Millennium Line Broadway Extension (MLBE) Project

Strategic Options Whitepaper

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partnerships
British Columbia

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SUMMARY

PURPOSE OF DOCUMENT

This strategic options analysis summarizes the analysis undertaken to identify a preferred option to address the transit needs for the Millennium Line Broadway Extension (MLBE or the Project) corridor.

This document provides an overview of studies carried out between 2009 and 2017 and includes a review of the potential service delivery alternatives, the decision criteria applied to evaluation alternatives as Project planning evolved, and the shortlist of options for analysis in the business case. A recommended service delivery alternative is identified.

RECOMMENDATION

Based on the background and analysis summarized within this report, a tunneled SkyTrain extension is recommended as the best approach to address the transportation challenges along the Broadway Corridor (the Corridor). The proposed six-kilometre Rail Rapid Transit (RRT or SkyTrain) extension to the existing Millennium Line SkyTrain from its current terminus station at VCC-Clark Station to a new western terminus station at Arbutus Street will provide significant transit user benefits and best aligns with regional planning strategies, the Mayor's Council Vision, and Provincial priorities.

1 INTRODUCTION

1.1 STRATEGIC OPTIONS ANALYSIS DOCUMENT OVERVIEW

This Strategic Options Analysis documents the findings of previous studies and the steps taken to study potential rapid transit alternatives to Business As Usual (BAU) (the 99 B-Line rapid bus). The document includes the following sections:

Section 2 – Requirements and Considerations for the Strategic Options Analysis: Reviews the policy requirements for an options analysis as well as project objectives for the Millennium Line Broadway Extension (MLBE).

Section 3 – Project Background: Reviews the Phase 1 UBC Line Rapid Transit Study and Phase 2 University of British Columbia (UBC) Line Rapid Transit Study, to examine potential rapid transit alternatives that connect VCC-Clark Station or Commercial-Broadway Station to UBC, and the initial Multiple Account Evaluation (MAE) performed in the Phase 2 UBC Rapid Transit Study on seven shortlisted alternatives and recommendation that three be considered for further study.

Section 4 – Selection of Preferred Alignment: Identifies the preferred Broadway alignment for the MLBE, and removes one of the shortlisted alternatives from further consideration.

Section 5 – A Phased Approach to Project Delivery: Provides an overview of the rationale behind the phasing of the MLBE and the location of the terminus station at Arbutus Street.

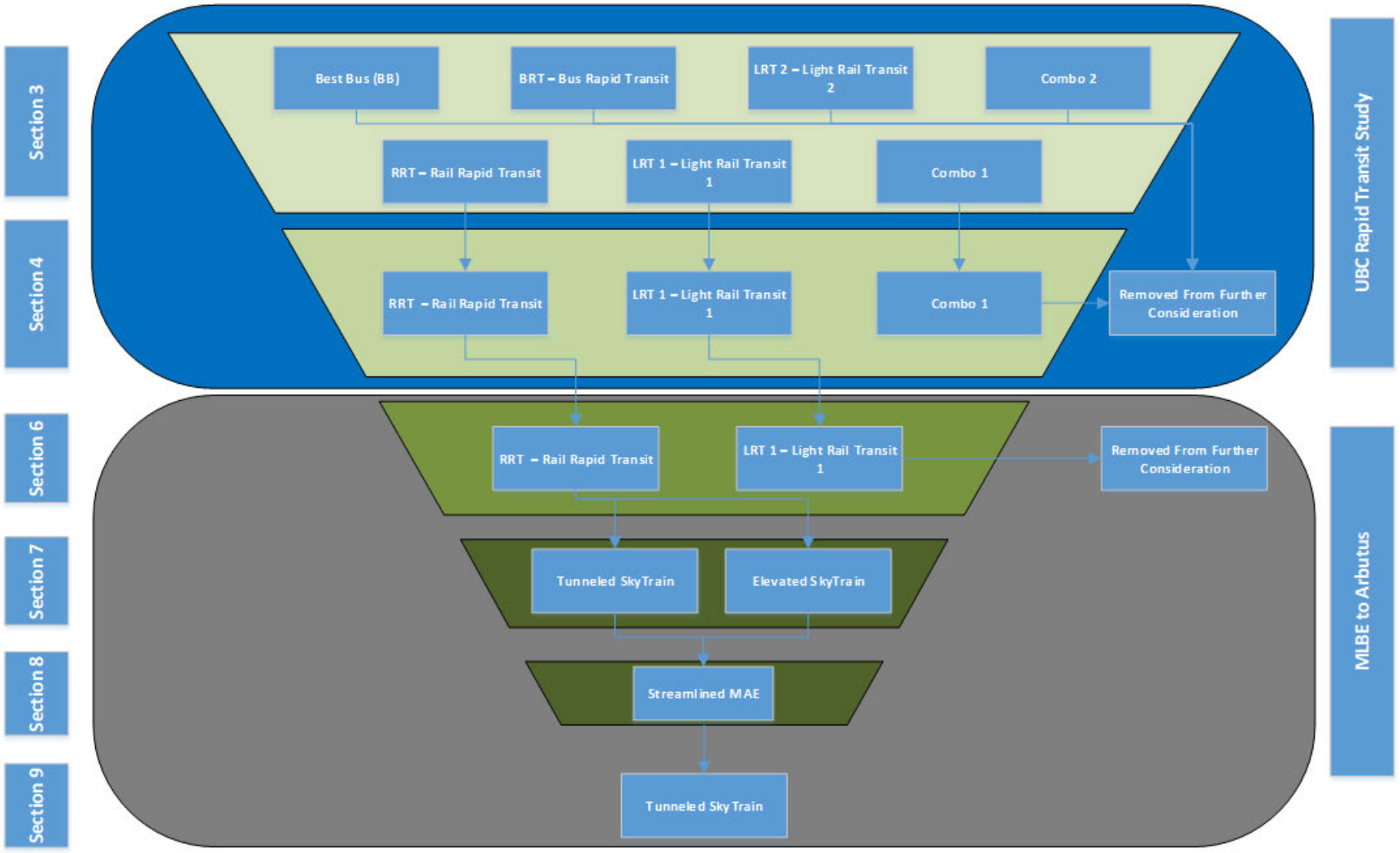
Section 6 – Review of LRT Technology versus Functional Requirements: Analyzes Light Rail Technology (LRT) in the context of meeting project requirements, and concludes that LRT does not meet some of the functional requirements and should not be considered further.

Section 7 – Feasibility of Elevated SkyTrain Option: With the preferred rapid transit technology being refined to SkyTrain, this section describes the scope of primarily elevated SkyTrain alternatives, and discusses some of the challenges and benefits associated with implementing this option.

Section 8 - MAE of Project Alternatives: An MAE is completed in this section for the tunneled and elevated options with comparative summaries for each account.

Section 9 – Summary of MAE and Conclusion: This section summarizes the analysis in Section 8 and recommends the tunneled SkyTrain as the preferred approach.

Figure 1. Options Analysis Document Funnel



2 REQUIREMENTS AND CONSIDERATIONS FOR THE STRATEGIC OPTIONS ANALYSIS

2.1 CAMF REQUIREMENTS FOR MULTIPLE ACCOUNT EVALUATIONS

The Province's Capital Asset Management Framework (CAMF) requires public sector agencies to explore alternatives to meet service delivery needs through a strategic options analysis. A strategic options analysis is a systematic approach to identifying options, evaluating them, and determining the best way to meet service delivery needs that meets public interest objectives.

This document takes into account recommendations from CAMF and the March 2013 ***Audit of the Evergreen Line Rapid Transit Project***[1] by the Office of the Auditor General of British Columbia.

2.2 MOTI TRANSIT BUSINESS CASE TEMPLATE

MOTI guidelines provide sector-specific guidance as to how the CAMF requirements are to be met including:

1. Guidelines for Preparing Business Cases: Overview[2];
2. BC MOTI Transit Business Case Template – Handbook[3] ("MOTI Handbook"); and
3. BC MOTI Benefit Cost Analysis Guidebook: Guidelines for the Benefit Cost Analysis of Highway Improvement Projects in British Columbia[4]

The ***Guidelines for Preparing Business Cases: Overview*** indicates that a multiple account evaluation (MAE) is to be used to evaluate alternatives for transportation projects while the MOTI Handbook provides MAE criteria specific to transit projects. An MAE process provides for the evaluation of both quantitative and qualitative factors across alternatives in terms of five different accounts: financial, customer service, environmental, economic development and social/community. Each account is represented by one or more metrics which represent the important implications of each alternative and demonstrates the trade-offs involved in selecting one alternative in relation to the others. The MAE analysis highlights the costs, benefits and other impacts of each alternative in relation to a base case or business as usual (BAU), which is the most likely solution in the event none of the alternatives moves forward.

The MOTI Handbook clarifies that not all inputs are applicable to all business cases, and should be tailored to fit the specifics of the individual project. With this guidance, the Project team reviewed each criteria identified in the MOTI Handbook and shortlisted criteria on the basis that they were relevant to the Project and Project objectives, and differentiated the alternatives being analyzed.

[1] https://www.bcauditor.com/sites/default/files/publications/2013/report_15/report/OAGBC%20Evergreen%20Line.pdf
[2] BC Ministry of Transportation and Infrastructure, "Guidelines for Preparing Business Cases: Overview," November 2015.
[3] BC Ministry of Transportation and Infrastructure, "Transit Business Case Template - Handbook," Revised November 2014.
[4] BC Ministry of Transportation and Infrastructure, "Benefit Cost Analysis Guidebook: Guidelines for the Benefit Cost Analysis of Highway Improvement Projects in British Columbia," Revised August 2014.

This document includes a summary of the previous MAE analysis undertaken for the Project and provides updates to reflect recent analysis.

2.3 INTEGRATION OF MOTI TEMPLATE INTO BUSINESS CASE MAE

The categories considered for MAE analysis within the MOTI Handbook differ slightly from the terms utilized in previous MAE studies performed for the Project. For clarity, the table below demonstrates how the major account categories are incorporated from the MOTI template into this MAE to ensure consistency. The MAE undertaken for this report is consistent with the prior work undertaken in the UBC Rapid Transit Study.

Table 1. Alignment of MAE Categories

MOTI Account Categories	Strategic Options MAE Categories
Financial Performance	**Financial**
Customer Service	**Transportation**
Economic Development	**Economic Development**
	Urban Development
Environment	**Environment**
Social	**Social and Community**
	Deliverability

*Note: The deliverability account is not referenced within the Guidelines for Preparing Business Cases: Overview nor the MOTI Handbook. However it aligns with CAMF in terms of protecting the public's interest and alignment with public policy issues and consistent with evaluation of large projects undertaken by the Province[5].

2.4 PROJECT OBJECTIVES AND REQUIREMENTS

The Broadway Corridor is an area within the Metro Vancouver Region extending approximately from Victoria Drive (East) to the University of British Columbia (West) and from 4th Avenue (North) to 16th Avenue (South). Central Broadway, the portion of the corridor between approximately Commercial Drive and Burrard Street, is part of the regional Metro core and is home to major health, civic, and educational institutions and job centres. The Project would address a large gap in Metro Vancouver's rapid transit network, and help the Metro Vancouver Region (the Region) to meet its transportation, environment, and urban development goals in a cost effective manner.

Based on previous studies[6] conducted for the Broadway Corridor, seven high level objectives were defined. The high-level objectives were used to establish more specific, measurable criteria, which could be used to gauge the success of the proposed Project. The Strategic Options MAE account categories

[5] Capital Asset Management Framework Guidelines (May 2002), Section 4.4.3, Sub-section 4.4.31
[6] Phase 1 UBC Line Rapid Transit Study (2009); Phase 2 UBC Line Rapid Transit Study (2012). See Section 3 of this report.

noted in the right column of Table 1 are accounted in the left column of Table 2 with measurable project objectives further defined.

The objectives for the Project are as follows:

Table 2. Project Objectives

High Level Objective	Project Specific Measurable Objectives
Financial: An affordable and cost-effective service.	• Capital Cost • Operating Cost • Revenue • Salvage • Cost-Effectiveness

Transportation:
A fast, reliable and efficient service that meets current and future capacity needs, supports achieving transportation targets, and integrates with and strengthens the regional transit network and other modes.
	• Ridership / Capacity
	• Transit User effects
	  ○ Travel Time Savings
	  ○ Reliability
	• Vehicle Operating Cost Savings
	• Accident Collision Cost Savings
	• Non-Transit User effects
	• Parking Loss
	• Traffic Impacts During Construction and Operations

Economic Development: A service that encourages economic development through construction related (direct and indirect) job creation and tax revenue, and minimizing impacts on goods movement during operations.	• New Direct and Indirect Jobs during Construction • Employment along the Corridor during service • Goods movement along the Corridor
Urban Development: A service that supports current and future land use development along the Corridor and integrates with the surrounding neighbourhoods through high quality urban design.	• Land use integration • Land use/Development potential • Property Value impacts • Access to Transit • Property Requirements
Environment: A service that contributes to meeting wider environmental sustainability targets and objectives by attracting new riders, supporting changes to land use and reducing vehicle kilometers travelled.	• Emission reductions • Noise and Vibration
Social and Community: A safe, secure and accessible service that also improves access to rapid transit for all and brings positive benefit to the surrounding communities, while managing impacts of rapid transit on heritage and archaeology.	• Residential Impacts • Business Impacts • Community Cohesion/Visual Impacts • Improve the safety performance for transit riders • Accessible transit for individuals with disabilities

High Level Objective	Project Specific Measurable Objectives
Deliverability: [7] A service that is constructible and operable, and publically acceptable.	• Consistent with the Mayors' Council 10-Year Vision • Project is perceived favourably by majority of consulted stakeholders • Assessment of Constructability

These objectives are used to guide the Multiple Account Evaluation presented in Section 8.

[7] As defined in Translink. (2012). UBC Rapid Transit Study Phase 2 Evaluation Report

3 PROJECT BACKGROUND

This section reviews the previous work done on behalf of TransLink - the Phase 1 UBC Line Rapid Transit Study and Phase 2 UBC Line Rapid Transit Study, completed respectively in 2009 and 2012. These studies assessed technology and alignment options for rapid transit connecting from the vicinity of Commercial-Broadway Station to UBC's Point Grey Campus. The Phase 1 UBC Rapid Transit Study's focus was the identification of potential technology and alignment alternatives, and concluded with the recommendation of seven alternatives, which were advanced for detailed analysis in the Phase 2 UBC Rapid Transit Study. This section summarizes this work.

3.1 CORRIDOR CONTEXT

The Broadway Corridor is a regionally important corridor that includes the largest university (University of British Columbia) and the largest hospital (Vancouver General Hospital) in Western Canada. The Corridor also represents the second largest jobs centre in the Province, contributing 105,000 jobs, and is a key source of employment for residents throughout the Region. This trend is expected to continue as the Corridor is projected to accommodate 30,000 more jobs by 2045. Further, land use planning was recently completed for the industrial area of the False Creek Flats, which represents a large employment opportunity that would be connected to rapid transit.

In addition to the growth in job demand along the Corridor, neighbourhoods adjacent to Broadway such as Southeast False Creek, Mount Pleasant, and Grandview-Woodland have approved land use plans that will further increase the expected growth of residents living within the Corridor. Currently there are over 125,000 people living in the Corridor, with a further 70,000 expected by 2045.

Broadway is part of the Region's Major Road Network (MRN) and is one of the busiest truck routes in the City of Vancouver. The corridor is also one of the busiest transit corridors in North America, with over 110,000 transit trips a day, 55,000 of which are on the 99 B-Line express bus. The 99 B-Line is currently over capacity during peak hours, with half a million pass ups annually. At present, Broadway is a street with significant traffic congestion during peak periods even with parking restrictions and dedicated bus lanes. This congestion negatively impacts all road users, including pedestrians, transit users, cyclists, drivers and goods movement. One of the key project objectives is to provide the transit capacity for now and in the future, and reduce congestion along the Corridor.

3.2 PHASE 1 WORK

In 2009, more than 200 technology and alignment options for rapid transit along the Broadway Corridor were screened as part of the Phase 1 UBC Rapid Transit Study. Through extensive public and stakeholder consultation (2,300 online questionnaires, 240 comments submitted online, five community workshops with 400 attendees, stakeholder meetings with local business groups) and a comprehensive technical analysis, a shortlist of seven rapid transit alternatives were identified:

Table 3. Phase 1 UBC Rapid Transit Study –Shortlisted Technology & Alignment Alternatives

Alternative	Description
BRT- Bus Rapid Transit	Low-floor articulated buses (running on diesel or electricity) running in their own right-of-way and separated from other traffic by a curb, and with stations located within the street. At-grade BRT route from UBC to Commercial-Broadway Station via University Blvd, West 10th Ave and Broadway using diesel or electric trolley articulated buses.
LRT1 - Light Rail Transit 1	Driver-operated rail vehicles powered from overhead wires running in their own right-of-way and separated from other traffic by a curb, and with stations located within the street. At-grade LRT route from UBC to Commercial/Broadway Station via University Blvd, West 10th Ave and Broadway.
LRT2 - Light Rail Transit 2	Combines LRT1 with a second branch from Broadway/Arbutus to Main Street-Science World via the CPR right-of-way, the City of Vancouver streetcar route and Station St.
RRT - Rail Rapid Transit (SkyTrain)	Driver operated or driverless rail technology that is powered by electricity. In Metro Vancouver RRT (SkyTrain) is driverless and automated and operates fully separated from other traffic in a tunnel or on elevated track, and with stations accessed by escalators, stairs and elevators. Mainly tunneled route via University Blvd, West 10th Ave, Broadway, with a short elevated section along Great Northern Way as an extension of the existing Millennium Line SkyTrain from VCC-Clark Station
Combo1 - Combination Alternative 1	Combination of RRT from VCC-Clark Station to Arbutus Street with the portion of the LRT2 route operating from UBC to Main Street/Science World.
Combo2 - Combination Alternative 2	A combination of RRT from VCC-Clark Station to Arbutus Street with the BRT alternative using diesel buses.
BB - Best Bus	Represents the best that can be achieved relying on conventional buses in the study area and demonstrates the impacts and benefits of bus service improvements within the Corridor including local, semi-express (B-Line) and express bus services.

Figure 2. Short-Listed Alternatives from Phase 1 UBC Rapid Transit Study

BRT - At-grade BRT route from UBC to Commercial-Broadway via University Blvd, West 10th Ave and Broadway using diesel articulated buses[1].

LRT1 - At-grade LRT route from UBC to Commercial/Broadway via University Blvd, West 10th Ave and Broadway.

LRT2 - combines LRT1 with a second branch from Broadway/Arbutus to Main Street-Science World via the CPR right-of-way, the City of Vancouver Streetcar route and Main St.

RRT - Mainly tunnelled route via University Blvd, West 10th Ave, Broadway, Great Northern Way as an extension of the existing Millennium Line SkyTrain from VCC-Clark.

Combination Alternative 1 - Combination of RRT from VCC Clark to Arbutus with the portion of the LRT2 route operating from UBC to Main Street/Science World.

Combination Alternative 2 - a combination of RRT from VCC Clark to Arbutus with the BRT alternative using diesel buses.

Best Bus - represents the best that can be achieved relying on conventional buses in the study area and demonstrates the impacts and benefits of bus service improvements within the corridor including local, semi-express (B-Line) and express bus services.

3.3 PHASE 2 WORK

3.3.1 Initial Multiple Account Evaluation

The Phase 2 UBC Rapid Transit Study developed design concepts for seven shortlisted alternatives and created the MAE framework. From March to April 2011, the study team presented preliminary design concepts and evaluation results for the seven alternatives to the public for input. Approximately 540 people participated in four in-person workshops, an online webinar, seven small group meetings and two drop-in sessions. Input was received and tracked through workshop minutes and more than 1,500 feedback questionnaires. Furthermore, a "TransLink Listens" survey (online advisory panel of regional residents) of over 1,800 people was used to gauge the public acceptability of each alternative.

The Business As Usual (BAU) option assumes that the Broadway Corridor would continue to be served by buses (including the 99 B-Line) with service increases consistent with past trends, population and employment growth. This option assumes no new rapid transit solution is developed along the Corridor and no significant changes are made to the 99 B-Line, which is already operating at maximum capacity and minimum headway. All alternatives were evaluated against this BAU case as a point of reference. A neutral rating (3) means that an alternative would perform no better or worse than "business as usual". These assessments have been summarized on a five-point scale, as shown below:

Figure 3. Five-Point Scale

The performance of each alternative within each account is summarized in the table below followed by an account-by-account description of the findings for each criterion. "Lifecycle" assessments were based on 30 years of operations of each alternative.

Figure 4. Multiple Criteria Analysis for Seven Shortlisted Technology Alternatives

Account	Alternative						
	BB	BRT	LRT1	LRT2	RRT	Combo1	Combo2
Transportation	◒	○	◒	◒	●	●	◒
Financial	○	◒	◒	○	◒	◒	◒
Environment	◒	◒	◒	◒	●	◒	◒
Urban Development	◒	◒	◒	◒	◒	◒	◒
Economic Development	◒	◒	◒	◒	●	◒	◒
Social Community	◒	◒	◒	◒	●	◒	◒
Deliverability (affordability not considered)	◒	◒	◒	◒	◒	◒	○

The Phase 2 UBC Rapid Transit Study concluded that, of the seven options, the RRT (SkyTrain) option was the top-ranked alternative in every category; and three of the seven options (LRT-1, RRT, and Combo-1) were highlighted for further consideration.[8]

[8] Translink. (2012). *UBC Rapid Transit Study Infographic.*

4 SELECTION OF PREFERRED ALIGNMENT

4.1 RATIONALE FOR THE ALIGNMENT ON BROADWAY

The analysis undertaken in the Phase 1 and 2 UBC Rapid Transit Studies contemplated multiple technologies and multiple alignments from UBC to VCC-Clark, Main Street-Science World, and Commercial-Broadway stations within the Corridor study area. The described area was selected for analysis due to its urban and economic importance within Metro Vancouver, the current and growing gap in available rapid transit, and its forecasted growth and demand. The Corridor, as defined in the Phase 2 UBC Rapid Transit Study, is roughly 500m north and south of Broadway and between Commercial-Broadway Station and UBC. One of the key findings from the original options analysis undertaken in the Phase 2 UBC Rapid Transit Study was that the most beneficial alignment within the Corridor was directly on or under Broadway.

All of the shortlisted options, including the three that were recommended for further consideration, set all or part (in the case of Combo 1) of the alignment on Broadway, for the following reasons:

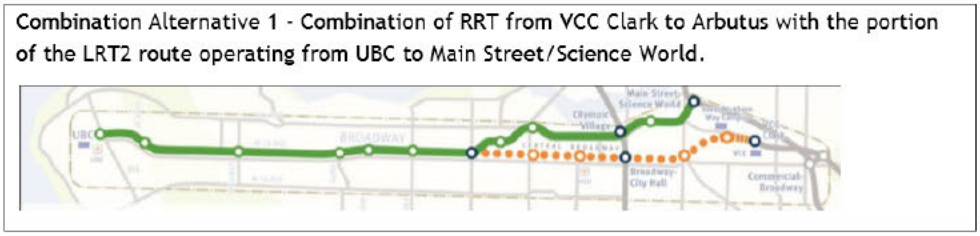
- Proximity to the major activity centres in the Corridor including the central business district and Vancouver General Hospital;
- Direct connection to existing rapid transit networks (Canada Line);
- Proximity to current and future employment in the Corridor; and
- Direct route to minimize travel time, cost, and effort, and maximize ridership.

An alignment on Broadway best serves the current and long-term demand for rapid transit offering transit customers convenient access to key destinations along the Corridor and throughout the regional transit network. Other alternatives that were not on Broadway had lower projected ridership and did not provide the same level of access to the jobs, services, institutions, and shops concentrated along Broadway.

4.2 COMBO 1 ALTERNATIVE

Combo 1 included an LRT line from Main Street-Science World to Arbutus Street on an alignment that ran parallel to but north of Broadway before continuing from Arbutus Street and Broadway onward to UBC. A RRT would run from VCC-Clark Station to Arbutus Street. Selecting RRT from VCC-Clark Station to Arbutus Street would leave the option open for Combo 1 in the future when rapid transit is expanded to UBC in the future.

Figure 5. Alignment of Combo 1 Alternative Shortlisted in Phase 2 UBC Rapid Transit Study



5 A PHASED APPROACH TO PROJECT DELIVERY

Following the assessment of technology and alignment alternatives for the Broadway Corridor to UBC, the TransLink Mayors' Council on Regional Transportation considered the proposed extension from a regional affordability perspective and in the context of a prioritized 10-year investment vision. Through the 2014 Mayors' Vision, the Mayors' Council confirmed the need for rapid transit on Broadway, to be delivered in two phases, with a first phase identified as a tunneled SkyTrain extension to Arbutus Street, located under Broadway (MLBE Phase 1).

This approach reflects the findings of the Phase 2 UBC Rapid Transit Study, which noted that an extension of Rail Rapid Transit to Arbutus Street is cost effective and would provide a better near-term benefit cost ratio than the full scope to UBC[9]. This was a result of higher densities, more significant traffic congestion, proportionally higher ridership, and greater near-term development potential along the eastern section of the Corridor. The analysis also showed that connecting the MLBE Phase 1 to a shortened B-Line would provide sufficient capacity to accommodate forecast ridership between Arbutus Street and UBC over the medium term (10-20 years)[10].

The decision to terminate the MLBE Phase 1 at Arbutus Street (rather than a more eastern terminus such as Granville), was based on three considerations:

- **Addresses the Immediate Need for Rapid Transit Service**: Arbutus Street is the most suitable terminus along the Corridor as it is west of the densest section of Central Broadway and thus provides much needed rapid transit service through the most critical section of the truncated Corridor. Traffic congestion in Central Broadway causes the vast majority of bus delays and unpredictability today. A terminus at Arbutus allows buses to operate more consistently and predictably in the less congested part of the corridor between Arbutus Street and UBC.
- **Does Not Preclude MLBE Phase 2 Options**: Terminating the first phase at Arbutus Street does not limit options or preclude technology alternatives from consideration for the future phase two rapid transit extension to UBC.
- **Space for Bus Integration:** Truncation of the SkyTrain extension at Granville Street creates significant challenges for bus operations. The higher variability in bus travel time between Arbutus Street and Granville Street as well as the 3 to 4 minutes required to make a left turn from Broadway onto Granville (a turning movement required if the B-Line were to terminate at Granville) have several implications, including higher bus operating costs, increased street congestion, and diminished passenger service reliability. There is greater congestion and less space to accommodate buses and passenger transfer movements at Granville compared with the Arbutus Street terminus location.

Given the regional affordability, benefit cost and other considerations outlined above, the Mayor's Vision identified a tunneled SkyTrain extension as the preferred alternative for delivery within the first

[9] Translink. (2012). *UBC Rapid Transit Study Phase 2 Evaluation Report, Page 146 Section 12.26.*
[10] Translink. (2012). *UBC Rapid Transit Study Phase 2 Evaluation Report, Page 146 Section 12.25.*

10 years, which would support regional objectives for community integration, land use, and mode-share. The Mayors' Vision also identified the completion of a rapid transit connection to UBC as a future priority, following development of the MLBE Phase 1 project to Arbutus Street.

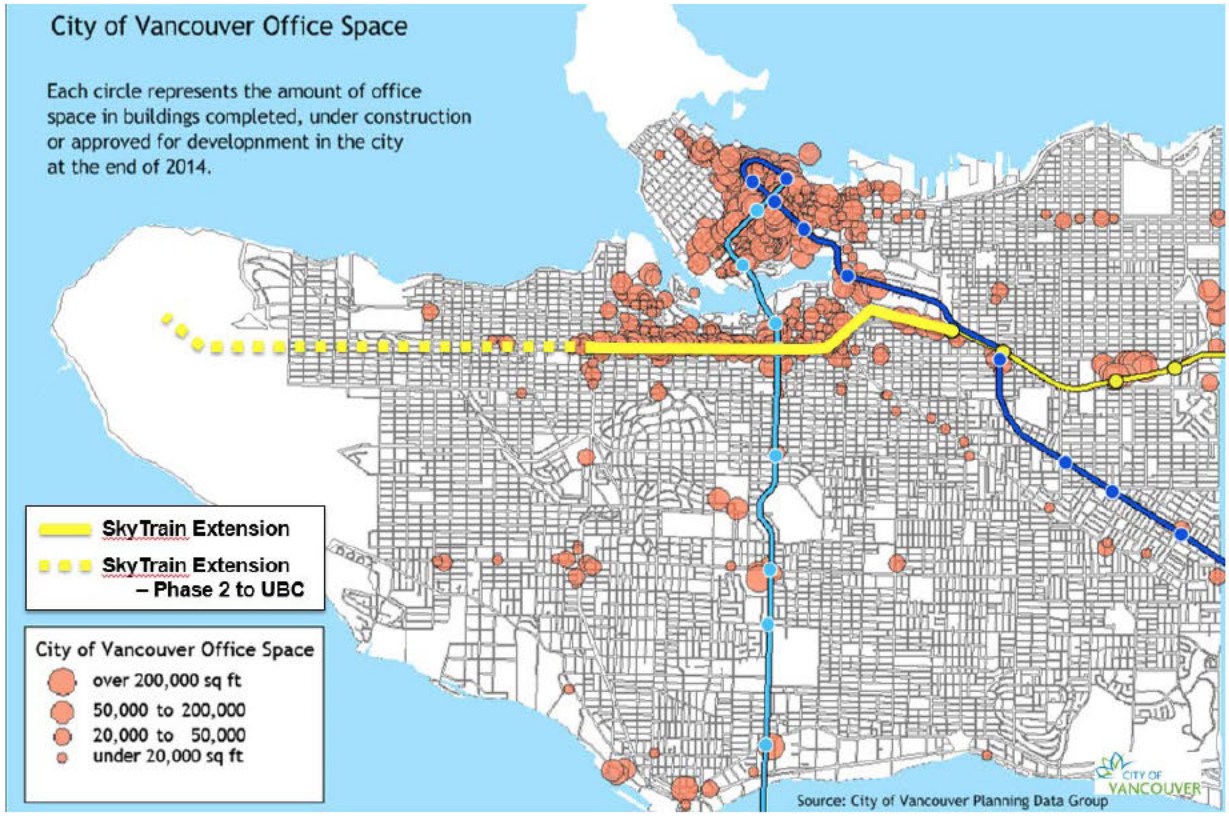
5.1 RATIONALE FOR PHASE 1 ARBUTUS TERMINUS

A variety of technical factors influenced the decision to terminate the MLBE Phase 1 at Arbutus Street. These included the employment density, transit ridership, traffic volumes and travel time reliability along the corridor east and west of Burrard, and the availability of lands at Arbutus to accommodate a bus transfer locations.

Employment Density

The Broadway corridor is the second largest employment centre in British Columbia. The large majority of these jobs are concentrated in the corridor east of Arbutus, as illustrated in Figure 11.

Figure 6. Office Space Locations Within City of Vancouver



Transit Ridership

Expected ridership by station correlates closely to the distribution of office space along the Corridor and declines rapidly west of Arbutus station. When reviewing 2045 eastbound peak compared to Cambie station, Arbutus Station would have 71% of the volume, whereas if the station were to be extended one stop further west to MacDonald, ridership volume decreases to 56%. Westbound peak indicates that

after Arbutus station, the majority of riders remain boarded until UBC. A terminus at Arbutus Station would ensure that Central Broadway and its employment centers would be well served by the MLBE and improve trip time and reliability through the busiest section of the Broadway Corridor.

Traffic Volumes and Travel Time Reliability

As described in Section 2.10 of the Phase 2 UBC Rapid Transit Study, trips between Commercial and Arbutus in both directions have a peak period average speed significantly lower than Arbutus to UBC. This information is provided in the table below:

Table 4. Transit Travel – Average Speed

Segment	Westbound Peak (avg km/h)	Eastbound Peak (avg km/h)
Commercial to Arbutus	24.8	17.7
Arbutus to UBC	39.1	33.8

Along with lower average speeds, the Commercial to Arbutus segment accounts for where the majority of trip time variability occurs. In addition, eastbound traffic volumes at Granville are significantly higher than at Arbutus (see Table 5 below) which would make bus integration with a Granville terminus challenging and would add additional variability to travel time, increased congestion, and requiring the bus to turn left turn from Broadway onto Granville. Westbound volumes are slightly lower at Granville than Arbutus as traffic to/from downtown can use Fir and Hemlock Streets to access the bridge. Higher pedestrian activity at Granville and narrow sidewalks could make termination at Granville challenging.

The Arbutus terminus, in contrast, has significantly lower traffic volume and additional space to integrate. Finally, the Arbutus Greenway connects to the future Arbutus Station location, which would provide a further pedestrian and cycling connection, with a future potential streetcar route being explored by the City of Vancouver.

Table 5. Traffic Volumes on Broadway, at Granville and Arbutus

2030 AM Peak hour MLBE Scenario		
Traffic Volume	**Westbound**	**Eastbound**
West of Granville	394	1,560
East of Granville	398	1,154
Traffic Volume	**Westbound**	**Eastbound**
West of Arbutus	525	809
East of Arbutus	551	922

Future Phasing

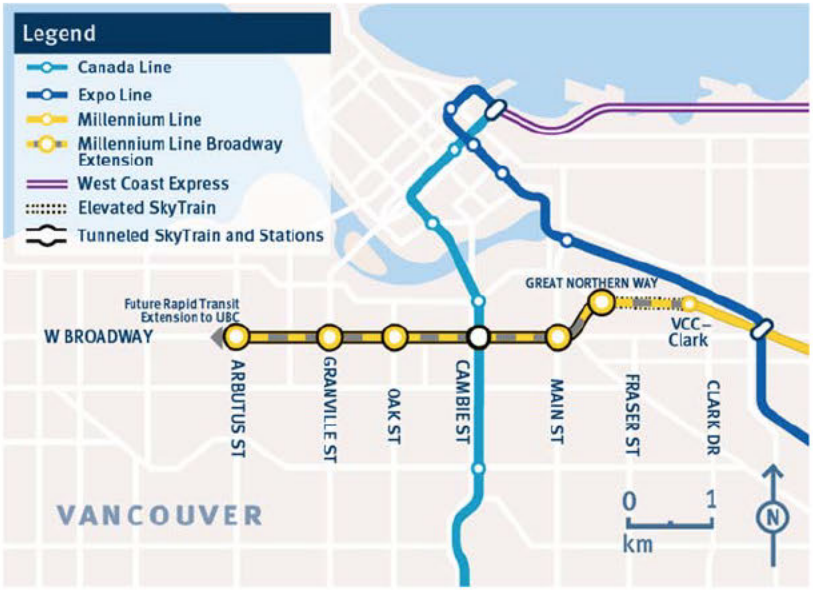
The potential second phase of the MLBE would likely connect Arbutus Station to UBC. To allow maximum flexibility for phase two options, the termination at Arbutus would allow alternative technologies to be considered. These could include:

- Bus Rapid Transit – The Arbutus to UBC route in phase one of MLBE currently utilizes a shortened 99 B-Line Rapid Bus. Continued use of this system, or considerations for separated and prioritized rapid bus service could be further studied.
- Light Rail Transit – As mentioned earlier in this document, Combo 1 included an LRT line from Main Street-Science World to Arbutus Street on an alignment that ran parallel to but north of Broadway before continuing from Arbutus Street and Broadway onward to UBC. The MLBE phase one would run from VCC-Clark Station to Arbutus Street. Given the intent to deliver the project in phases, delivering RRT from VCC-Clark Station to Arbutus Street would leave the option open for Combo 1 in the future when phase two of rapid transit to UBC is planned.
- RRT/SkyTrain – Similar to the phase one expansion of MLBE from VCC-Clark Station to Arbutus, a second phase could extend the line from Arbutus to UBC.

5.2 TUNNELED SKYTRAIN/RAIL RAPID TRANSIT (RRT) SCOPE

The scope of the tunneled SkyTrain extension includes a short elevated section extending west from the current terminus at VCC-Clark Station, and entering a tunnel north of Great Northern Way and east of Thornton Street. From the tunnel portal, the alignment shifts southward to a station located at Main/Broadway. The alignment continues under the centre of Broadway, terminating at Arbutus Street. Stations would be located within one block of Great Northern Way/Thornton, Main, Cambie, Oak, Granville, and Arbutus. Stations along Broadway would be constructed using excavation from the surface with traffic decking in order to maintain sufficient traffic and transit flow during construction.

Figure 7. Tunneled SkyTrain Scope



6 REVIEW OF LRT TECHNOLOGY VS FUNCTIONAL REQUIREMENTS

6.1 OVERVIEW

As noted, Light Rail Transit along the Broadway Corridor (LRT1) was shortlisted in the Phase 2 UBC Rapid Transit Study. At that time, RRT was identified as providing equal or greater benefits than LRT in all of the account categories when the full scope to UBC was considered (See Figure 4). The following sections summarize the differences between RRT and LRT1 in the Phase 2 UBC Rapid Transit Study, and compare the two technologies in the context of the project being delivered in two phases. This analysis shows that, as with the Phase 2 UBC Rapid Transit Study, LRT does not perform as strongly against project objectives as RRT. The study also notes that a phased approach (with the first phase to Arbutus Street) for LRT would not be cost effective due the short length of the alignment and requirement of a new Operations and Maintenance Center (OMC) facility nearby to service the system.

Ultimately, this section concludes that the implementation of an LRT system is not feasible, and recommends its removal from further consideration.

6.2 KEY TRANSPORTATION OBJECTIVES

6.2.1 Ridership/Capacity

The ability to meet current and future capacity challenges in the Corridor, and to encourage a shift in trips from auto to transit are key project objectives. SkyTrain technology offers the greatest ultimate capacity (almost four times that of in-street LRT1), and has a greater capability to manage longer-term transit demands over the life of the project.

Primary considerations in ridership include reliability and speed. The RRT extends from the existing SkyTrain system, provides the shortest journey time and delivers more transportation benefits than LRT1. The RRT option was 35% faster than the LRT1 option which is a key driver behind larger forecast ridership demand. RRT is expected to attract almost five times more new daily transit trips than LRT.

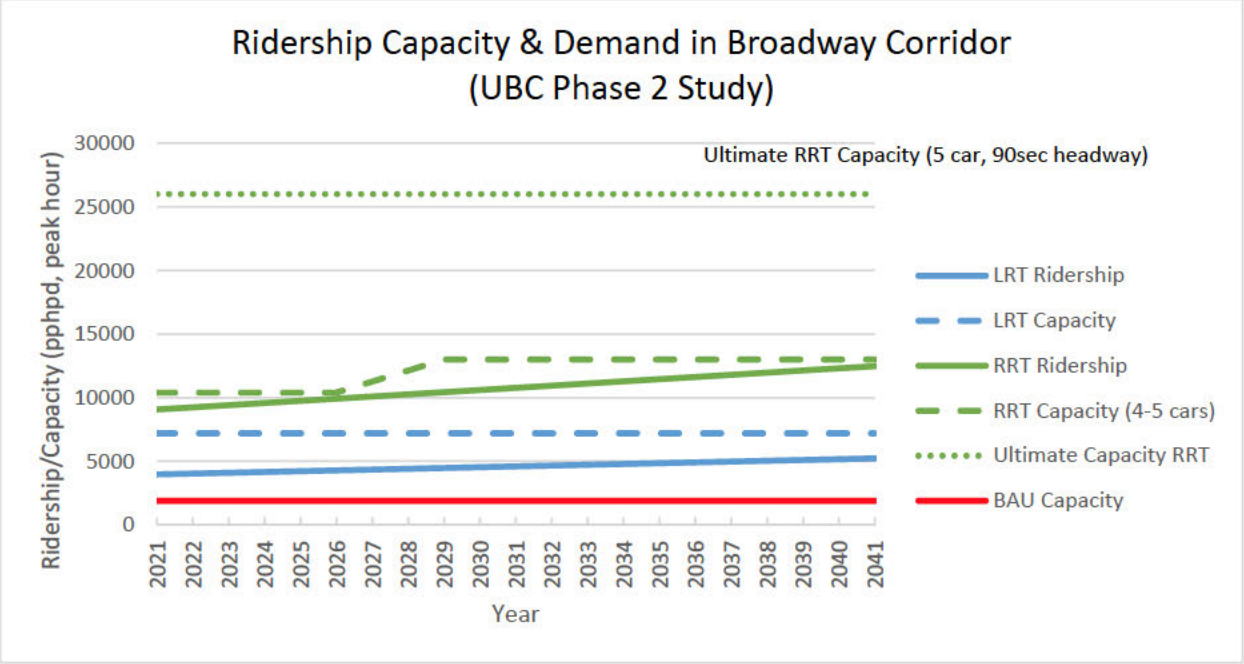
Table 6. Forecast of Key Ridership Measures – Phase 2 UBC Rapid Transit Study[11]

MEASURE (Unit)	LRT1	RRT	% DIFFERENCE
2041 Forecast Peak Load (pphpd[12])	5,200	12,500	240%
Assumed Ultimate Capacity (pphpd)	7,200	26,000	361%
2041 Weekday Ridership (Trips/day)	160,000	322,000	201%
New Weekday Transit Trips (New Trips/Day vs BAU)	11,000	54,000	490%

[11] Translink. (2012). *UBC Rapid Transit Study Phase 2 Evaluation Report, Page x.* Retrieved from Translink Website
[12] pphpd is people per hour per direction

It should be highlighted that although both technologies operate below their stated capacities in 2041, the LRT1 only achieves this due to the much lower expected ridership compared to RRT (5,200 on LRT vs. 12,500 on RRT at peak load). The slower expected travel times associated with the LRT1 solution is a disincentive to ridership. Further, adding additional capacity to LRT1 by increasing the number of vehicles decreases travel time reliability as LRT1 would have reduced transit prioritization at intersections due to the reduced headways between vehicles.

Figure 8. Ridership Capacity & Demand from Phase 2 UBC Rapid Transit Study



6.2.2 Requirement of an OMC Yard

The introduction of LRT technology along the Broadway Corridor would also require the construction of a separate operation, maintenance and train storage facility, with a spur line connecting the facility to the alignment. As there is insufficient land along Broadway, a secondary spur of at least 0.5 km would be required to take trains off Broadway to an operation and maintenance centre located on industrial land.

6.2.3 Impacts on the Broadway Corridor Users

A significant difference between the RRT and the LRT1 alternatives is the grade separation of the RRT option. While the LRT1 provides easier street level access for boarding, its introduction to an already congested Broadway Corridor would have a number of impacts to non-transit users. The requirement of two lanes to be repurposed for a dedicated LRT right of way would eliminate all street parking on Broadway. To ensure reliability of travel times for LRT1, signal prioritization at intersections is required, along with the restriction of non-transit turning movements at almost all (67 of 73 intersections) along

the alignment[13]. The implementation of both measures would negatively affect other road users and cause increases in traffic on parallel local streets and bikeways.

6.2.4 Operational Cost Efficiency

Although RRT has a higher capital and lifecycle cost in comparison to LRT1, RRT generates more travel time savings and attracts more riders than LRT1. The result of this is that RRT performs better on a number of measures of cost-effectiveness (e.g. cost per new transit rider) despite their capital and lifecycle costs being over 2.5 times greater than those of LRT1 (for the full UBC Scope). In the 2012 evaluation, the inefficiency of LRT results in LRT1 operational costs per passenger that is 37% higher than RRT[14].

6.3 OTHER IMPACTS (ENVIRONMENT/URBAN/ECONOMIC/SOCIAL)

The Phase 2 UBC Rapid Transit Study noted that both LRT1 and RRT can be constructed from a technical point of view. The construction impacts relating to LRT1 would be over the entire length of the alignment but with a shorter duration, while the RRT would have longer duration impacts at the station locations but no impacts between stations along the Broadway Corridor if the alignment was tunneled.

From an environmental perspective, RRT has the highest modal shift from car to transit, leading to the greatest levels of auto emissions reductions, and lowest noise/vibration impacts to local residents and businesses. RRT would also encourage more active modes of transportation (walking, biking, etc.).

Table 7. Comparison of Key Environmental Measures (Phase 2 UBC Rapid Transit Study)[15]

MEASURE	LRT1	RRT	% DIFFERENCE
Lifecycle Reduction in Auto Vehicle Kilometers Travelled (million kms to 2045)	1,014	2,361	233%
Lifecycle GHG Emissions Reduction (Kilo Tonnes to 2045)	235	335	142%

The grade separated tunneled SkyTrain option provides additional benefits within the Corridor in that its footprint during operations at the street level is primarily limited to station entrances. By maintaining the existing Corridor's traffic/parking lanes and streetscape, this allows the greatest level of flexibility for any future improvements to the urban realm along the Broadway Corridor.

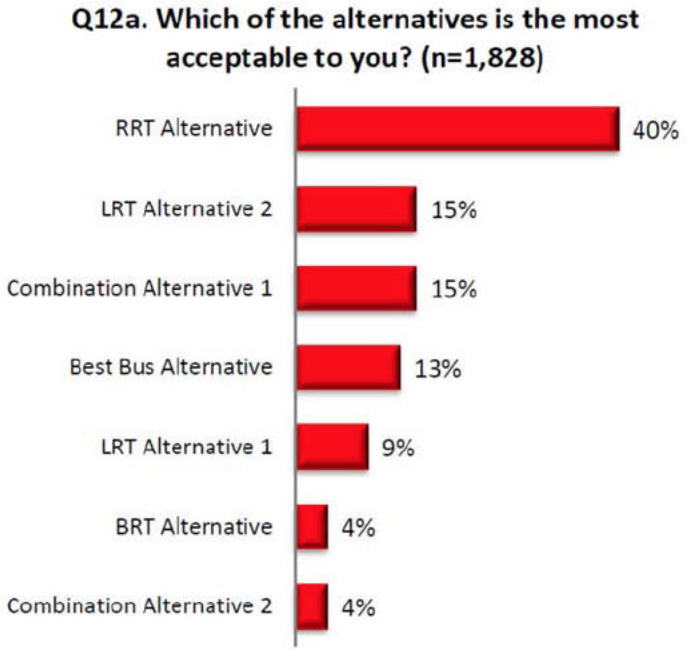
6.4 PUBLIC ACCEPTANCE/MAYORS' VISION

Finally, during the public consultation of the seven shortlisted options within the Phase 2 UBC Rapid Transit Study, RRT was found to have the highest public acceptability of all the rapid transit alternatives,

[13] TransLink. (2012). *UBC Rapid Transit Study Phase 2 Evaluation Report, Page 54 (Table 5.8).*
[14] TransLink. (2012). *UBC Rapid Transit Study Phase 2 Evaluation Report, Page 86.*
[15] TransLink. (2012). *UBC Rapid Transit Study Phase 2 Evaluation Report, Page 93.*

over four times that of LRT1 (see figure below). The Mayor's Council Vision supported this conclusion by including it within its ten-year investment priorities with strong support from regional representatives.

Figure 9. UBC Line Rapid Transit Study – Public Acceptability



6.5 IMPACTS OF PHASED APPROACH

The RRT alternative was highlighted as providing the most flexibility for potential MLBE Phase 2 options. A phased initial six kilometre operating segment of an LRT system would be very inefficient from both a cost and operations perspective. The Phase 2 UBC Rapid Transit Study notes that: "The Combination alternatives and RRT could be built in phases through, for example, extending SkyTrain to Broadway and Arbutus Street as an interim stage towards extending rapid transit to UBC which would spread out the capital requirements over a longer period of time. The LRT alternatives would require an LRT operations and maintenance centre; a minimum route length is typically needed to warrant such a facility making the phasing of LRT1 unlikely"[16].

6.6 SUMMARY

The findings of the MAE with respect to terminating at Arbutus Street have not materially changed when compared to the Phase 2 UBC Rapid Transit Study which compared alternatives on the full alignment to UBC. The phased approach addresses the need for rapid transit along the central business

[16] Translink. (2012). *UBC Rapid Transit Study Phase 2 Evaluation Report, Page 146 12.21.*

areas along the Corridor, with many of the key impacts, benefits, and differentiators between alternatives are amplified due to the population density in the area, the number of businesses within Central Broadway and congestion. The analysis shows that RRT provides significantly better transportation and transit performance, lower operational costs per passenger, and higher ranking in a number of other MAE criteria, in comparison to LRT. RRT (SkyTrain) best addresses the critical transportation challenges facing the Broadway Corridor, and supports the further economic and urban development of the region. It provides the greatest travel time savings, reliability, greenhouse gas emissions reduction, and highest benefit to cost ratio of all alternatives considered.

As a result of the analysis above, LRT was removed from further consideration of strategic options.

7 FEASIBILITY OF ELEVATED SKYTRAIN OPTION

In this section, an elevated SkyTrain alignment along the Broadway Corridor is reviewed to determine if it would be a feasible solution for the Broadway Corridor. In subsequent subsections, benefits and challenges associated with the implementation of an elevated SkyTrain are identified and quantified where possible. Ultimately, this section concludes that the implementation of an elevated SkyTrain is not feasible, and recommends its removal from further consideration.

7.1 SCOPE OF ELEVATED SKYTRAIN OPTION FOR BROADWAY

An elevated option would have the same general alignment and station locations as the tunneled alignment. The alignment would start with a short elevated section at VCC-Clark Station before entering a tunnel north of Great Northern Way and east of Thornton Street due to gradients required to allow the project to emerge on the Broadway alignment. From the eastern tunnel portal, the alignment shifts southward to meet the station located at Main/Broadway. A western tunnel portal would be located between Main and Cambie Stations, where the guideway would transition to being elevated. The elevated guideway would be situated in the centre of Broadway, with elevated stations straddling Broadway (similar to Brentwood Station, above Lougheed Highway, on the Millennium Line).

Figure 10. Elevated SkyTrain Option

7.2 BENEFITS OF AN ELEVATED SKYTRAIN

An elevated SkyTrain alignment would share many of the benefits that a tunneled SkyTrain offers for transit users, when compared to the BAU.

Grade separation between street level traffic and rapid transit offers transit user benefits such as increased travel time reliability, and speed. Additionally, either SkyTrain alternative would provide sufficient capacity and expandability capabilities to meet the growing demand along the Broadway corridor. The project alignment would provide convenient access for transit passengers to key locations along the corridor, including both current and future educational, research and health care facilities, as well as retail, commercial, and residential developments. As a result of these benefits to transit users, both options would attract high ridership.

An elevated SkyTrain approach would contribute to meeting environmental sustainability targets and objectives by attracting new riders, partially supporting changes to land use and reducing vehicle kilometers travelled. Whether elevated or underground, SkyTrain is expected to provide a reduction of GHG emissions of over 8,000 metric tonnes in 2045.

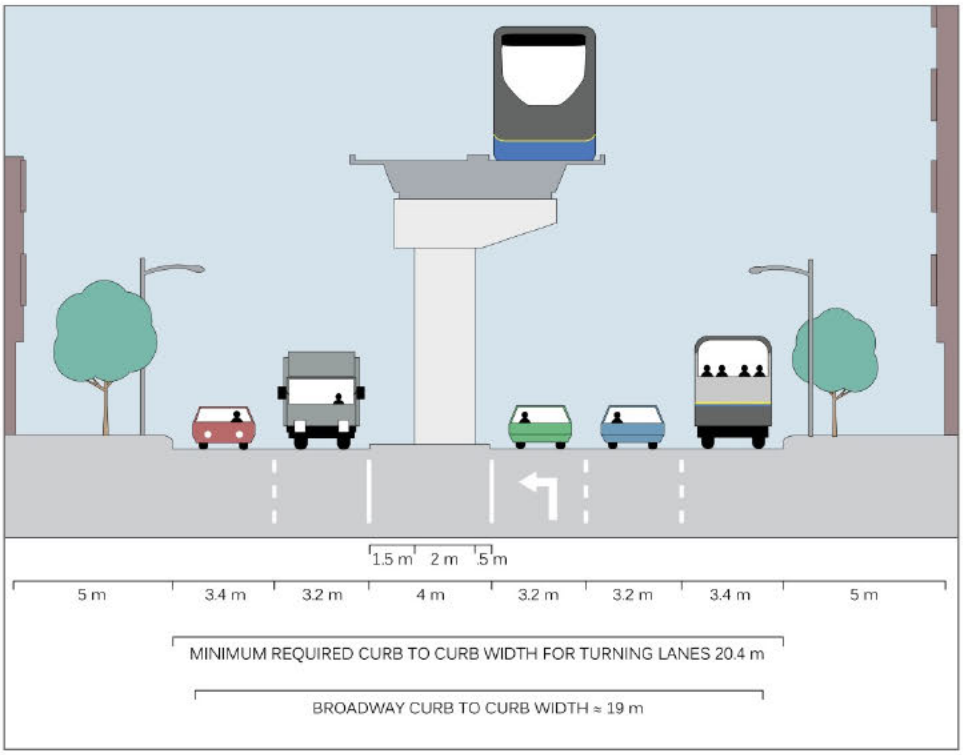
Typically, an elevated guideway alignment offers a more economical solution in terms of construction costs, however, impacts of an elevated guideway within a corridor must be considered and weighed against potential construction cost savings when determining an optimal solution. Previously, on both the Expo Line and Canada Line, the benefits provided by tunneling in an existing dense urban environment outweighed the additional costs associated with that construction methodology. The impacts of an elevated guideway on Broadway are addressed in detail in the subsequent subsections.

7.3 TRANSPORTATION IMPACTS AND COSTS

Using a similar street design as the Evergreen Line elevated guideway, the columns and offsets to travel lanes would take up 5m of the approximately 19m curb to curb within the street right of way. This would permanently eliminate two of six lanes used as available travel lanes during peak hours and all on street parking located on Broadway. As a result, buses will be required to stop within the travel lanes at bus stops, further reducing capacity on Broadway and leading to additional congestion at peak hours.

In addition to the removal of travel lanes, the elevated alignment introduces sight distance restrictions around the columns, which will require dedicated turn lanes to accommodate protected turn phases at major intersections. These turn lanes can be accommodated within the alignment at major intersections without further land acquisition, however, insufficient space exists for these movements at minor intersections. As a result, 32 left turns would no longer be permitted. With only 11 left turn opportunities on Broadway between Arbutus and Main Street at the major intersections, the result will be significant business impacts, and increased traffic on adjacent local streets as vehicles are forced to use local streets for both parking and to access businesses between the major streets where left turns are no longer possible. Traffic diverted onto local streets will also have significant impacts on the local street bikeways located with a block or two of Broadway. The difficulties associated with business access in this scenario would lead to fewer trips to businesses along the Corridor.

Figure 11. Typical Broadway Elevated Cross-section

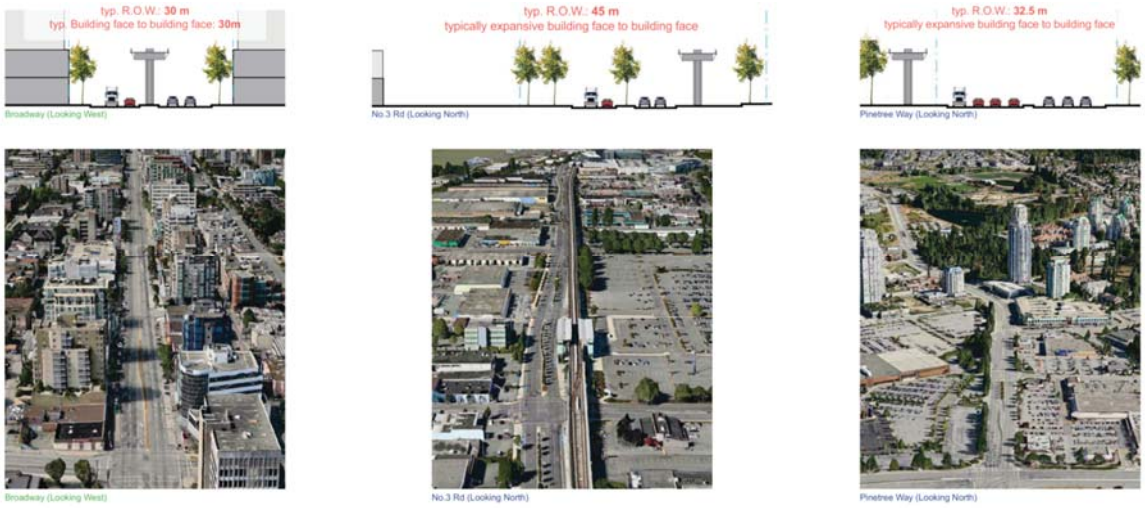


These access and circulation restrictions will negatively impact businesses along Broadway and would make goods movement and delivery difficult. Some businesses, particularly those with vehicle access needs (specialty retail or services, furniture stores, grocery stores) will also be adversely affected by the removal of all on-street parking. The City of Vancouver also anticipates approximately [redacted] a year in lost parking revenue which equates to 2017 PV of approximately [redacted] between 2023 and 2041.

7.4 URBAN/ECONOMIC/LAND IMPACTS ON EXISTING DEVELOPMENTS ON BROADWAY

Developments along the Broadway corridor are typically on or close to the property line on both sides of the street and setbacks are atypical. On recent SkyTrain projects (See Figure 12 below) the elevated guideway was situated on the side of the road where there were limited impacts on adjacent buildings due to large setbacks for surface parking lots. Due to buildings bordering both sides of the road, the guideway on Broadway would need to be located in the middle of the street to maximize the distance from existing buildings. The introduction of an elevated SkyTrain along Broadway would introduce noise and vibration issues for existing buildings that were not designed to mitigate these issues. The noise resulting from trains on the elevated guideway would affect the 5,500 existing residents living on or within a block of Broadway.

Figure 12. Compare Broadway (Vancouver, left), No. 3 Road (Richmond, centre), and Pinetree Way (Coquitlam, right).



7.4.1 Tunnel Portal Land Requirements

There are also additional property implications associated with an elevated guideway due to the requirements of a western tunnel portal. Similar to the tunneled SkyTrain alignment, a tunnel connection between Great Northern Way and Broadway is required due to grades. The result of this tunneled section is that there is a portal required where the underground tunnel emerges above ground (west of Main Street Station) that will require the acquisition of two blocks of properties on the north side of the street.

7.4.2 Elevated Stations

Stations located along the elevated guideway would have land requirements similar to the tunneled option. One key difference between the two is that as the footprint of the station (with the exception of the headhouse) is located below grade with the tunneled option, which would allow for potential development and integration with a building above. An elevated station would require additional airspace above the headhouse to move passengers from the platform level down to the street level, limiting its development potential.

7.4.3 Business Impacts

Broadway is characterized by commercial uses at grade for the entire length of the MLBE. Beyond business access issues discussed above, an elevated guideway would reduce street tree coverage in many locations, block sightlines and views, and shade sidewalks, patios and businesses at grade. Concerns from businesses and commercial property owners are expected related to decreased retail sales and lower lease rates resulting from the access issues and an unwelcoming streetscape. In other areas of the region, elevated alignments have been implemented in corridors that typically do not have the existing commercial development extending to the property line. The additional distance from existing commercial properties mitigates some of the associated issues noted in this section.

Due to the proximity to business and residential areas, there are other impacts that are not quantified here.

7.5 LIMITING FUTURE DENSITY AND GROWTH ON BROADWAY

Development potential along the Corridor would be negatively impacted as new developments will need to have greater setbacks, which in some cases will reduce developable land. Given height restrictions in much of Central Broadway due to medical flight paths and protected views, the larger setbacks will have significant impacts on development in much of Central Broadway, with lost development potential valued in the range of [redacted] (nominal[17]). This value only addresses specific areas on Broadway where these planning criteria would preclude any options to mitigate lost development and density and can be quantified. Broadway has been highlighted as a priority location to encourage greater housing development to aid affordability in the Metro Vancouver region, and the elevated guideway would challenge achieving greater housing opportunities close to transit.

The noise from the guideway would also require changes to the design of future buildings to make them more soundproof which may include fewer windows, triple paned glazing, and air conditioning (residential buildings in Vancouver do not tend to have air conditioning). These noise mitigation interventions would add costs to new developments and may make Broadway developments less attractive for developers. A less attractive high street at the heart of Central Broadway's emerging high tech and biomedical sector could have impacts on the attractiveness of the area to employers.

7.5.1 Future Growth Limitations

Central Broadway is the second largest job centre in British Columbia and is the home of a growing biomedical and high tech sector. It is also a key transportation corridor that links some of Metro Vancouver's largest centres of innovation at UBC's West Point Grey Campus, Emily Carr University of Arts and Design, and the Centre for Digital Media. This is a unique area that competes in a global market place for employers as well as the best and brightest talent. Broadway lies at the heart of this job centre and has the potential to become a street that effectively balances transportation needs while maintaining an urban realm that attracts businesses to the area. In a global marketplace, technology companies are looking to set up in locations with a broad talent pool. To attract and retain a workforce of talented and innovative tech people, regions need to have effective transportation systems, interesting cultural opportunities and attractive public realms (place making) among other things. Negatively impacting the Broadway streetscape could make Metro Vancouver less attractive to the talent pool, and employers may choose to set up in other regions such as Seattle, San Diego, Toronto, or London.

7.6 SUMMARY

While an elevated SkyTrain would achieve some of the project objectives relating to transit user benefits and financial benefits and is technically constructible, it introduces many negative aspects to the Corridor that run counter to the project objectives set out in Section 2.4.

[17] City of Vancouver Memo – Methodology for Value of Development Potential Lost with Elevated Guideway (2017)

8 MAE OF PROJECT ALTERNATIVES

The following subsections will provide a summary of advantages and disadvantages of the tunneled and elevated project alternatives (see Section 7) against the BAU option. This information will then populate the MAE table that evaluates both quantitative and qualitative factors, and the type of measurement used for criteria is denoted in the Appendix A table. The results of the following section are summarized within Section 9.

8.1 TRANSPORTATION

The two options differ in several key respects. The shorter station access routes for the tunneled alignment, especially at the Cambie Station (Canada Line transfer), provide a greater level of passenger convenience and result in higher peak and overall ridership for tunneled SkyTrain in comparison with the elevated SkyTrain. Elevated SkyTrain requires supporting columns in the Broadway right-of-way, which reduces traffic lanes and street parking, resulting in greater long-term congestion on Broadway compared with tunneled.

Elevated and tunneled SkyTrain options have similar transit network performance characteristics when compared with BAU. These include improved transit service reliability and reduced travel time. Traffic impacts of these two options during construction differ in detail, but would have similar overall impacts on traffic, and degree of business disruption. These factors do not differentiate the two SkyTrain options.

With a direct connection between Canada Line and Millennium Line at the current Broadway City Hall Station, the ridership model shows that a tunneled SkyTrain would have higher ridership. Consequently, it would reduce vehicle usage, promotes greater mode shift away from private vehicles and more effectively diminishes traffic congestion on Broadway as compared to elevated SkyTrain.

Tunneled SkyTrain provides a better transportation solution than Elevated SkyTrain and a significant improvement when compared to the BAU.

8.2 FINANCIAL

While the project cost of tunneled SkyTrain is greater than elevated SkyTrain, as stations and guideways cost less to construct in the elevated option, these savings are partially offset by the higher temporary and permanent land costs of elevated SkyTrain. The elevated option estimate used here does not include compensation for claims regarding loss of development potential within the Broadway Corridor. Given the likely impact of an elevated guideway on future development, compensation might be required and would be expected to further diminish the cost differential between elevated and tunneled SkyTrain. Operations, maintenance and rehabilitation costs are 5% higher for tunneled SkyTrain.

With higher ridership than elevated SkyTrain, tunneled SkyTrain fare revenues are forecast to be higher. In the BAU option, no meaningful capital costs are expected to be incurred.

8.3 ENVIRONMENT

The planned time between trains, (train headways) is approximately 2.5-3.5 minutes in each direction. Train times may become more frequent as ridership grows. Consequently, trains in the elevated option would affect residents and businesses along Broadway with noise and vibration as frequently as roughly once per minute during peak hours. Noise and vibration associated with tunneled SkyTrain is not anticipated to be perceptible at grade or in buildings. For much of the year, elevated guideway along Broadway will overshadow the north sidewalk and properties. It will also impact views to the downtown and North Shore from properties south of Broadway.

The elevated guideway impacts of noise, vibration, and over-shadowing of sidewalks and properties, will significantly diminish livability along the Broadway Corridor. As noted in the financial section above, this may also impair development potential along Broadway, which is the second highest employment centre in British Columbia.

With higher ridership, less street congestion and greater mode shift away from private vehicles, tunneled SkyTrain has a greater greenhouse gases (GHG) reduction than the elevated option, and both have significantly greater reductions in comparison to the BAU option.

The tunneled option entails disposal of a much larger amount of construction spoils than elevated. As the elevated option requires a much larger amount of property acquisition (due to the requirement of a tunnel portal on Broadway) and building demolition due to the property takes required near stations to allow adequate circulation between station entrances and existing sidewalks, more contaminated material disposal is anticipated for this option. Appropriate disposal methods and sites would need to be developed for both elevated and tunneled approaches.

Tunneled SkyTrain has fewer negative environmental impacts on the Broadway Corridor, and greater GHG reduction benefits compared with elevated. Both options face challenges around spoils and construction waste disposal. On balance, the tunneled option significantly outperforms elevated SkyTrain in the environmental account.

8.4 ECONOMIC/URBAN DEVELOPMENT

The Economic/Urban Development account compared the potential economic and urban development impact of the two alternatives in the Metro Vancouver region. It considered the overall potential for residential and commercial development and the associated impact on property value, as well as the short and long-term impact on regional employment.

Between the two SkyTrain options, the tunneled SkyTrain performed significantly better in the Economic Development account than the elevated SkyTrain. While either will generate short-term employment from construction, and will address the gaps in the rapid transit network, the elevated SkyTrain limits the longer-term economic and urban development of the Region and reduces the ability to increase land use density and integrate new developments with the rapid transit network. Furthermore, the proximity of the elevated guideway to buildings would produce shading and noise impacts on businesses and reduces the commercial and residential potential of the region. The additional traffic lanes required for construction would also be required for operations (would become part of the centre median), meaning

the traffic lanes would be lost permanently. The tunneled SkyTrain approach provides greater opportunity to support higher density land use, address critical congestion, and supports the development of a more attractive streetscape.

Both SkyTrain options demonstrated significantly greater urban and economic development potential for the region than BAU. Additionally, both SkyTrain options would create a similar level of direct and indirect jobs during the construction phase of the project, and generate significant long-term employment in the Corridor as a result of improved connections to centres of innovation and employment, and the increased density of land use. By comparison, the BAU option would negatively impact the development of Broadway Corridor and the region, resulting from increased traffic congestion and the ongoing gap in the rapid transit network.

As a result, the tunneled SkyTrain represents the best option within the Economic/Urban Development account.

8.5 SOCIAL AND COMMUNITY

The Social and Community account compared some of the localized impacts of the two options within the context of the Broadway Corridor. It considered local impacts for residents, businesses, and community/street level impacts on citizens.

For local residents and businesses, the construction of an elevated guideway along the centre of Broadway would introduce guideways and stations that would be close to existing buildings that had not been designed with this in mind. This would negatively affect the quality of life for residents and businesses fronting the Broadway Corridor. The ability to mitigate these impacts is limited and could introduce additional capital costs to the Project. In addition, the loss of parking under the elevated SkyTrain option would discourage non-transit users from trips to businesses along the Corridor due to perceived accessibility difficulties.

At the community level, the introduction of an elevated guideway results in a significant visual impact at the street and building level. With the tunneled solution, surface-level infrastructure would be primarily limited to station head houses, which can be integrated into the Corridor and support integrated land use opportunities.

Other criteria were considered, but were not ultimately differentiating factors between the two SkyTrain options. Both options provided the largest reduction in trips utilizing personal vehicles when compared to BAU. As both options had the same general alignment and station locations, both served the same proportion of low-income residents. The grade separation of both options greatly increased the passenger safety versus a bus sharing the road with other traffic, pedestrians, and cyclists. Elevated stations are perceived as slightly safer from a personal safety standpoint versus underground, however, this can be mitigated through high-quality design of underground passenger facilities. In addition, both would replace vehicle trips in the Corridor and would subsequently improve air quality for people living in the area.

Overall, the tunneled SkyTrain option performs better than the elevated SkyTrain option for Social and Community, based on impacts to residents, businesses, and adjoining land uses.

8.6 DELIVERABILITY

Within the deliverability account, three main criteria were considered within the MAE: an assessment of the constructability of alternatives; the level of public acceptance for the alternatives; and whether the alternatives aligned with the Mayors' Vision.

Both the elevated and tunneled SkyTrain alternatives are technically feasible to construct. The elevated SkyTrain option would have construction impacts along the length of the Broadway Corridor (21 blocks) as foundations required to support the elevated guideway would need to be installed within the middle of the road from Manitoba St. to Arbutus St. During the construction phase, there would be localized traffic impacts along the alignment, with impacts to local businesses from construction, noise, and parking loss.

The tunneled SkyTrain alternative would have approximately seven blocks of localized traffic impacts around the areas of the underground stations, with impacts to local businesses due to the construction activity, noise, and temporary parking changes. Once construction was complete, traffic lanes utilized during construction would be returned, allowing for both goods movement and parking.

The level of public acceptance for SkyTrain technology has been tested through various surveys and public engagements. During Phase 2 of the UBC Line Rapid Transit Study, the tunneled SkyTrain was identified as the alternative with the highest level of public acceptance.

In terms of alignment with the Mayors' Vision for Broadway, the tunneled SkyTrain option has been endorsed by the Mayors' Council as meeting the current and long-term needs and goals of the region.

8.7 BENEFIT COST ANALYSIS

Table 8. Benefit Cost Comparison (Net Present Value)

Benefit Cost	Elevated (a)	Tunneled (b)	Delta (b-a)
Total Costs ($million PV)	$1,585	$1,802	$217
Total Benefits ($million PV)	$2,774	$2,948	$174
Benefit : Cost Ratio (BCR)	1.75**	1.64	

A BCR above 1.0 means that the project benefits exceed the project costs and indicates that the Project provides value for money. In this case, $1 invested in the Project would return $1.64 in benefits for the tunneled SkyTrain and $1.75 for the elevated SkyTrain.

** It is important to note that the elevated BCR does not account for potentially significant costs associated with compensation, mitigation, or litigation that would develop as a result of construction and long term operation of an elevated solution. These additional costs would reduce the BCR of the elevated option significantly. An overview of these impacts are noted as including:

- Noise impacts on existing residents and business during operations, with little opportunity to mitigate the impact on existing buildings;
- Impacts on the value of properties facing Broadway due to the impacts noted above;
- The potentially significant cost associated with any compensation, mitigation, or litigation that would develop as a result of implementing an elevated solution; and
- Delays in the implementation of the project due to further public consultation.

9 SUMMARY OF MAE AND CONCLUSION

9.1 ASSESSMENT SCALE

An assessment scale was applied to represent the extent to which each option addresses each criterion, with reference to the specific objectives associated with each category. The following scoring framework provided the basis for the qualitative assessment:

Table 9. MAE Five Point Scale

Scale	Description
✓	Significantly Worse
✓✓	Worse
✓✓✓	Same as Business As Usual
✓✓✓✓	Better
✓✓✓✓✓	Significantly Better

9.2 SCORING AND WEIGHTING

Numerically weighting and scoring the criteria are not recommended for the following reasons:

- Numerical scoring is not sufficiently flexible to allow for consideration of situational nuances in what is essentially a qualitative exercise. The assessment scale is heavily supported by the qualitative and quantitative information provided within this Strategic Options Analysis.
- The strategic options assessment is developed in a workshop format, with key positions and assumptions explicitly noted in this report. A numerical result may be interpreted with a false level of precision.
- Weighting the relative importance of the criteria removes flexibility in decision making from the decision makers. Decision makers likely have different priorities and the procurement options assessment process should be sufficiently flexible to allow decision makers to evaluate the relative importance of the criteria on their own.

9.3 RESULTS

The MAE results are summarized in the following table.

Table 10. Summary of MAE Results

Account	Alternative		
	BAU	RRT Elevated	RRT Tunneled
Transportation	√√√	√√√√	√√√√√
Financial	√√√	√√√√	√√√
Environment	√√√	√√√√	√√√√√
Economic Development	√√√	√√√√	√√√√√
Urban Development	√√√	√√	√√√√
Social and Community	√√√	√√	√√√√√
Deliverability	√√√	**N/A**	√√√√√

The results in Table 10 represent the summary of a workshop attended by TransLink, City of Vancouver, and the Project team. Details of the workshop are detailed in Appendix A.

9.4 CONCLUSION

This Strategic Options Analysis demonstrates that a tunneled SkyTrain extension for the MLBE Project is best suited to address the numerous transportation challenges along the Broadway Corridor. The tunneled extension will provide significant transit user benefits, and most effectively integrates into the existing Corridor. It best supports economic and urban development within the Region by providing an effective transportation solution without negatively affecting congestion, access to businesses, and livability along the Corridor during operations. Finally, the tunneled SkyTrain extension has the highest level of support from the public and businesses, and is endorsed by the Mayors' Council.

It is recommended that the tunneled SkyTrain extension be selected as the preferred service delivery option for the MLBE Project.

10 APPENDIX A

- Full MAE table, populated with summary descriptions against each criteria

Representatives from the Province, TransLink, City of Vancouver, and the Project team have jointly developed the enclosed MAE output table below. It has been developed based on the MOTI Transit Business Case Template, and considers three options:

- **Business As Usual**: No new rapid transit solution is developed along the Broadway Corridor and no significant changes are made to the 99 B-Line.
- **Elevated SkyTrain**: This option includes a partial tunnel between Great Northern Way and Manitoba, with the remainder elevated down the middle of Broadway. Stations are anticipated to straddle Broadway, and property takes considered are limited to those required to construct and operate the project.
- **Tunneled SkyTrain**: This option is based on the current post due-diligence reference concept.

Millennium Line Broadway Extension

Account	Criteria (*Assignment*)	Measurement	Unit	Business As Usual	Elevated SkyTrain	Tunneled SkyTrain
Financial	Capital cost	**Nominal/Present value**	(M$)	• No new capital cost (except fleet replacement and associated maintenance & administrative facilities)	• Nominal Cost in 2017 dollars is [redacted] • Present Value is [redacted]	• Nominal Cost in 2017 dollars is [redacted] • Present Value is [redacted]
	Operations, Maintenance and Rehabilitation costs	**Annual/Present value**	(M$)	• Present Value of Increased bus operating costs is $70m	• Annual OMR costs expected to be [redacted] • Present Value is [redacted]	• Annual OMR costs expected to be [redacted] • Present Value is [redacted]
	Revenue (Ridership revenue minus lost parking revenue)	**Present value**	(M$)	•	• Present Value revenue from ridership/parking is [redacted] • Reduction in ridership over tunneled MLBE option due to the loss of direct connection between the Millennium and Canada Lines at Broadway City Hall Station • Parking is lost on Broadway	• Present Value revenue from ridership/parking is [redacted] • Increase in ridership over elevated MLBE option due to the direct connection between the Millennium and Canada Lines at Broadway City Hall Station • No parking revenue loss
	Salvage	**Present value**	(M$)	•	• Present Value is [redacted]	• Present Value is [redacted]
	Total Costs	**Present Value**	(M$)		• Present Value Total Cost is 1,584 Million	• Present Value Total Cost is 1,802 Million
	Cost Effectiveness (study to 2045)			• The benefit/cost ratio will decline as bus operating costs increase by an estimated $70m(PV), and fare revenue decreases by an estimated $168m (PV) • There are no journey time savings, no auto operating cost savings, no collision cost savings, no GHG emission reductions, no reliability improvements, no urban realm improvements, no wider economic benefits, and no reduction in pass-ups	• Present Value of total benefits is $2,774 Million • Benefit/Cost ratio is 1.75	• Present Value of total benefits is $2,948 Million • Benefit/Cost ratio is 1.64

Transportation	Ridership/Capacity	**Peak Load/Ridership:** • **2030** • **2045**	(pphpd)	• 2030 peak load is 3,790 pphpd (people per hour per direction) • 2045 peak load is 4,110 pphpd • 2030 forecasted daily ridership is 100,000 • 2045 forecasted daily ridership is 108,000	• 2030 peak load is 4,950 pphpd (people per hour per direction) • 2045 peak load is 5,450 pphpd • 2030 forecasted daily ridership is 135,900 • 2045 forecasted daily ridership is 139,000 • Greater transfer times between transit Line at City Hall Station causes a reduction in ridership	• 2030 peak load is 5,250 pphpd (people per hour per direction) • 2045 peak load is 6,000 pphpd • 2030 forecasted daily ridership is 142,200 • 2045 forecasted daily ridership is 167,000 • (Note Values equal 20% increase from previous business case to reflect due diligence changes)
	Travel time savings	**Average travel time for 2045 from Commercial-Broadway to:**	Minutes	• Forecast average peak hour transit time (in minutes) Commercial-Broadway Stations to: o UBC 50 o YVR 40 o City Hall 14 o VGH 17 o Arbutus St. 28	• Forecast average peak hour transit time (in minutes) Commercial-Broadway Stations to: o UBC 33 o YVR 34 (1 min longer due to transfer time) o City Hall 6 o VGH 8 o Arbutus St. 11	• Forecast average peak hour transit time (in minutes) Commercial-Broadway Stations to: o UBC 33 o YVR 33 o City Hall 6 o VGH 8 o Arbutus St. 11
	Service Reliability	**2045 travel time variability from Commercial-Broadway to:**	Minutes	• Forecast 2045 travel time variability (in minutes) Commercial-Broadway Stations to: o UBC 43-64 o YVR 38-52 o City Hall 12-22 o VGH 14-26 o Arbutus St. 23-44	• Forecast 2045 travel time variability (in minutes) Commercial-Broadway Stations to: o UBC 33-37 o YVR 33-37 (1 min longer due to transfer time) o City Hall 6 o VGH 8 o Arbutus St. 11	• Forecast 2045 travel time variability (in minutes) Commercial-Broadway Stations to: o UBC 33-37 o YVR 32-36 o City Hall 6 o VGH 8 o Arbutus St. 11
	Vehicle operating costs savings	**Present value**	(M$)	• No Change	• The calculated present value of savings is $79M.	• The calculated present value of savings is $77M.
	Accident (collision) cost savings	**Present value**	(M$)	• May result in reduced safety associated with the increase traffic congestion	• The calculated present value of savings is $75M.	• The calculated present value of savings is $72M.
	Non-Transit User Effects – Journey Time/Restrictions	**Qualitative**		• Congestion would continue to worsen along the Broadway Corridor. Non-Transit Users would also experience similar negative impacts	• 32 of 43 left turn opportunities would be restricted along the Broadway Corridor due to loss of traffic lanes from foundations located in the center of Broadway and inability to create left turn lanes that are required due to sight distance restrictions	• B-Lines would be removed from Broadway, freeing up additional road capacity. Tunneled SkyTrain does not affect non-transit users during operation
	Parking Loss	**Qualitative**		• BAU would involve no additional parking loss	• All parking removed permanently from Quebec to Arbutus due to 5.0 m median being required for station and guideway columns	• No permanent parking loss. • Temporary parking loss at five underground station construction sites
	Traffic Impacts (Construction)	**Qualitative**		• No Construction traffic impacts in BAU option	• Nighttime traffic restrictions to one lane in each direction for 5-6 months at all elevated guideway locations • Night time traffic restrictions to one lane in each direction for 8-10 months at 4-5 stations(4 elevated guideway locations and Main Street underground station), plus additional closures for utilities work • Daytime traffic restrictions to two lanes in each direction plus required left turn bays	• Nighttime traffic restrictions to one lane in each direction for 8-10 months at 5 underground stations, plus additional closures for utilities work • Daytime traffic restrictions to two lanes in each direction plus required left turn bays

	Traffic Impacts (Operation)	**Qualitative**		• Congestion would continue to worsen along the Broadway Corridor	• Broadway would have two traffic lanes in each direction with only left turn bays at major intersections, with left turn movements banned elsewhere	• Broadway would have up to three traffic lanes in each direction and required left turn bays at major intersections, with turning from traffic lanes at minor intersections
Economic Development	Construction Effects - Job Creation	**Number of direct and indirect jobs created**	FTE	• Because there are no changes associated with Business As Usual, there is minimal economic impact of construction. As noted, there are long term negative economic impacts associated with the current gap in the rapid transit network	• Based on the capital investment required for this project, significant direct and indirect job opportunities would be created	• Based on the capital investment required for this project, significant direct and indirect job opportunities would be created
	Employment	**Qualitative**		• There are long term negative economic impacts associated with the current gap in the rapid transit network	• The elevated alignment's proximity to nearby businesses lining the Corridor could have negative implications to the attractiveness of prospective companies who may elect to locate elsewhere • The elevated MLBE will provide improved connections between centres of innovation such as UBC and SFU and the major employment centre in Central Broadway. This includes the emerging innovation economy of Central Broadway, the Mount Pleasant Industrial Area, Burrard Slopes and the False Creek Flats	• The Broadway Corridor will be more accessible and more attractive to commercial tenants, their customers, and their employees • The tunneled MLBE will provide improved connections between centres of innovation such as UBC and SFU and the major employment centre in Central Broadway. This includes the emerging innovation economy of Central Broadway, the Mount Pleasant Industrial Area, Burrard Slopes and the False Creek Flats
	Goods Movement	**Qualitative**		• Existing goods movement challenges will significantly worsen with the increase traffic congestion	• Goods movement will be improved over the BAU. However, the reduced number of lanes, and subsequent reduction in parking, would hinder goods movement through the Corridor	• Goods movement will benefit as auto trips are replaced by trips on the MLBE, creating less congestion and more opportunities for loading
Urban Development	Land Use Integration/ Improved access (government services, education, employment, natural resources)	**Qualitative**		• The current regional connectivity challenges remain, and are not addressed	• The elevated MLBE addresses the current gap in the rapid transit network, offering improved transportation of riders between regional town centres	• The tunneled MLBE addresses the current gap in the rapid transit network, offering improved transportation of riders between regional town centres
	Urban Design Potential/Urban Realm Impacts	**Qualitative**		• The business as usual provides no opportunity to improve the urban realm without reducing transportation capacity	• Integrating an elevated guideway and stations along an already established and busy Corridor will create challenges that may not be easily overcome. This is particularly true for stations located above the road right of way where the sidewalk and pedestrian experience would suffer from a lack of sunlight, and increased congestion cause by station structural requirements and station access, including bus connections	• The tunneled MLBE option provides an opportunity to reallocate road space to other modes and to improve the urban realm to make a more attractive streetscape and improve sidewalk capacity and comfort
	Land Use/Development Potential (Commercial and Residential)	**Qualitative**		• The Corridor and Region will be challenged to accommodate higher density land use. It will also likely result in worse traffic congestion than currently found	• While the elevated MLBE will permit higher density land use, an elevated guideway and stations 5-10 metres away from building faces, with no opportunity for overbuild, would likely limit this potential for higher density land use	• The tunneled MLBE will permit higher density land use and address critical congestion issues. With underground stations, there is a significant opportunity to utilize the space above station head houses for further development (e.g. King Edward Station on the Canada Line)

	Property Value Impact	**Qualitative**		• There are no land value impacts from the business as usual case that would put either positive or negative pressure on land values	• An elevated MLBE is anticipated to positively affect land value; however, this impact will be limited on Broadway by the close proximity to the elevated guideway and station and additional noise associated with the elevated train	• The tunneled MLBE will likely make properties more attractive for redevelopment, particularly if future land use plans respond by allowing higher densities. The streetscape opportunities provided by an underground system could make Broadway a more attractive street and further increase land values and lease rates for both residential and commercial properties
	Access to Transit	**Quantitative/ Qualitative**	Number of residents/ jobs in 800m	• Number of residents within 800m of rapid transit: o 28,000 (2011) o 37,000 (2045) • Number of jobs within 800m of rapid transit: o 35,000 (2011) o 46,000 (2045)	• Number of residents within 800m of rapid transit: o 28,000 (2011) o 37,000 (2045) • Number of jobs within 800m of rapid transit: o 35,000 (2011) o 46,000 (2045) • The quantified values do not account for potential future density within the Broadway Corridor as a result of the introduction of elevated SkyTrain. Due to potential setback requirements for future buildings which could limit buildable space, overall density around stations would be expected to be lower than the tunneled SkyTrain	• Number of residents within 800m of rapid transit: o 28,000 (2011) o 37,000 (2045) • Number of jobs within 800m of rapid transit: o 35,000 (2011) o 46,000 (2045) • The quantified values do not account for potential future density within the Broadway Corridor as a result of the introduction of tunneled SkyTrain. Density around stations would be expected to be higher than the elevated SkyTrain
	Takings (business, residential)	**Estimated**	Number of Impacted Business	• No properties impacted in Business As Usual	• 95 businesses displaced by temporary and permanent property acquisition	• 68 businesses displaced by temporary and permanent property acquisition • 8 residential properties displaced by temporary and permanent property acquisition
Environment	Greenhouse Gas Emission Reduction	**2030 reduction** **2045 reduction**	GHG Emission Reduction	• No forecasted reduction in greenhouse gas emissions	• GHG Emission Reductions (auto) in 2030 of 9,200 (metric tonnes) • GHG Emission Reductions (auto) in 2045 of 8,160 (metric tonnes)	• GHG Emission Reductions (auto) in 2030 of 9,390 (metric tonnes) • GHG Emission Reductions (auto) in 2045 of 8,330 (metric tonnes)
	Noise and Vibration	**Qualitative**		• Noise and Vibration associated with the operation of the diesel powered 99 B-Line would continue	• Significant construction phase noise and vibration along the full Broadway alignment • Significant operational noise impacts from trains on the elevated guideway	• Significant construction phase noise and vibration at the five Broadway underground station sites • No significant operational noise and vibration impacts
Social	Residential Impacts (Social)	**Qualitative**		• As growth occurs in the Broadway Corridor and around the region, traffic congestion on Broadway will increase without an increase in transit capacity. This congestion will have negative impacts on local resident's air quality	• An elevated guideway and stations would be within metres of existing residential units. Existing buildings have not been designed for increased noise and visual intrusion from an elevated SkyTrain • The elevated guideway will reduce the openness of the area that will reduce the opportunity for 'eyes on the street' that is a central component of Crime Prevention Through Environmental Design (CPTED). This in turn could deter pedestrians from using the Corridor particularly in the evening	• Replacing vehicle trips with trips on tunneled MLBE supports street level improvements that are consistent with (CPTED) principles, and can support a more pleasant and pedestrian friendly environment

	Business Impacts (Social)	**Qualitative**		• The existing transportation network is at capacity (traffic and transit). Business as usual offers no opportunities to create a more attractive Broadway and offers no benefits to businesses	• Many of the medical offices in the Corridor require quiet environments and an elevated system in close proximity to the buildings would add to the noise in the street. Existing buildings have not been designed for increased noise from an elevated SkyTrain. • The loss of parking access to businesses lining the Corridor will likely discourage non-transit users from some trips to businesses along the Corridor	• A tunneled SkyTrain option provides the opportunity to make the Broadway Corridor more attractive, which will help to attract businesses and employees, and improve the Corridor's competitiveness in an increasingly global marketplace. A more attractive streetscape with less traffic will improve the lease ability of ground floor retail units • Existing businesses, particularly medical and research facilities will benefit from less noise and vibration from the transportation network in the Corridor
	Community Cohesion/Visual impacts	**Qualitative**		• No difference in the visual impacts	• Significant visual impacts will result from an elevated guideway in close proximity to buildings that affect both the streetscape as well as existing residences and buildings fronting on Broadway. These buildings were not designed around the presence of an elevated rapid transit system and as such are significantly impacted.	• Underground rapid transit allows for the reconsideration of the streetscape of Broadway, which could lead to a more attractive street in the long term
Deliverability	Mayors' Vision	**Qualitative**		• BAU does not meet the Mayors' Council vision to alleviate congestion along the Broadway Corridor • The least efficient mode to move transit users along the Broadway Corridor, and would be perceived least favourably	• Does not meet the Mayors' council vision of a tunneled SkyTrain along the Broadway Corridor	• Included in the Mayors' Council Vision. Public acceptance of the underground option is high with a majority of regional residents supporting the project (61% based on a telephone poll of 800 regional residents and 92% based on 4200 surveys completed in early 2017)
	Public Acceptance	**Qualitative**		• Only 13% selected Best Bus as the most acceptable alternative for Broadway (of 7 options) *Note that BAU was not surveyed and Best Bus offers improved bus service over BAU	• Members of the public were not asked about an elevated SkyTrain option during public consultations	• Percentage who selected SkyTrain as the most acceptable alternative for Broadway (of 7 options) = 40%
	Assessment of Constructability	**Qualitative**		• There are no construction impacts associated with Business As Usual.	• Construction impacts along 21 blocks of the Broadway Corridor • Business disruption along the full Broadway Corridor due to construction activity, noise and parking loss • Goods movement impacts due to traffic lane and parking restrictions along the full Broadway Corridor	• Construction impacts at five underground stations (6 blocks) of the Broadway Corridor • Business disruption at six blocks of the Broadway Corridor due to construction activity, noise and parking loss • Goods movement impacts due to traffic lane and parking restrictions at five locations

Note to reader: There are some items that were in the MAE table for the Phase 2 UBC Rapid Transit Study report that were omitted from the table above as they were non-differentiating criteria. Transit Network and System Access, along with Capacity and Expandability would both be the same whether the SkyTrain was elevated or tunneled. As the alignments considered within this paper are the same, health effects, low income population served, and heritage and archaeology, along with environmental considerations, would largely be unchanged between the two options.