger train capacity without improving vertical circulation capacity at specific stations will limit the system in achieving optimal line capacity.

2.2.2 Station and platform accessibility issues will continue to reduce transit convenience to passengers

The aging population in Metro Vancouver is a key factor affecting the need to provide accessible transit.

Some Expo Line Stations lack up-escalators making it difficult for some riders to use rapid transit. While down-escalators are provided at a few stations that have relatively large grade changes between station levels, consistent provision of escalators at all stations will improve accessibility.

2.2.3 Stations and platforms will continue to fall below design, aesthetics and security standards

Many of the Expo Line Stations are 15 to 25 years old. Some will, over time, not comply with the latest design standards and any related risks associated with substandard emergency evacuation capacities.

If left unresolved, transit attractiveness will be affected. The current design standards and aesthetics along most of the Expo Line are also different from those on the Millennium and Canada Lines. Any major upgrades to Expo Line Stations should consider a review and confirmation of the current applicable safety standards for rail transit stations and upgrades to station elements that enhance patron safety and comfort.

2.2.4 The potential for transit-oriented development will be reduced

While substantial development and related densification has occurred near transit stations in recent years, municipal support for further transit-oriented development along the Expo Line may be reduced if existing and future capacity constraints on the system are not addressed. This may, in turn, discourage the inclusion of transit-oriented development in municipal and regional growth plans that identify development in areas served by rapid transit.

2.2.5 The effectiveness of the regional transit network will be reduced

Planned rapid transit lines that feed and distribute Expo Line passengers to adjacent city centres, such as the Evergreen Line and potential UBC and Surrey lines, will be limited in their ability to attract new riders if the Expo Line capacity is not increased to meet demand. The new lines will not diminish the passenger demands on the Expo Line; rather, they will expand the demand.

It is therefore important to develop a strategy that will not only address the capacity of the system, but also passenger convenience and comfort and the ability for the Expo Line to sustain required service levels as the backbone of the region's rapid transit network.

2.3 Review of Subsystem Constraints

This study included a review of Expo Line subsystems to confirm and assess their condition and limitations and their ability to function when capacity is increased. This included the following:

2.3.1 Propulsion Power Systems

The Expo Line Propulsion Power System was designed to accommodate the MKI vehicles for at least the first 20 years without needed upgrades, with some additional spare capacity. With the recent increases

in fleet and the introduction of the MKII vehicles, power upgrades are necessary to maintain a level of performance that meets minimum service criteria and to ensure enough capacity for future fleet expansion and related headway reductions.

Recent review of the Propulsion Power System and its ability to handle more capacity highlighted the need to immediately upgrade the system as it was already insufficient to handle the existing capacity for an extended period of time. The addition of 48 new MKII vehicles in Spring 2010 added to this need for capacity and power system enhancements.

2.3.2 Trackwork

The existing system was designed to handle a full MKI, 6 vehicles per train fleet operating at recovery headway of 75 seconds. A 6 vehicle MKI train has a length of 76.2 metres. The system's headway is constrained primarily by the Waterfront Station terminus reversal, and no other major issues were identified relating to trackwork in relation to capacity.

2.3.3 Guideways and Structures

The structural components along the Expo Line are generally in good condition. Although it may be possible to increase train lengths, further structural analysis is suggested to assess the service life capacity of the guideway and station structural elements.

2.3.4 Automatic Train Control

The Automated Train Control (ATC) system was originally designed and installed over 20 years ago but has been upgraded with successive fleet and line additions, including the Millenium Line. As some of the equipment is nearing end of life, a series of upgrade programs has been initiated to improve reliability and replace aging equipment.

ATC system upgrades now underway will accommodate future extensions for at least 25 years.

2.3.5 Station Emergency Evacuation

Using a holistic approach, passenger safety can still achieved for the 2010 operating condition; however an independent review should be conducted to validate the conclusions from this study. Identification of long term expansion requirements to accommodate ridership growth and adoption of 5-car MKII trains will require strategic planning and implementation into TransLink's infrastructure development program. More significantly, the introduction of 5-car MKII train operations would impose an increased ridership burden on the system that the stations were not designed to accommodate in their as-built conditions. As such, the required exiting capacity at most stations will need to be supplemented with new or expanded vertical circulation.

2.3.6 Operations and Maintenance Facility

The operation and maintenance facility is currently being upgraded. The current facility is expected to store 150 MKI and 36 MKII cars. The facility is being expanded to its maximum physical capacity to store an additional 14 4-car MKII trains.

Due to storage yard facility constraints, there are currently 16-21 trains stored on tail and pocket tracks on the mainline before the new MKII trains were introduced. Even with the expanded OMC storage yard, there is a shortage of storage space for four 4-car MKII trains at the April 2010 fleet size.

2.3.7 Platform Lengths

The platform length currently provided at most Expo Line Stations is 80 metres. This length would enable operations of five vehicle MKII trains with four stations requiring modest platform extensions. Although six vehicle MKII trains were also considered initially, it is not possible to accommodate this train length without significant and costly reconstruction of all stations, which would be particularly costly for the underground stations.

3.0 Ridership: Existing and Forecast

The Expo Line experienced significant growth in ridership demand in the past decade. Journey-to-work census data between 1996 and 2006 was reviewed to obtain a historical perspective on transit trip demand growth along the Expo Line catchment area to downtown Vancouver. The data is shown in Exhibit 6.

Exhibit 6: Journey-to-Work Census Data and Downtown Transit Mode Share (1996 and 2006)

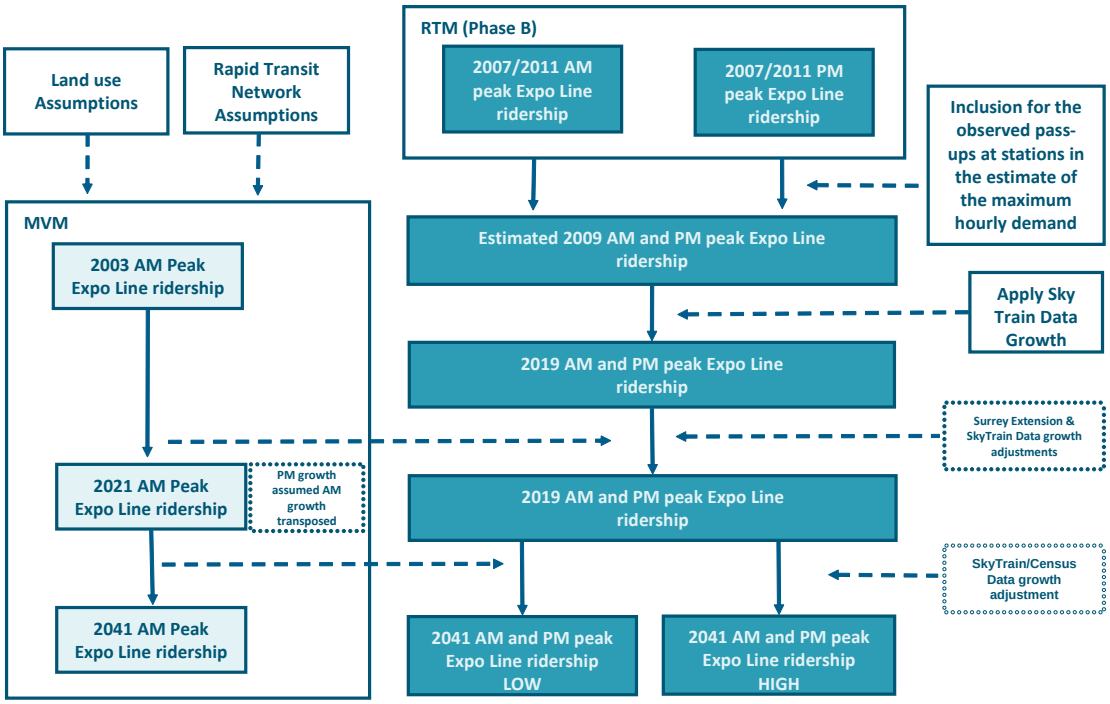
	Downtown Vancouver Employment	Expo Line Catchment Area Total Trip Demand	Expo Line Catchment Area Transit Trip Demand	Transit Mode Share to Downtown from the Expo Line Catchment Area
1996	113,410	42,225	21,060	50%
2006	128,875	47,800	27,810	58%
Annual Growth	1.3%	1.2%	2.8%	

Over the 10-year census period, the annual growth rate observed for the Expo Line catchment area transit trip demand was more than twice the growth rates observed for downtown Vancouver employment and the total trip demand in the Expo Line catchment area. Between 1996 and 2006, transit trip demand along the Expo Line catchment area grew by approximately 32 percent and the transit mode share increased from 50 percent in 1996 to 58 percent in 2006 along the corridor.

The current “peak-load point” of the Expo Line occurs during the AM peak period between Commercial-Broadway and Main Street-Science World Stations in the westbound direction. According to BCRTC data, the AM peak-hour link flow at this section grew at an average rate of 5 percent per annum between 1998 and 2008, and 3.4 percent per annum between 1990 and 2008.

In order to capture the most realistic passenger growth patterns for the Expo Line, the statistics noted above were incorporated into the existing available models (Metro Vancouver model (MVM) and Regional Transit Model (RTM)) and an Expo Line specific ridership forecast model was developed as shown in Exhibit 7.

Exhibit 7: Expo Line Ridership Forecasting Methodology

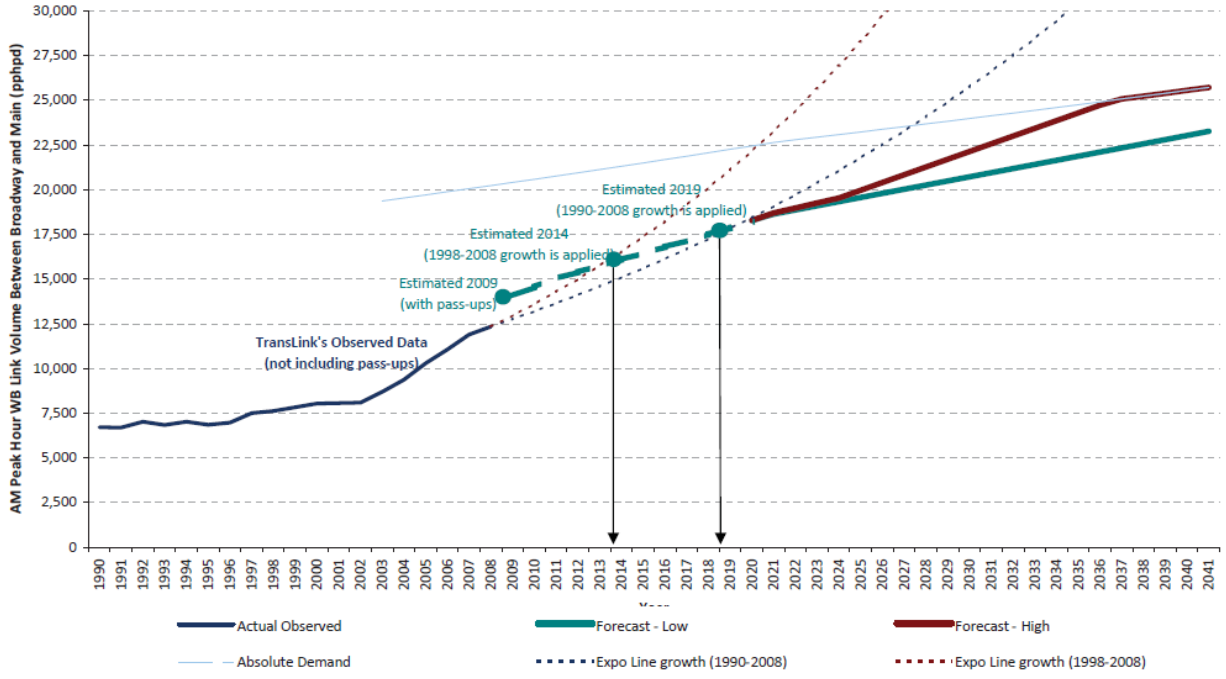


The adopted ridership forecast approach up to 2041 for the peak-load segment (between Commercial-Broadway Station and Main Street-Science World Station) consists of the following:

- Taking into account the observed pass-ups at stations in the estimate of the maximum hourly demand
- Between 2009 and 2019:
    - Assuming the significant growth of the past decade will continue over the next five years (using the observed growth rate between 1998 and 2008), the projected ridership to 2014 is established
    - Assuming less significant growth will continue in the next 10 years (using the observed growth rate between 1990 and 2008), the projected ridership to 2019 is established
    - A line connecting the current estimated maximum ridership (with pass-ups), the projected 2014 ridership and the projected 2019 ridership is established
- Beyond 2019, adopting high and low growth scenarios:
    - Low growth is based on network-wide growth from the Metro Vancouver Model (at about 1.1 percent per year).
    - High growth uses low growth as a base and factored up based on historical patterns (at about 1.5 percent per year up to 2025, and at about 2.0 percent per year beyond 2025).

Exhibit 8 presents the AM peak hour flow on the Commercial-Broadway to Main Street-Science World station based on the adopted forecast approach. “Absolute demand” represents the “ceiling” of all demand (includes all modes of both public and private transport) that travel into downtown Vancouver across the Quebec Street-Hastings screenline.

Exhibit 8: Anticipated Growth in Critical Link Flow Demand



4.0 Alternatives to Meet Future Ridership Demand

Based on the anticipated Expo Line growth in ridership demand over the next 30 years, and knowing that a maximum potential capacity of 25,700 pphpd can be achieved based on running a fleet with 5 MKII vehicles per train, operating at 93 second headways, a series of alternatives was considered.

At the same time, not all alternatives can achieve the ultimate capacity and therefore alternative methods of meeting the balance of the demand were also considered.

4.1 Alternative Measures to Relieve Future Expo Line Demand

The Expo Line is the most attractive transit service into the city centre for daily commuters within its catchment area, as Expo Line Stations serve the majority of downtown offices. While much has been done to optimize system performance and to maximize system capacity to ensure that the line will continue to support increased ridership, this study also reviewed potential measures to divert the increasing passenger demand.

4.1.1 B-Lines Bus Routes

The implementation of B-Line services along the 41st Avenue and Hastings Street corridors was reviewed. However, model results showed that the growth in Expo Line demand is not sensitive to these B-Line Services and the diversion of the Expo Line demand to these parallel corridors would be minimal.

4.1.2 Peak-Hour Express Bus Service on Highway 1

The implementation of peak-hour express bus services connecting Surrey, Langley and Burnaby/Coquitlam to downtown Vancouver via the Highway 1 corridor consists of three related routes:

- Walnut Grove, Langley – downtown Vancouver
- Surrey Central - downtown Vancouver
- Lougheed Town Centre Burnaby/Coquitlam – downtown Vancouver

While some relief to the Expo Line may be realized by such a service, the level of service will determine how many passengers will be willing to switch to bus as will the location of the bus terminal that will be required to receive the buses and their passengers in the city centre.

4.1.3 Peak Transit Fare Pricing

Increasing fares in the peak periods may reduce the level of demand at critical points of the network and "smooth" the demand patterns. The application of peak pricing is relatively limited in transit system and there is little literature review on its effectiveness. However, particularly in the absence of peak pricing of the road network, implementing it on the transit network alone would limit the ability to meet regional travel and GHG objectives.

4.1.4 Peak-Hour Shuttle Bus Service between VCC-Clark Station and Granville

The suggested service would be from VCC-Clark to Granville/Burrard with a stop near Canada Line Olympic Village Station and use 18 metre articulated buses running at 5 minute headways in the AM peak period. The service would have a one-way travel time of approximately 20 minutes and the headway would be synchronized to coincide with the headway of the Millennium Line service.

4.1.5 Effectiveness of Alternatives

While each of the alternative measures would help relieve some of the increase in Expo ridership demand, they cannot completely replace the added capacity that will be required over the 30 year time frame. As well, some of the options will also be adversely affected over time by congestion, not be considered acceptable to the public (peak fare pricing) or have high capital costs..

As such, most of these options should be considered as potential temporary relief to the continuing Expo Line capacity constraints until major upgrades are implemented.

4.2 Expo Line Upgrade Alternatives

To help meet future passenger demand on the Expo Line, two upgrade alternatives were developed. These were compared to a base case scenario where minimum upgrades would be implemented at minimal cost. Each alternative would achieve a different maximum capacity and therefore generate different costs and benefits.

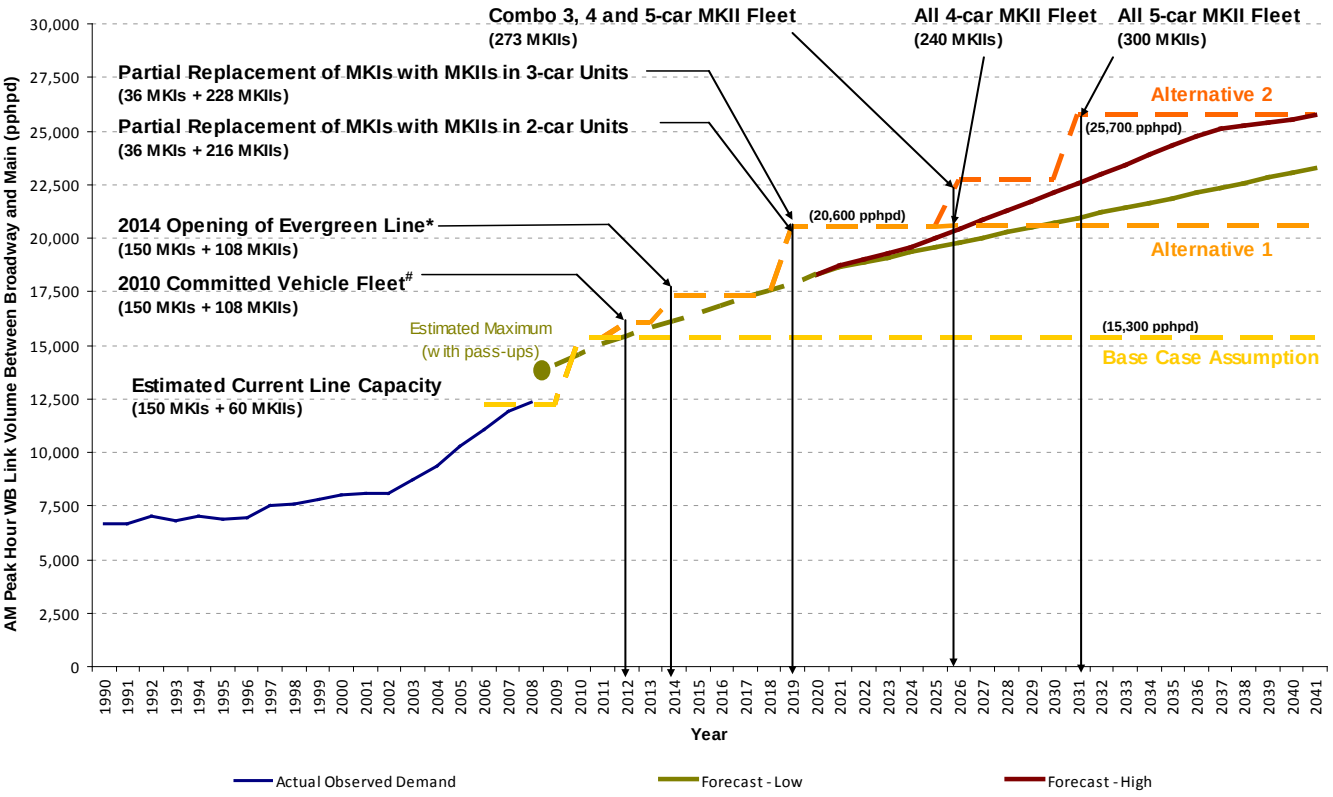
The upgrade alternatives are as follows:

- Base Case: Minimum upgrade and "state-of-good" repairs only, current capacity will be maintained (maximum capacity 15,300 pphpd)
- Alternative 1: System is upgraded for the operation of exclusively 4-car MKII trains to achieve a capacity of 20,600 pphpd

- Alternative 2: System is upgraded for the operation of exclusively 5-car MKII trains to achieve a capacity of 25,700 pphpd

Exhibit 9 shows the capacity constraints of the alternatives relative to the projected demand. It also shows the upgrade paths relative to vehicle replacement and new vehicle orders for both a 4-car and 5-car MKII alternative.

Exhibit 9: Expo Line Upgrade Alternatives



Note: # The line capacity of 16,000 pphpd provided by the current fleet will be achievable once the vertical circulation capacity at Burrard Station is improved by 2012

* The capacity increase in 2014 is due to truncating the "Millennium" Line at Lougheed Town Centre, allowing increased Expo Line capacity with the same fleet size

No short-turn service is assumed beyond 2014

5.0 Expo Line Upgrade Strategy: Evaluation of Alternatives

System reliability and service levels that provide passenger convenience, accessibility and comfort are crucial for attracting ridership. The benefits of public transit ridership further extend to broader objectives, such as reducing greenhouse gas emissions and improving quality of life for the public. In recent years, transit-oriented developments have occurred around transit stations and have proven successful in encouraging more public transit, walking and cycling trips.

Therefore, it is important to ensure that system reliability and optimal service levels can be maintained on the Expo Line for the long-term, as it is and will remain the backbone of the region's public transit network spanning across the most populous parts of the region between downtown Vancouver and municipalities further east to Surrey.

Currently, there are issues on the Expo Line related to capacity, accessibility and general station design and aesthetics. Despite currently committed TransLink near-term upgrades, capacity issues related to delays and overcrowding at some stations will occur in the future as ridership growth results in demand that exceeds the near-term capacity. This will be a particular issue at the "peak load point" between the Commercial-Broadway and Main Street-Science World Stations. As other regional centres develop along the Expo Line, delays and overcrowding may also occur at an increasing number of stations.

5.1 Fleet Upgrades

The key element to be considered in upgrading the Expo Line is matching growth in capacity with growth in demand. The fleet size and its ability to provide adequate capacity over the next 20 to 30 year become the focus and affect all subsystems during that period. In the case of the 5-car MKII alternative, station infrastructure is also affected at key locations.

Considerations for transition from a combination 6-car MKI/4-car MKII to a 5-car MKII fleet is also important if the Alternative 2 upgrade path is chosen.

Exhibit 10 illustrates a decision flowchart showing the timeline of key decisions related to the suggested fleet expansion and the resulting theoretical capacities. The proposed upgrade path identifies the intermediate steps from the 2009 fleet size of 150 MKIs and 60 MKIIs to an ultimate all 4-car MKII fleet (Upgrade Alternative 1) and an ultimate all 5-car MKII fleet (Upgrade Alternative 2), as well as the Base Case. The fleet requirement shown does not include vehicles required for the Evergreen Line or any potential Surrey and UBC line extension. In Exhibit 10 the line capacity presented for the Base Case is 16,000 pphpd because the chart intends to show only the capacity of the vehicle fleet without taking other subsystem constraints, such as the vertical circulation at Burrard Station, into account.

A key decision must be made by 2015 on whether to purse a 5-car MKII fleet.

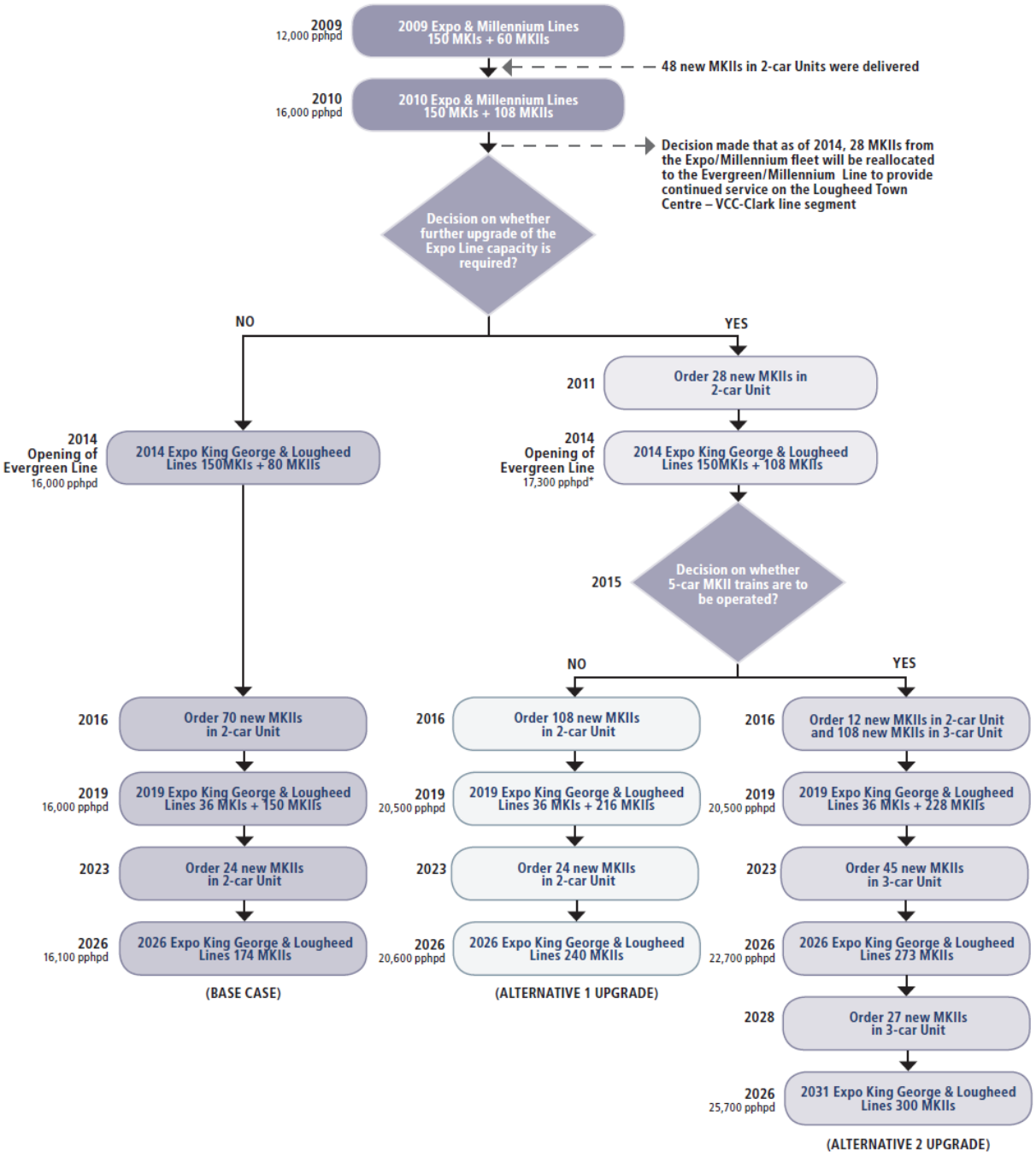


Exhibit 10: Decision Flowchart for Fleet Upgrades

***** The capacity increase in 2014 is due to truncating the "Millennium" Line at Lougheed Town Centre, allowing increased Expo Line capacity with the same fleet size

The special AM peak hour short-turn Commercial-Broadway to Waterfront westbound service is maintained in the Base Case.

No short-turn service is assumed beyond 2014 in Alternative 1 and Alternative 2 Upgrades.

The line capacity of 16,000 pphpd in the Base Case does not take into account the vertical circulation constraint at Burrard Station.

The flowchart was developed on the assumption that to make up a 5-car MKII train, new stand-alone 3-car MKII units will be purchased and coupled with 2-car MKII units. While a design already exists for a third car ("C-car") that can be inserted into an existing 2-car MKII unit to make up a 3-car MKII unit, consideration should be given to the benefits of adding a "new" element into a train that may be as much as 15 years old.

Another important consideration with regards to fleet expansion is the availability of storage capacity. A new storage yard must be planned, designed and constructed before operating additional fleet. In the long term (by 2026), there is some storage capacity in the existing OMC yard that can be provided for the additional MKII cars when the MKI fleet is retired; however, additional storage yard space needs to be made available to store all vehicles on-site. Potential sites for a new storage yard were identified in this study.

5.2 Station Upgrades

Where upgrades will be affected by the introduction of fare gates (29th Avenue and Stadium-Chinatown Stations), incorporation of design requirements associated with the operation of 5-car MKII trains as part of the Smart Card and Fare Gate Program would mitigate future needs to reconstruct some of the infrastructure.

For stations in general, it will be more effective to implement all the identified upgrades at a particular station under one construction period rather than spread out over time to avoid causing inconvenience or disruptions to passenger flow on a recurring basis and increase efficiency.

Consideration should also be given to avoid waiting until the last possible moment to implement upgrades as mitigation during construction may be more challenging due to increased passenger volumes.

In summary, station upgrades may be prioritized as follows:

a) Address station emergency egress upgrades. Considerations should include upgrading egress capacity to support the operation of an all 5-car MKII fleet (ultimate requirement) to avoid needing to upgrade egress capacity again in the future.

b) Implement platform extension in the short term, as part of the Smart Card and Fare Gate Program, at the Stadium-Chinatown and 29th Avenue Stations (only required for Upgrade Alternative 2).

c) The planning of major upgrades for selected stations should be tied with fare gate requirements. Where the implementation of fare gates triggers other station renovations, such renovations should be accounted for as part the major upgrades.

d) Provide a new east entrance at the Burrard Station where vertical circulation constraints are currently experienced and there is inadequate space for fare gates to meet long-term demand.

e) While guidelines on the provision of up- and down-escalators are still pending, should such provisions be implemented at stations they may be combined with other improvements to minimize construction impacts associated with station renovations.

5.3 Capital and Operational Costs

The costs of the base case and the two upgrade alternatives were estimated based on the following capital and operation cost assumptions:

- Capital Expenditures (in 2010 constant $)
  - Vehicle acquisition costs are spread out over a 3-year interval
  - Station costs are based on order of magnitude lump sums
  - Subsystem costs are based on lump sum or unit costs
- Operating Expenditures (in 2010 constant $)
  - A base operating cost plus a variable vehicle operating cost based on the number of cars
  - The base operating cost is $34 million per year
  - The average vehicle operating cost is $195,000 per year (for both MKI and MKII vehicles)

Exhibit 11 summarises the total capital and operating costs for the two upgrade alternatives and the incremental costs against the base case.

Exhibit 11: Capital and Operation Cost by Alternative

	Capital Cost (2010 $)		*Operating Cost – Over the Next 30 Years (2010 $)*	
	Total	*Incremental to Base*	*Total*	*Incremental to Base*
Base Case	309 M	-	3,027 M	-
Alternative 1	841 M	532 M	3,478 M	451 M
Alternative 2	1,092 M	783 M	3,739 M	712 M

Exhibit 12 and 13 present the profile of upgrade incremental capital expenditures for Alternatives 1 and 2, respectively.

Exhibit 12: Committed Incremental Capital Expenses Profile for Upgrade Alternative 1 (in 2010 Constant $)

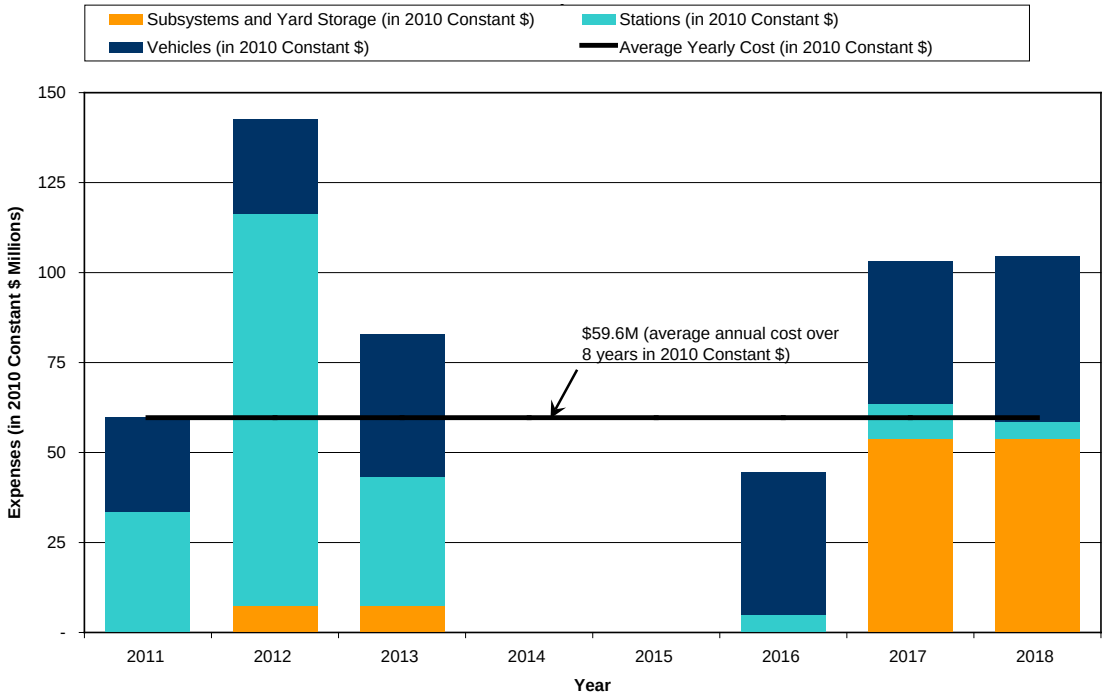
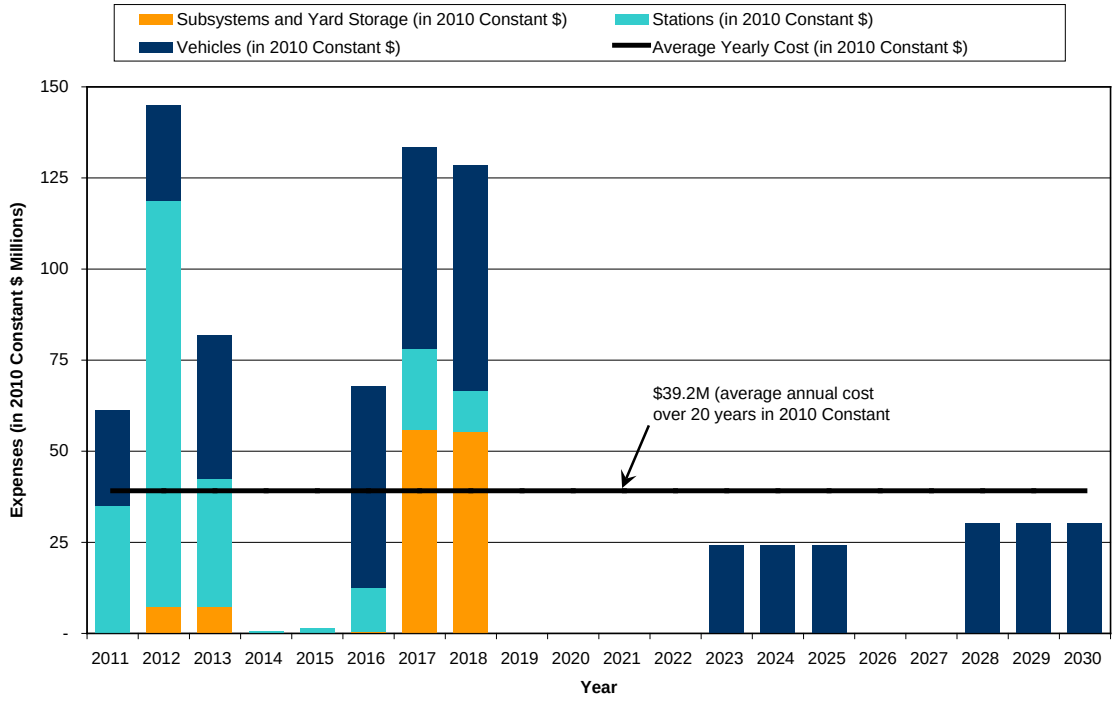


Exhibit 13: Committed Incremental Capital Expenses Profile for Upgrade Alternative 2 (in 2010 Constant $)



6.0 Significance of Study and Client Satisfaction

This study looks at ways to increase capacity on the Expo Line to match projected demand. It also supports the objective of the B.C. Government's Provincial Transit Plan to double the capacity of the line. In the coming years, the strategy will be used to shape future discussions about increasing the Expo Line's capacity and the investment decisions needed to make it happen.

The total cost, spread over the next 30 years, is estimated at $850 million for the 4-car option and $1.1 billion for the 5-car option. These figures include the cost of the additional trains and required infrastructure upgrades.

The estimates also include the $150 million in station upgrades that will be taking place over the next few years at Main Street-Science World, Commercial-Broadway and Metrotown Stations. These upgrades are recommended in this study and have been included in TransLink's 2012 Moving Forward Supplemental Plan and Outlook passed by the Mayors' Council in October 2011.

Jeffrey Busby, Manager of Infrastructure Planning at TransLink, wrote in a reference letter to SNC-Lavalin Inc. that TransLink was *"very pleased with the work done as it was throrough and demonstrated the comprehensive systems approach needed for the project. It also showed an ability to respond effectively to changes in our requirements, such as the addition of business case development to the scope and schedule changes."*