Final Report

Burnaby Mountain Gondola Transit
Technology and Alignment Alternatives Assessment

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Prepared for TRANSLINK

Prepared by CH2MHILL

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Exhibits

EXECUTIVE SUMMARY

Forecast growth of both the Simon Fraser University (SFU) campus and UniverCity neighbourhood on Burnaby Mountain will increase transit demand in 2021 and 2041 beyond the capacities that can be met by frequent bus service. This increasing demand indicates the need to review alternative technologies to meet the future requirements, particularly given the unique topographical challenges imposed by the mountain-top location of the campus and neighbourhood.

Higher level policies need to be taken into account when reviewing potential solutions for addressing the transit needs of Burnaby Mountain to ensure that any actions are consistent with overall goals. The Provincial Climate Action Program and Transit Plan have set aggressive targets in terms of reductions in emissions and gains in transit mode share. TransLink has adopted these targets and has further formulated strategies to achieve these – as well as supporting goals – in its Transport 2040 planning process. The consideration of alternative transit solutions for Burnaby Mountain speaks directly to three of the strategies outlined in Transport 2040:

- Make early investments that encourage development of communities designed for transit, cycling, and walking (SFU and UniverCity are good examples of such communities)
- Optimize the use of the region’s transportation assets and keep them in good repair (a potential reallocation of diesel bus service to areas with gentler grades and an overall reduction in transit operating costs for serving the mountain would support this)
- Build and operate a safe, secure, and accessible transportation system (alternative transit solutions for Burnaby Mountain would be superior to buses in these respects)

The technology alternatives examined include the following:

- Ground-based solutions
  - Bus Rapid Transit (BRT) - Diesel/Trolleybus
  - Light Rail Transit (LRT)
  - Guided Light Transit (GLT)
  - Funicular
  - Rack Railway
  - Rail Rapid Transit
- Aerial solutions
  - Aerial Tram/Reversible Ropeway
  - Gondola (Monocable/2S/3S)
  - Funitel

Alternatives were evaluated against a broad range of criteria and classified under the primary accounts described in the Purpose and Need Report, namely:

- Financial
- Transportation
- Environmental
- Urban Development
- Economic Development
- Social/Community
- Deliverability

Based on screening-level analysis, ground-based transit solutions were excluded from consideration based on the following:

- Technical infeasibility due to standard performance requirements such as maximum grades and minimum turning radii being exceeded; and,

- Significantly higher economic and environmental costs of obtaining right-of-way compared to other options.

The diesel base case and trolleybus alternative have challenges in meeting capacity in an efficient manner.

The aerial solutions are compared in greater detail, with the 3S and Funitel systems identified as the preferred candidates for best achieving the evaluation criteria.

With the technology family identified, prospective alignments were evaluated, including routes starting at the existing Lake City Way and Production Way – University SkyTrain stations, as well as at the future Burquitlam Station on the Evergreen Line. A direct route from Production Way – University SkyTrain Station to the SFU Bus Exchange emerged as the one that best meets the following objectives:

- Minimize conservation area impacts;
- Minimize neighbourhood impacts;
- Minimize length of route – (reduce cost and travel time, avoiding kinked alignments);
- Minimize specific impacts of tower locations; and,
- Maximize transit integration – with SkyTrain and SFU/UniverCity.

ACRONYMS AND ABBREVIATIONS

BAU	business as usual
BRT	Bus Rapid Transit
CAC	criteria air contaminant
CMBC	Coast Mountain Bus Company
CNG	compressed natural gas
FTN	Frequent Transit Network
GHG	greenhouse gas
GLT	Guided Light Transit
ha	hectare(s)
IFS	Initial Feasibility Study
km	kilometre(s)
km^2	square kilometre(s)
LID	Low Impact Development
LIM	linear induction motor
LRT	Light Rail Transit
m	metre(s)
m^2	square metre(s)
O&M	operations and maintenance
OCP	Official Community Plan
pphpd	passengers per hour per direction
PRT	Personal Rapid Transit
PTP	Provincial Transit Plan
RGS	Regional Growth Strategy
ROW	right-of-way
RRT	Rail Rapid Transit
RTD	Regional Transportation District
SCBCTA	South Coast British Columbia Transportation Act

SFU	Simon Fraser University
TCQSM	Transit Capacity and Quality of Service Manual
TRB	Transportation Research Board
TSP	transit signal priority

1. INTRODUCTION

Forecast growth of both the Simon Fraser University (SFU) campus and UniverCity neighbourhood on Burnaby Mountain will increase transit demand in 2021 and 2041, beyond the peak capacities that can be met by frequent bus service. This increasing demand indicates the need to review alternative technologies to meet the future requirements, particularly given the unique topographical challenges imposed by the mountain-top location of the campus and neighbourhood.

Higher level policies need to be taken into account when reviewing potential solutions for addressing the transit needs of Burnaby Mountain to ensure that any actions are consistent with overall goals. The Provincial Climate Action Program and Transit Plan have set aggressive targets in terms of reductions in emissions and gains in transit mode share. TransLink has adopted these targets and has further formulated strategies to achieve these – as well as supporting goals – in its Transport 2040 planning process.

The consideration of alternative transit solutions for Burnaby Mountain speaks directly to three of the strategies outlined in Transport 2040:

- Make early investments that encourage development of communities designed for transit, cycling, and walking (SFU and UniverCity are good examples of this community type)
- Optimize the use of the region's transportation assets and keep them in good repair (through potential reallocation of diesel bus service to areas with gentler grades and an overall reduction in transit operating costs for serving the mountain)
- Build and operate a safe, secure, and accessible transportation system

The region's SkyTrain rapid transit network is closest to the mountain at the Production Way – University Station of the Millennium Line, located approximately 2.7 km from the mountain's current transit hub. The next station to the west, at Lake City Way, is only slightly farther from the mountain. The Evergreen Line will have a station at Burquitlam, also a similar distance from the transit hub. The Business Case focuses on alternatives linking one of these three stations to the transit hub with a higher-order transit system.

This report summarizes the findings of the Review of Alternatives for the Burnaby Mountain Gondola Transit Business Case.

2. PURPOSE

The purpose of this report is to document the findings of the Review of Alternatives for the Burnaby Mountain Gondola Transit Business Case. It expands upon the transit alternatives assessment discussed in the SFU Community Trust's Initial Feasibility Study (IFS). The intent of this exercise is to narrow the transit technologies to be considered in Phase 2 – Design for Indicative Costing, by screening out technically infeasible and/or cost prohibitive alternatives.

The report includes the following sections:

- Physical Constraints
- Review of Existing Transit Service
- Overview of Transit Solutions
- Secondary Screening
- Alternative Alignment Assessment
- Technology and Alignment Conclusion

3. Physical Constraints

There are a number of physical conditions that place constraints on potential transit solutions.

3.1 Road Network

The road network serving Burnaby Mountain is shown in the map below.

Exhibit 3-1 – Road Network within Study Area

Road access to SFU is limited to Hastings Street/Burnaby Mountain Parkway from the west and Gaglardi Way from the south. These two routes intersect with University Drive East to form the primary access point to the campus. From this intersection, traffic can travel on University Drive East to enter either the eastern or western/northern sides of the campus.

Just east of Duthie Avenue, Hastings Street becomes Burnaby Mountain Parkway and provides access to the SFU campus for traffic originating from northern Burnaby and Vancouver. Between Duthie Avenue and Gaglardi Way, the route has an overall elevation change of approximately 240 m and experiences grades of 6.5 to 7 percent over an approximate length of 2.2 km.

Gaglardi Way is the primary route used by traffic originating from the regions to the south and east of Burnaby Mountain. A major component of the traffic using this route is coming from Highway 1 via the Gaglardi Way interchange. Between the Lougheed Highway/ Gaglardi Way intersection and the Burnaby Mountain Parkway/Gaglardi Way Intersection, there is an approximate elevation change of 330 m. The first section of this route, between Lougheed Highway and the intersection of Gaglardi Way and Broadway (which becomes Como Lake Avenue to the east of North Road), is approximately 1.7 km long and experiences grades of 1.5 to 3 percent. The second section, between Broadway and Burnaby Mountain Parkway, is approximately 2.7 km long and has a continuous grade of approximately 7.5 percent.

From the Gaglardi Way/Burnaby Mountain Parkway intersection, traffic can travel eastbound along University Drive East for approximately 1.7 km to reach the eastern access of the SFU campus. The average grades along this route are 7 percent. As an alternative, traffic can travel northbound on University Drive East for approximately 1.3 km to enter the western/ northern side of the campus. The average grades along this route are approximately 6 percent.

3.2 Surrounding Land Uses

Near the Production Way – University Station (the nearest SkyTrain station to the mountain): the areas adjacent to the Millennium Line are zoned for industrial and commercial use and are part of Burnaby's Lake City business centre area. This area is characterized by low- to mid-rise warehouse-type and commercial buildings.

North of the business centre area, the zoning transitions to primarily residential use, featuring attached housing in the Forest Grove neighbourhood.

The Lake City Way Station area is also generally zoned for industrial and commercial use as part of the Lake City business centre. Charles Rummel Park lies immediately south, across Lougheed Highway, from the station. Petroleum product tank farms begin about 850 m upslope of the station.

Near the future Burquitlam Station, the area fronting on to Clarke Road is zoned for commercial use. Further northwest the zoning transitions to residential use, primarily in the form of detached homes.

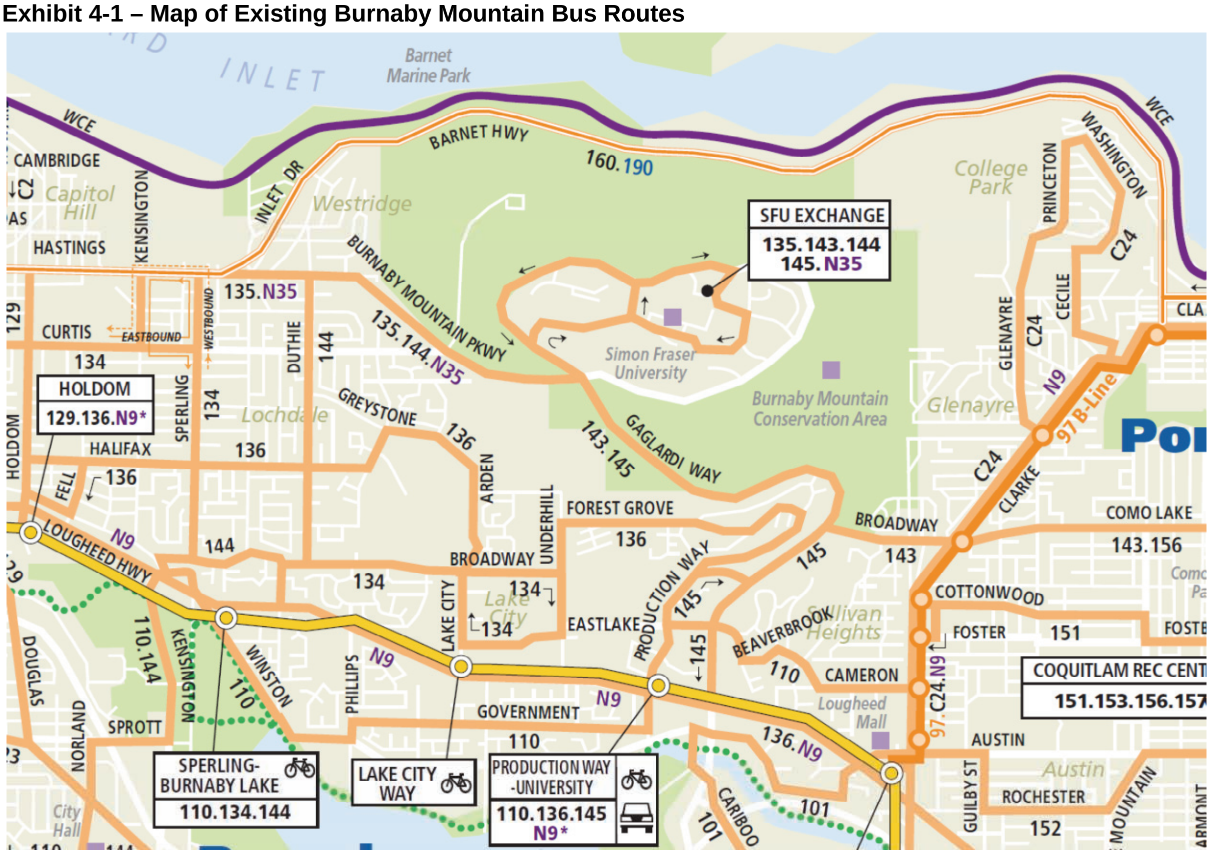
The green zone surrounding SFU and UniverCity is classified as the Burnaby Mountain Conservation Area. This area includes various tributaries and creeks of environmental significance as well as an extensive trail network that is well used by hikers and mountain bikers.

4. REVIEW OF EXISTING TRANSIT SERVICE

Existing transit service to Burnaby Mountain consists of four bus routes: 135, 143, 144, and 145. Of those four routes, route 145 is most directly linked to the current rapid transit network, via the Millennium Line. All four routes follow a figure-eight routing on the mountain, first arriving at the SFU Transportation Centre at the west end of the academic campus. They then continue to the terminus at the SFU Bus Exchange, where layover and recovery time are taken at the eastern edge of the academic campus and adjacent the western end of UniverCity. A straight-line distance of 550 m separates the Transportation Centre and the Bus Exchange. Buses then leave the Bus Exchange, serve the south-eastern edge of the campus, pass through the Transportation Centre, then serve the extreme west end of the campus, where most student residences are located, before proceeding off the mountain.

This section presents a brief description of each route, as well as a breakdown of the relative proportion of Burnaby Mountain ridership served. An excerpt of the regional transit map below illustrates the routes described.

Exhibit 4-1 – Map of Existing Burnaby Mountain Bus Routes



4.1 Existing Bus Routes

- Bus route 145, the busiest transit route serving Burnaby Mountain, links the SFU Bus Exchange to the Production Way – University SkyTrain Station on the Millennium Line and carries half of the transit commuters to and from the mountain. The route from SkyTrain to the Bus Exchange is approximately 7.1 km, vs. a straight-line distance of 2.7 km. Travel time varies by time of day and passenger volume but 15 minutes is typical. This route is typically operated with articulated buses.
- The second-highest ridership bus, route 135, carries commuters to and from downtown Vancouver along Hastings Street. This route requires over twice as many buses as route 145 at peak hours due to the much longer travel time from downtown, though ridership to SFU is half that of route 145. Much of the service provision on this route is driven by the downtown-related demand at the western end of the route. This route is typically operated with articulated buses.
- Bus route 144 travels from Metrotown Station to the Sperling – Burnaby Lake SkyTrain Station on the Millennium Line in 26 minutes and then continues to the SFU Bus Exchange in an additional 19 minutes. The low passenger loads of route 144, with less than one-tenth of the total ridership to and from Burnaby Mountain, can be explained by the fact that the commuting time from Metrotown to Production Way via SkyTrain and then by bus to the SFU Bus Exchange is a shorter duration. As a result, route 144 ridership is likely limited to passengers accessing mid-route at local stops away from a SkyTrain station. However, crowding on the 145 may lead some passengers to divert to the 144, despite its lower frequency and longer travel time. This route is operated with standard buses.
- Route 143 from Coquitlam Station is the only direct transit service to and from Burnaby Mountain for the Tri-cities region (Coquitlam, Port Coquitlam, and Port Moody). This route, a 35-minute bus trip at peak times, will eventually be partially replaced by the Evergreen Line extension, with the plan being for a revised 145 to be extended to Burquitlam Station from the SFU Bus Exchange, leaving the 143 as a local route along Como Lake Avenue between Coquitlam Centre and Burquitlam. This route is typically operated with a mix of standard and articulated buses.

4.1.1 Proportion of Service

The current alternatives assessment focuses on the key linkage to Burnaby Mountain, namely bus route 145 which carries half of the daily ridership. The following table shows the ridership of each bus route serving the mountain, the share of total transit trips to and from the mountain that it accounts for, the share of riders using that route that are related to mountain trips (i.e., the number of daily riders on that route travelling to and from the mountain divided by the route’s total boardings), and the number of buses assigned to each route. The data shown is for fall 2009; preliminary fall 2010 data show little change in the figures.

Exhibit 4-2 – Current (2009) Bus Ridership on Burnaby Mountain Routes

Bus Route	Origin: to/from SFU	Share of Transit Trips to/from SFU	Route Daily Ridership	Share of Route Riders Related to SFU	Current Peak Bus Allocation
135	Burrard Station (via Hastings Street)	27%	21,900	31%	22
143	Coquitlam Station	12%	4,500	69%	6
144	Metrotown Station	10%	6,600	39%	10
145	Production Way – University Station	50%	13,300	95%	10

4.2 Capacity Requirements

A number of travel demand model runs have been conducted to forecast ridership demand to Burnaby Mountain. The findings to date are summarized in Tables 4.2 and 4.3 below. In order to determine the demand for rapid transit, the model runs assumed similar operating characteristics as the gondola described in the conclusions of the IFS, in other words, a non-stop connection between Production Way – University Station and the SFU Bus exchange. This establishes the level of demand that the technology solutions should have the capacity to meet but allows for the analysis to be repeated should the assessment suggest a different technology/alignment combination with differing performance characteristics should also be examined.

For modelling purposes, the rapid transit link was assumed to operate with a vehicle departing every 34 seconds and offer a one-way travel time of 7 minutes. Bus service levels in the model were kept at a very high level to assess the maximum bus service demand that might remain following introduction of a rapid transit link. The bus service levels in the scenarios with the Evergreen Line were based on the bus integration plan for the Evergreen Line and therefore assume that route 145 is extended to operate between Production Way and Burquitlam stations, via SFU, replacing the 143 between SFU and Burquitlam. Ridership forecasts include the horizon years 2021 and 2041. The basis of comparison in each scenario is defined as a Business as Usual (BAU) scenario and represents the anticipated transit service if buses remain the key transit service serving Burnaby Mountain.

The findings indicate the following:

- The observed diversion from BAU bus service to gondola is significant, with over 80% of Burnaby Mountain transit trips expected to use the rapid transit link
- The peak hour volumes are generally consistent with the expected volumes described in the IFS
- The overall diversion of bus ridership to the rapid transit link is considered to be conservative, since the frequency of competing bus service has not been optimized in order to illustrate the effectiveness of rapid transit relative to intense parallel bus service
- Demand for the rapid transit link is only slightly lower in the absence of the Evergreen Line, with peak rapid transit volumes in 2041 without the Evergreen Line being 92% of those with the Evergreen Line

The preliminary findings from the model runs (with Evergreen Line) were used to define the required system capacity: that is, 2021 peak requires 2,900 passengers per hour per direction (pphpd) and 2041 peak requires 3,400 pphpd. Note that the peak AM hour load figures in the tables are for the peak location, wherever it occurs on the route. For the 135 this location is close to downtown Vancouver, so the service requirements are driven by that end of the route and not by Burnaby Mountain demand.

The model results suggest that implementation of a gondola (or other rapid transit technology with similar travel time and frequency) between Production Way – University Station and Burnaby Mountain would allow the elimination of route 145 in all with rapid transit scenarios given the small demand that remains for it. The local stops served by the 145 near Production Way – University Station are also served by routes 110 and 136 and these would continue. (Customers using the sole unique 145 stop at NB Gaglardi at Broadway (near Centaurus Circle) would be required to walk to route 136 stops on Forest Grove Drive or route 110 stops on Eastlake. The affected area would still be largely within 400 m of transit service at these stops.) Route 144 between Sperling – Burnaby Lake Station and Burnaby Mountain would also continue in order to maintain a direct service to Burnaby Mountain from the residential area south of Hastings, to provide local service on the Burnaby Mountain summit plateau, and to provide an alternative to the gondola for passengers who have concerns about riding it.

The without Evergreen Line scenarios show a modest reduction in demand for the 143 to SFU but this is not sufficient to assume that it can be removed, as a scenario that did remove it showed a reduction in travel time benefits. Consequently, the study has assumed retention of the 143 when evaluating the without Evergreen Line scenarios.

4.3 Travel Time and Transit Service Requirements

A key objective of any rapid transit system is a reduction in travel time to and from desired destinations. For this reason, an adequate solution is one that has a travel time that is no longer than the existing bus connection between SFU and the Production Way – University SkyTrain Station, currently 13-16 minutes via route 145.

A relatively unique factor in providing transit service to Burnaby Mountain is the comparatively severe winter weather experienced on the mountain. The mountain experiences snowfalls more often than other key destinations and the road network serving it is particularly susceptible to disruption in these conditions due to its exposure and grades. Transit service to the mountain is estimated to be affected to varying degrees 10 days every winter. This can range from substitution of standard buses for articulated buses, due to the poor handling of the latter in slippery road conditions, to a complete curtailment of transit service due to poor conditions and blockage of the roads by stuck vehicles.

Exhibit 4-3 – Ridership Forecasts with Evergreen Line

			BAU (Without Gondola)				With Gondola			
Year	Route	Service	Peak Headway (min)	AM Peak Hour Boardings	Estimated Daily Boardings	Peak Volume (pphpd)	Peak Headway (min)	AM Peak Hour Boardings	Estimated Daily Boardings	Peak Volume (pphpd)
2021	135	SFU – Downtown	4.0	2,081	24,200	946	4.0	1,420	16,500	421
	144	Metrotown Stn – SFU	10.5	1,119	13,000	293	10.5	1,079	12,600	293
	145EG	Production Stn – SFU – Burquitlam Stn	3.0	2,045	23,800	1,049	3.0	78	900	48
	BMGT	Burnaby Mtn Gondola	n/a	n/a	n/a	n/a	0.6	3,255	37,900	2,844
2041	135	SFU – Downtown	3.0	2,379	27,700	988	3.0	2,124	24,700	558
	144	Metrotown Stn – SFU	8.0	1,620	18,900	492	8.0	1,598	18,600	492
	145EG	Production Stn – SFU – Burquitlam Stn	2.5	2,657	31,000	1,282	2.5	107	1,200	60
	BMGT	Burnaby Mtn Gondola	n/a	n/a	n/a	n/a	0.6	4,174	48,600	3,341

pphpd: passengers per hour per direction

Exhibit 4-4 – Ridership Forecasts without Evergreen Line

			BAU (Without Gondola)				With Gondola			
Year	Route	Service	Peak Headway (min)	AM Peak Hour Boardings	Estimated Daily Boardings	Peak Volume (pphpd)	Peak Headway (min)	AM Peak Hour Boardings	Estimated Daily Boardings	Peak Volume (pphpd)
2021	135	SFU – Downtown	4.0	2,070	24,100	891	4.0	1,440	16,800	437
	143	Coquitlam – SFU	8.0	578	6,700	373	8.0	441	5,100	344
	144	Metrotown Stn – SFU	10.5	1,139	13,300	286	10.5	1,080	12,600	287
	145	Production Stn – SFU	3.0	1,594	18,600	1,462	3.0	3	0	2
	BMGT	Burnaby Mtn Gondola	n/a	n/a	n/a	n/a	0.6	3,129	36,500	2,625
2041	135	SFU – Downtown	3.0	2,487	29,000	941	3.0	1,833	21,400	608
	143	Coquitlam – SFU	7.0	715	8,300	412	7.0	482	5,600	356
	144	Metrotown Stn – SFU	8.0	1,698	19,800	483	8.0	1,591	18,500	485
	145	Production Stn – SFU	2.5	1,983	23,100	1,709	2.5	5	100	4
	BMGT	Burnaby Mtn Gondola	n/a	n/a	n/a	n/a	0.6	4,020	46,800	3,062

pphpd: passengers per hour per direction

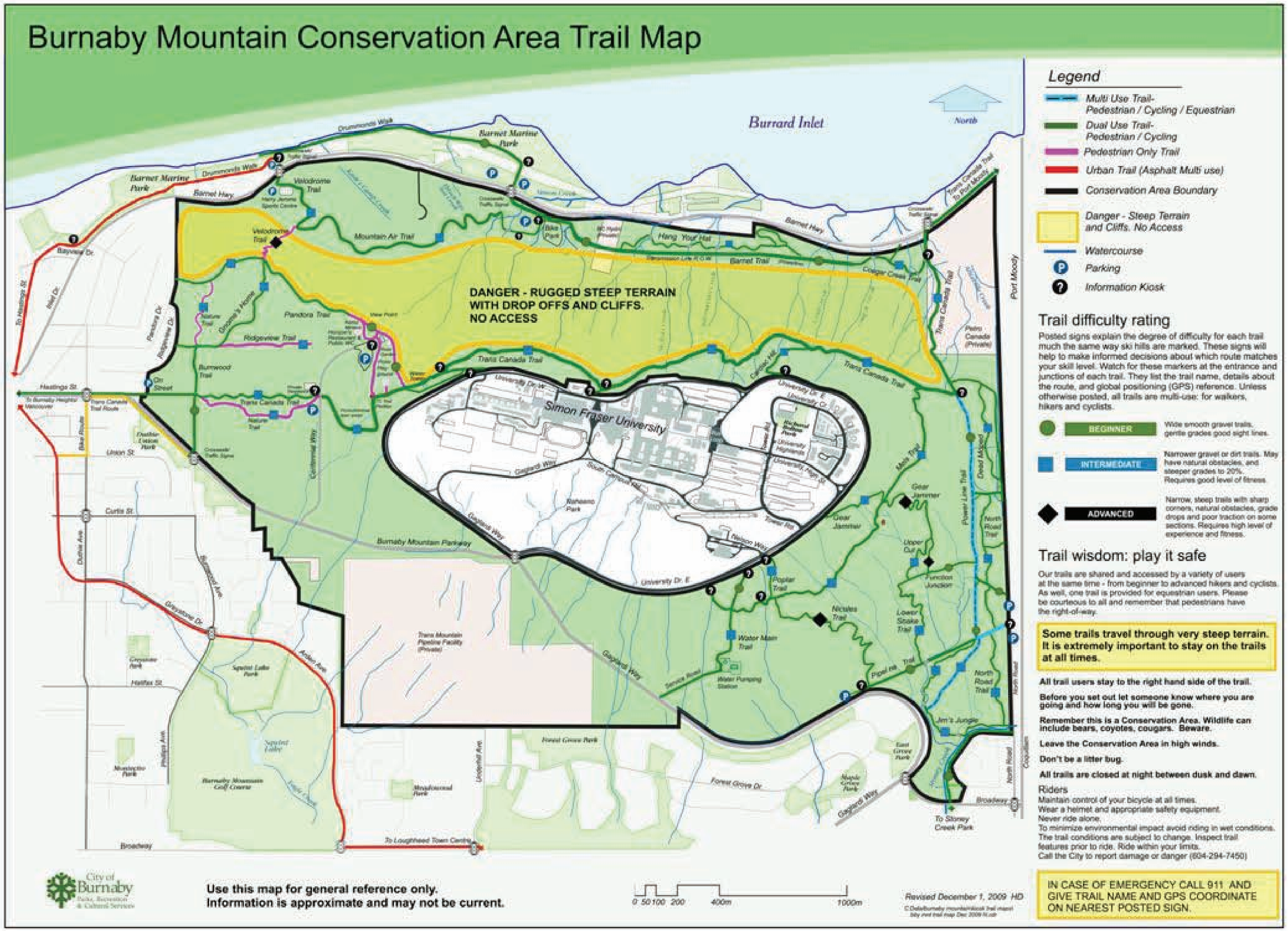
4.4 Multi-Modality

The following extract from the City of Burnaby's Cycling Map shows a mix of shared vehicle/bicycle roadways and urban trails in the vicinity of Burnaby Mountain. Use of the current system for commuting to SFU is limited due to the steep grades. Recreational use of the trail network on Burnaby Mountain, as shown in the second map, by mountain bikers is high. Many recreational downhill cyclists are observed using bus bike racks to ascend the mountain.

Improved multi-modal accessibility of the transit system could increase ridership for bicycle commuters and recreational riders alike.

Exhibit 4-5 – Shared Vehicle/Bicycle Roadways and Trails

Exhibit 4-6 – Burnaby Mountain Conservation Area Trail Map



5. Overview of Transit Solutions

This section provides high level commentary and initial screening of the potential transit solutions for Burnaby Mountain. Included are descriptions of the base case, i.e., the current service provided by diesel buses, ground-based transit, and aerial solutions. It must be noted that all the assessments are relative to this application, its constraints, and the range of other technologies being examined. Other studies reviewing the same technologies in other corridors could reach different conclusions depending on local conditions.

At this stage, a primary screening phase is used to filter out alternatives that are not technically viable. Alternatives that appear viable proceed to the Secondary Screening for evaluation in greater detail

The evaluation is done on a primarily qualitative basis, with select criteria being quantified or monetized where possible. The results of the comparison are summarized in a structured format to facilitate understanding and decision-making.

5.1 Primary Screening Evaluation Criteria

The primary screening phase is intended to exclude technically infeasible solutions from further consideration. The alternatives are rated against the following pass/fail criteria:

Travel Time

The travel time to commute between Production Way - University Station and the SFU Bus Exchange on a diesel bus along route 145, i.e. the base case, is 15 minutes excluding boarding and alighting times. Does the alternative offer travel time savings, or at least equal performance compared to the base case? Any alternative that takes longer than 15 minutes will fail this test.

Operating Limit

Does the expected alignment/operation of a particular alternative fall within the operating parameters of that technology? This test accounts for factors such as maximum allowable grade, minimum allowable turning radius, and passenger capacity.

Surface Impact

Are the topographic, property and/or environmental impacts of the alternative too great to overcome; that is, without provision of prohibitively costly mitigation measures?

5.2 Base Case – Diesel Bus

Exhibit 5-1 – Articulated Diesel Bus Serving SFU

Diesel buses are the workhorses of TransLink's fleet, and they have served Burnaby Mountain for decades. However, current demand and forecast growth put pressure on this system which is already over capacity on certain routes, namely 145, as evidenced by queuing and pass-ups during peak periods.

The 60 foot diesel buses currently used on the 145 are capable of carrying approximately 1,700 passengers per hour during peak periods, at a headway of approximately 3 minutes (17 trips/hour currently scheduled). The peak capacity is insufficient to meet the projected demands in 2021 and 2041. The capacity for this route could be improved by increasing the frequency during peak periods, following a BRT model.

Further study is required to determine the necessary reduction in headway. However, when factoring in boarding/alighting time, it is possible that buses may need to run without layover and with minimal recovery time during peak periods. The increased cost and complexity of operating in this fashion, combined with the socio-economic impacts on residents and the local environment demonstrates the need to review other, higher capacity technologies.

Other issues associated with diesel buses for Burnaby Mountain include:

- Diesel drive is not well not suited for hilly terrain with high passenger volumes, especially in winter conditions.
- Traffic impacts and noise would be exacerbated if operating at increased frequencies.
- Diesel propulsion is associated with greenhouse gas (GHG) and criteria air contaminants (CAC).

- Diesel is a non-renewable, fossil fuel resource that is subject to future supply scarcity and price volatility. Since a large portion of TransLink's fleet is dependent on diesel as a mobile fuel source, it would be prudent to explore alternatives to diesel in this setting.
- Scheduling and driver requirements with very frequent bus service result in a need for extensive layover/recovery facilities, which are land extensive and costly to provide in urban settings.
- Operating costs are largely directly proportional to the capacity of service provided, particularly when articulated buses are already employed.

While it may be technically feasible to meet capacity demands using diesel buses, the associated problems and costs of doing so call for consideration of alternative high-capacity systems.

5.3 Ground-Based Solutions

The following subsections describe ground-based transit alternatives. Alternatives that are technically infeasible are screened out from further consideration. All ground-based solutions, unless they are completely grade-separated, are subject to roadway congestion. By nature, ground-based alternatives would require additional property for their rights-of-way, increasing property requirements and affecting the conservation area. Although transit signal priority measures could be implemented to reduce travel times on existing roads, there are relatively few signals on the route, thus limiting the potential benefits.

5.3.1 BRT – Trolleybus

Exhibit 5-2 – TransLink Articulated Electric Trolleybus

Benefits

Trolleybuses offer broad environmental benefits including: elimination of diesel fuel consumption, reduction in both GHG and CAC emissions, longer vehicle life, better ride quality, as well as decreases in internal and external noise. Fuel switching from a fossil fuel (diesel) to renewable, hydroelectric power provides advantages in terms of system resilience and risk mitigation, though increasing electricity demand needs to be evaluated in concert with BC Hydro.

In 2006-2008, TransLink replaced its aging trolleybus fleet with new state of the art trolleybuses. This reaffirmed that trolleybuses are a proven transit solution in the Lower Mainland, particularly for hilly terrain applications with high passenger volumes, where the electric drive provides more torque than a conventional diesel engine allowing better acceleration and higher speeds.

Drawbacks

Trolleybuses would encounter the same capacity-related problems as diesel buses. There may be opposition to the installation of trolley wires both leading up to Burnaby Mountain as well as to provide routing between Production Way and the nearest transit depot.

Provision of redundant switching and higher maintenance requirements for the wires are also potential drawbacks. While trolleybuses are better suited to hilly terrain, the higher altitudes near the top of Burnaby Mountain are susceptible to heavier snowfall and thus excellent traction is required to maintain service. Driving the second and third axles of articulated trolleybuses is possible as a means to increase traction but they would still be susceptible to disruption from other traffic. Accumulation of frost and ice on the trolley wires prevents a good electrical contact being made and would be a common occurrence given the elevation.

Conclusion

Using trolleybuses to serve Burnaby Mountain yields the environmental benefits of fuel switching from diesel to electricity, e.g., reduced GHG, CAC, noise, etc. However, trolleybuses face the same capacity constraints as the base case, while offering little reduction in travel time. The community challenge of installing trolley wires, accommodating layover requirements, and operations and maintenance issues due to frost/ ice on trolley wires also limit the ability of trolleybuses to be the most effective alternative relative to others. Since the trolleybus alternative does not offer many advantages over the base case, it is not retained for further evaluation.

5.3.2 Light Rail Transit (LRT)

Exhibit 5-3 – LRT Train in Paris

Benefits

LRT has higher capacity than buses (up to 15,000 pphpd). Since LRT systems feature embedded rails, they hold a subjective advantage over buses in terms of signalling a degree of permanence to the development community and to discretionary riders.

LRT would carry similar benefits of fuel switching as the trolleybus alternative. The operating speed (and travel time) would be similar to current traffic, although the introduction of transit signal priority could result in a moderate improvement in travel time.

Similar to buses, LRT is driver operated.

Drawbacks

It is assumed that LRT would be operated within a dedicated right-of-way alongside existing traffic. Property easements or full takes may be required along the route. Widening of the right-of-way would also impinge on the Burnaby Mountain Conservation Area.

LRT systems are typically powered from an overhead wire. This would have similar issues as described previously for trolley wires.

Road grades along Hastings Street and Gaglardi Way range from 7% to 9%, which exceeds the recommended 6% operating parameter of typical LRT systems. Though the mechanical systems can ascend steeper grades, there are consequent operational issues that would increase long-term costs, particularly in light of snow conditions. Downhill speeds would need careful regulation given the limited adhesion and extended stopping distances. Given the grades, the LRT route would be no shorter than the exiting bus route, suggesting little gain in travel time would be possible.

Looking specifically at the roadway alignments of Gaglardi Way and University Drive East, the hairpin curves are not ideal for LRT operations, i.e. curves can be negotiated, but would require operating at reduced speeds.

Conclusion

LRT would push beyond typically acceptable operational ranges, and would not garner measurable benefits in terms of travel time. It is recommended that LRT be omitted from further consideration.

5.3.3 Guided Light Transit (GLT)

Benefits

Several proprietary systems of this type exist but all are rubber-tired and use a track for guidance. Rubber tires allow it to go up steeper grades than LRT, and allow vehicles to travel off of the embedded guide track when needed, offering greater system flexibility. Capacity is slightly less than articulated LRT vehicles (less than 15,000 pphpd).

GLT was at one time considered for the Evergreen Line. The following is an excerpt from the Northeast Sector Rapid Transit Alternatives Project – Phase 2 – Evaluation of Rapid Transit Alternatives Study:

> The guided light transit vehicle is similar to a shorter version of the articulated LRT vehicle, has similar multiple-door configuration, but operates on rubber tires. As such, the GLT operates on paved roadways, either in mixed traffic or in a separate right-of-way. The guidance systems are either optical magnetic or mechanical. They permit operators to dock at stations with small clearances to platforms, reducing boarding time, and to drive at higher speeds within narrower rights-of-way than bus vehicles. The GLT is normally diesel powered, but could also have electric motors and obtain power from overhead power lines, or could be dual, diesel and electric powered for on-line and off-line operation. GLT vehicles can carry approximately 100 passengers each and cost approximately $2 million per vehicle or $20,000 per passenger.

Drawbacks

Other installations have encountered mechanical problems, guidance issues, and wheel rutting in pavement. These operations and maintenance issues have deterred wide adoption of this technology. A GLT alignment to SFU would require a separate alignment protected from other traffic, imposing its own snow removal issues as well as property requirements and environmental concerns.

Conclusion

GLT can operate on steeper grades, but carries the same disadvantages outlined for LRT. It is recommended that GLT be omitted from further consideration.

5.3.4 Funicular

Exhibit 5-4 – Funicular (Hungerbergbahn) in Innsbruck, Austria

Benefits

Funiculars use railway cars that are connected to each other by a cable looped around the upper station of the route, allowing one car to ascend while the other descends. Some systems use a single car with a counter-weight replacing the second car. They are ideal for constant steep grades and can contain horizontal curves in their alignment. Generally, a single track is used for the majority of the route, with a double track at the mid-point to allow for passing of the two cars. Because they operate at ground level and do not rely on wheel/rail adhesion for traction, funiculars can operate in all weather conditions if the tracks are cleared.

Drawbacks

Funiculars require land for their track, which poses a problem since there is no obvious right-of-way that can be followed to reach the SFU Bus Exchange. Any direct or indirect route would have significant impacts to existing development, Gaglardi Way, and the Burnaby Mountain Conservation Area, and carry with it commensurate capital costs. Another disadvantage of a funicular occurs when the grade varies along the route, which results in the funicular floor not remaining level unless special measures are taken, such as cabins on gimbals, adding complexity and cost and reducing capacity.

Since funiculars employ two cabins running in opposition, the potential frequency and thus capacity is a direct function of the route length and speed – the longer the route, the lower the capacity that can be provided. The route to Burnaby Mountain is too long for a funicular providing the required capacity. At the typical speed of 25 km/h over 2.7 km, the round trip cycle would be about 10 minutes. Assuming the maximum precedent car capacity of 400 passengers, this would result in a capacity of 2,400 pphpd, which is below the projected demand in 2021. The potential headway of a departure every 10 minutes would also be a significant drawback, providing lower frequency than the bus in the base case.

Conclusion

The absence of an obvious constant grade right-of-way, the long route length of more available rights-of-way, and the large land impacts and resulting costs offset the benefits of this technology for a Burnaby Mountain application. The capacity that can be provided is also below anticipated demand so funiculars are excluded from further consideration.

5.3.5 Rack Railway

Exhibit 5-5 – Rack-equipped Metro Line in Lyon, France

Benefits

Rack railways are rail systems that ascend steep grades using a rack and pinion system for traction power. With this form of traction they can climb much steeper grades than standard railways though speeds are limited. If right-of-ways were available, a rack railway could ascend directly up Burnaby Mountain. A rack railway would have the ability to operate more frequent service than a funicular, since more than two trains could be operated simultaneously.

Drawbacks

A rack railway would need more right-of-way than a funicular since more of the line would need to be double-tracked to allow operating flexibility but no suitable right-of-ways exist.

Additionally, the cars/trains would be relatively large suggesting that significantly less frequent, and thus less attractive, service than offered by buses would be provided.

Conclusion

Rack railways are excluded from further consideration due to the lack of suitable right-of-ways up Burnaby Mountain (as with the funicular system).

5.3.6 Rail Rapid Transit (SkyTrain)

Exhibit 5-6 – SkyTrain near Main Street – Science World Station

Benefits

SkyTrain is a proven technology in the region, and forms the backbone of TransLink's rapid transit system. The SkyTrain network already operates within 2.7 km of the mountain.

Drawbacks

SkyTrain is not technically reasonable on this route given its operating grade limitation of 6%, high capital cost, environmental impacts (including a large number of columns that would need to be erected within the Burnaby Mountain Conservation Area), and difficult system integration, e.g., building switches to branch off the Millennium Line while maintaining service. The technology is also capable of providing vastly more capacity (25,000+ pphpd) than this application requires. A potential benefit of SkyTrain would be to have direct trains to Burnaby Mountain from elsewhere on the network but this would be challenging to integrate in an already complex network.

Conclusion

The drawbacks above preclude SkyTrain from further study.

5.3.7 Personal Rapid Transit (PRT)

Benefits

Personal rapid transit is based on small, automated vehicles operating on a dedicated network of guideways. The premise of these systems is that they can provide high frequency, on-demand service with a high degree of privacy given the small vehicles and, ideally, point-to-point service without intermediate stops. They are meant to function like a horizontal elevator and provide a level of service like that of a private automobile but as a public transit service. Relatively few PRT systems are in regular operation with the best known one being in Morgantown, West Virginia. New systems have recently opened in Masdar City, UAE; and a prototype as a parking shuttle at London’s Heathrow Airport.

Drawbacks

Very few PRT systems are in operation and all are unique so it is difficult to identify “typical” characteristics. PRT systems are optimally deployed where there is moderate demand among a group of origins and destinations, which is not the case for this higher volume, point-to-point application. The capacity required here is also approaching the limit of what has been identified as reasonable for many systems, and likely exceeds it. Further, PRT systems need alignments (typically elevated) that are independent of other traffic and so incur surface impacts, albeit these are intended to be a lower scale than for other ground-level technologies.

Conclusion

PRT is not considered suitable for this application as the ridership demand is higher than such systems are designed for and the point-to-point nature of demand would not play to PRT’s strengths.

5.3.8 Escalator

Benefits

Public escalators are commonly used to handle low-speed short-distance vertical transitions in urban areas. They are a familiar and proven technology.

Drawbacks

The distance from any possible escalator base terminal to the top of Burnaby Mountain would result in a route with a travel time three to four times longer than the current bus service, and with large land requirements and environmental effects.

Conclusion

Escalators offer non-competitive travel times and high surface impacts and so are excluded from further study.

5.3.9 Ground-based Conclusions

Exhibit 5-7 summarizes key capabilities of the ground-based systems. None of the ground-based alternatives offer significant benefits with acceptable impacts relative to the base case.

Exhibit 5-7 – Table of Ground-Based Technologies Assessed

	Diesel Bus (artic)	Trolleybus (artic)	LRT	GLT	Funicular	Rack Railway	SkyTrain	PRT	Escalator
Typical Mode of Operation	Driver	Driver	Driver	Driver	Operator/ Attendant	Driver	Driverless	Driverless	Driverless
Level of Segregation	Mixed traffic	Mixed traffic	Priority/ Segregated	Priority/ Segregated	Fully Segregated	Fully Segregated	Fully Segregated	Fully Segregated	Fully Segregated
Land Requirements	Existing road network	Existing road network	Exclusive right-of-way	Exclusive right-of-way	Exclusive right-of-way	Exclusive right-of-way	Exclusive right-of-way	Exclusive right-of-way	Exclusive right-of-way
Maximum Gradient	12%	Up to 23%	10%	13%	128%	48%	6%	10%	60%
Capacity (passengers/ hour/direction)	2,400 (existing)	2,400	1,200 to 15,000	1,200 to 15,000	3,000 (depends on length)	1,200 to 15,000	25,000	1,000 to 7,000	1,000 to 3,500
Capacity per car (approx)	100	100	200 to 250	200 to 250	400	200 to 250	130	4 to 6	n/a
Accessibility	Ramp	Ramp	Level boarding	Level boarding or ramp	Potentially level boarding	Potentially level boarding	Level boarding	Level boarding	Level boarding
Depot Facilities	Off-line	Off-line	On-line	On-line	On-line	On-line	On-line	Off-line	Off-line
Maximum Speed	Posted speed	Posted speed	80+ km/h	80 km/h	50 km/h	25 km/h	90 km/h	50 km/h	1 to 2 km/h
Motive Power	Diesel/Hybrid	Electric	Electric	Diesel/Electric Hybrid	Electric	Electric or Diesel	Electric	Electric	Electric
Evacuation	Window/ self-rescue	Window/ self-rescue	Window/ self-rescue	Window/ self-rescue	Window/ self-rescue	Window/ self-rescue	Window/ self-rescue	Window/ self-rescue	Stairs
Safety/Security (all can have CCTV, intercoms)	Driver	Driver	Driver	Driver	Attendant	Driver	Attendant	Camera/ Attendant	Camera/ Attendant
Heating/Ventilation	Heating/AC	Heating/AC	Heating/AC	Heating/AC	Heating	Heating/AC	Heating/AC	Heating/AC	Weather protected
Vehicle Life	12 to 15 years	15 to 17 years	30+ years	15 to 17 years	30+ years	30+ years	30+ years		20 to 30 years

5.4 Aerial Transit Solutions

The following subsections provide details on potential aerial ropeway transit solutions. As opposed to ground-based transit, aerial transit is not affected by roadway conditions. As these are a closely related family of technologies, they are described individually but then assessed in detail in following sections.

5.4.1 Aerial Tram/Reversible Ropeway

Exhibit 5-8 – Portland (Oregon) Aerial Tram

Benefits

Aerial Trams, also known as Reversible Ropeways, include two passenger cabins that hang on one or two track ropes. A haul rope that passes through a drive system at one of the terminals connects the two cabins and pulls one cabin up while lowering the other. To complete the system, a counter rope is tensioned between both cabins and the opposite terminal. Functionally the system is very similar to a funicular, except that the aerial track ropes replace ground-mounted rails.

These tramways are capable of spanning great distances and can operate in extreme weather conditions, including periods of high winds, particularly if two track ropes are used. They are also highly reliable and can be used for applications requiring long operating hours and minimal downtime, something that would be a benefit to transporting people to and from Burnaby Mountain.

There are many aerial trams operating throughout the world for a wide range of applications. Local examples include the Portland Aerial Tram and Grouse Mountain Skyride.

Key features of aerial trams include:

- Large cabins that can carry up to 200 people,
- Potential system capacities up to 2,000 pphpd (governed by cabin size, speed and length),
- Current installations typically operate at capacities of 500 – 2,000 pphpd,
- Line speeds up to 35 km/h, and
- Large spans of several hundred metres between towers.

This is the only system where it is reasonable – due to limited numbers of cabins – to have an operator or attendant in the cabins.

Drawbacks

As with funiculars, the route under consideration is too long to allow an aerial tram to provide sufficient capacity, considering journey times and cabin capacity. The potential headway of a departure every 10 minutes would also be a significant drawback, providing lower frequency than the bus in the base case.

Conclusion

While an aerial tram would allow minimal surface impact, its lack of capacity and low frequency preclude it from further consideration.

5.4.2 Detachable Gondolas

Benefits

Gondolas consist of enclosed cabins that are connected to a circulating haul rope that provides propulsion and may also give vertical support. Unlike aerial trams where the haul rope moves in reversible directions, the gondola rope normally only moves in one direction. Most gondolas used today are detachable to allow for high line speeds while maintaining safe and easy loading and unloading. The cabins approach the terminal via the haul rope, then detach onto a conveyor system within the terminal. The conveyor operates at a lower speed than the haul rope and gently decelerates the cabins to speeds that are acceptable for loading and unloading. The cabins are then accelerated to match the speed of the haul rope before they are reattached to it. By providing a continually moving system, capacity and efficiency are increased. The current technology does not allow for gondolas to change direction (turn) part way through the system. In order to achieve this, two separate systems would have to be connected via a mid-point terminal located at the point of the desired direction change. A “through service” can be provided by passing cabins between the two systems but provision of a mid-point terminal would increase costs, increase surface impacts, and extend travel times.

A common feature of gondolas is that all stations are staffed to supervise loading and unloading and monitor system operation.

There are a number of different types of gondolas used today, all with varying key features. A brief description of some of the most commonly used gondolas and their features are provided in the following sections.

Monocable

Exhibit 5-9 – Whistler Village Gondola

A monocable gondola consists of cabins that are supported and propelled by a single cable. The use of a single cable results in smaller cabins, decreased tower spacing, and a low tolerance to winds. However, the footprint of each tower is also smaller. The Whistler Village Gondola is an example of a monocable system. Key features of monocable gondolas include:

- Cabin capacities of 4 to 15 persons
- Maximum system capacity of 3,600 pphpd
- Tower spacing of 100 to 200 m
- Tower footprint of 0.6 to 1.5 m diameter
- Stability and operational issues in winds of 80 km/h or greater

2S and 3S

Exhibit 5-10 – Whistler Peak 2 Peak 3S Gondola

The 2S and 3S (or Bicable and Tricable Ropeways) are gondola systems that combine features of a gondola type system and an aerial tram. The 2S is supported by one track cable and propelled by a second haul cable. The 3S is supported by two track cables and propelled by a third haul cable. Due to the distribution of loads between the supporting and hauling cables, 2S and 3S systems can have much longer spans than monocable systems, which allows for fewer towers but increases the overall footprint for each tower. The design of these systems also allows for increased wind stability. The Whistler Peak2Peak gondola is a local example of the 3S system.

Key features of 2S and 3S gondolas include:

- Cabin capacity of up to 15 persons for the 2S and 40 persons for the 3S
- Maximum potential system capacity of 3,500 and 6,000 p/h for the 2S and 3S systems, respectively
- Stability in winds up to 80 km/h for 2S and 110 km/h for 3S
- Tower spacing of 1,500 m and 3,000 m for 2S and 3S, respectively (dependent on the distance to ground and allowable sag)
- Tower footprint of 2 to 3 m diameter for 2S and 25 m square for 3S
- Maximum line speeds of 27 km/h

Funitel

A funitel gondola uses two parallel widely-spaced haul ropes to move the cabins to and from the terminals. Unlike the 2S and 3S systems, the haul ropes also provide the vertical support for each cabin. Funitel gondolas are capable of spanning much greater distances than that of monocable gondolas, though not as great as 2S and 3S systems, and due to the wide spacing of the haul cables, have excellent lateral stability during high winds.

Key features of funitel gondolas include:

- Wide haul rope spacing that provides increased stability
- Cabin carrying capacity of 20 to 30 persons
- Potential transport capacity of 3,200 to 4,000 pphpd
- Current systems operate at 1,500 to 3,000 pphpd with systems in Austria and the USA (Squaw Valley) claiming 4,000 pphpd
- Maximum line speed of 27 km/h, but not generally more than 22 km/h
- Tower spacing of 500 to 1,000 m
- Tower footprint of 2 to 3 m diameter 2
- Lateral stability in winds of up to 110 km/h

Drawbacks

While all the gondola technologies can provide the capacity needed for this application, each has some drawbacks of note. The monocable system is less weather-resistant and has smaller, less universally accessible cabins than the other types. Its capacity is likely adequate but the system would be at the upper end of its capabilities. It also has higher surface impacts since a high-capacity monocable system needs close tower spacing to support the haul cables.

The 2S and 3S systems allow progressively wider tower spacing but each tower becomes larger so there are fewer locations of surface impact but each one is larger. The 3S system is also relatively new, though there are precedent systems with a history of reliable operation and the technology is a development of the more established varieties.

Funitels are similar to the 3S system in many performance and design aspects but are mechanically more complex given the double-looping of the haul cable, to provide two cables for ascending gondolas and two for descending. This also increases energy use since the funitel’s cables must be large to provide both traction and support, while a 3S has separate, stationary track cables for support.

Conclusion

All of the detachable gondola variants offer the potential to improve on the transportation provision of the base case while also offering the potential for manageable surface impact/right-of-way requirements. As such, all are taken forward to the secondary screening.

5.4.3 Aerial Transit Conclusions

Aerial tram/reversible ropeway is the only form of aerial technology that does not meet the primary screening criteria, due to its low capacity for this application. The various forms of detachable gondolas all meet the criteria. Exhibit 5-11 summarizes key capabilities of the aerial systems.

Exhibit 5-11 – Table of Aerial Technologies Assessed

		Detachable Gondolas			
	Aerial Tram	**Monocable**	**2S**	**3S**	**Funitel**
Typical Mode of Operation	Operator/ Attendant	Terminal attendant	Terminal attendant	Terminal attendant	Terminal attendant
Level of Segregation	Fully Segregated	Fully Segregated	Fully Segregated	Fully Segregated	Fully Segregated
Tower Spacing (Maximum)	~2,000 m	100 to 200 m	1,500 m	3,000 m	1,000 m
Tower Height (Maximum)	85 m	90 m		70 m	
Land Requirements	Towers and stations	Towers and stations	Towers and stations	Towers and stations	Towers and stations
Maximum Gradient	100%	80%	100%	80%	80%
Potential Passenger Capacity (pphpd)	2,000 (depends on length)	3,600	3,500	Up to 6,000	Up to 4,000
Capacity per car (approximate)	Up to 200	4 to 15	4 to 15	20 to 40	20 to 30
Accessibility	Level boarding	Level boarding	Level boarding	Level boarding	Level boarding
Depot Facilities	On-line	On-line	On-line	On-line	On-line
Maximum Speed	35 km/h (10 m/s)	22 km/h (6 m/s)	22 km/h (6 m/s)	27 km/h (7.5 m/s)	22 km/h (6 m/s)
Motive Power	Electric	Electric	Electric	Electric	Electric
Evacuation	Winch/Vertical Rescue	Winch/Vertical Rescue	Winch/Vertical Rescue	Winch/Vertical Rescue	Winch/Vertical Rescue
Safety/Security (all can have CCTV, intercoms)	Attendant	Camera/ Stn Attendant	Camera/ Stn Attendant	Camera/ Stn Attendant	Camera/ Stn Attendant
Heating/Ventilation	Window	Window/Vents	Window/Vents	Window/Vents	Window/Vents
Vehicle Life	30+ years	30+ years	30+ years	30+ years	30+ years
Maximum Operation Wind Speed	80 km/h	80 km/h	80 km/h	110 km/h	110 km/h

5.5 Primary Screen Conclusions

Exhibit 5-12 summarizes the results of the primary screening.

Exhibit 5-12 – Results of Primary Screening

Primary Screening Criteria	Travel Time	Operating Limit	Surface Impact	Overall
Diesel Bus (Base Case)	–	–	–	–
Trolleybus	Fail	Pass	Pass	Fail
LRT	Fail	Fail	Fail	Fail
GLT	Pass	Fail	Fail	Fail
Funicular	Pass	Fail	Fail	Fail
Rack Railway	Pass	Pass	Fail	Fail
RRT (SkyTrain)	Fail	Fail	Fail	Fail
PRT	Fail	Pass	Fail	Fail
Escalator	Fail	Pass	Fail	Fail
Aerial Tram	Pass	Fail	Pass	Fail
Monocable/2S	Pass	Pass	Pass	Pass
3S/Funitel	Pass	Pass	Pass	Pass

6. SECONDARY SCREENING

The secondary screening phase captures the relative performance of the remaining alternatives. The accounts are intended to be comprehensive. Some subsets within each account are interrelated.

Financial Account

- Capital Cost – to be determined in Phase 2
- Operating Cost – to be determined in Phase 2

Transportation Account

- Travel Time – preference will be given to maximum reduction in travel time, typically associated with direct routes/alignments
- Capacity – ability to meet forecast travel demand and minimize queuing
- System Expandability – ability to expand capacity to meet future demand
- Extreme Weather Performance
  - Wind – aerial solutions most susceptible
  - Snow –ground-based solutions most susceptible
- Maintainability – Ease of maintenance
- Availability/Redundancy – Service provided while system/cabin are taken off-line for maintenance
- Downtime Impact – Provision of back-up service
- Multi-modality – Extent that the alternative supports other modes, especially active transport modes

Environmental Account

- Energy Consumption – Considers overall energy use, and source of energy (renewable versus non-renewable)
- GHG Reduction – Including source of GHG (point versus mobile source)
- CAC Reduction – Including source of CAC (point versus mobile source)
- Noise – Relative to baseline levels
- Hydrologic Impact – Consistency with high standards set by UniverCity Low Impact Development (LID) for maintaining pre-development hydrology
- Habitat Impact – Primarily impacts on Burnaby Mountain Conservation Area, and wildlife habitat

Urban Development Account

- Land Use Impact – Potential to positively or negatively impact adjacent land uses
- Urban Fit – Integration of transit infrastructure into surrounding community from urban design perspective

Economic Development Account

- Construction Impacts
- Economic Benefits

Social Account

- Accessibility – Ability of wheelchairs, strollers to access vehicle or cabin
- Public Safety – Ability to safely evacuate vehicle or cabin in the event of an emergency
- Security – Measures to enhance personal security
- Privacy – possible mitigation measures
- Property Requirements
- Recreation – Direct impacts on and accessibility to outdoor recreation areas, such as hiking and mountain biking areas.

Deliverability Account

- Alignment with Policy Objectives - Consider how well overall Transport 2040 goals are met
- Constructability – Physical feasibility of constructing subject to external constraints; design flexibility
- Funding

6.1 Evaluation Summary

The qualitative assessment of the transit modes is summarized in the attached tables. The discussion in this section highlights key differentiating features between the alternatives.

Exhibit 6-1 – Burnaby Mountain Gondola Transit – Alternative Technology Secondary Screening

Secondary Screening Criteria		Importance of Criterion	Diesel Bus (Base Case)		Monocable/2S		3S/Funitel	
			Rating	Comments	Rating	Comments	Rating	Comments
FINANCIAL	Capital Cost	High	○	Burnaby Mountain fleet primarily articulated diesel and hybrid bus (capital cost approximately $800k/bus)	◐	Higher capital costs for procurement of gondola system	◐	Higher capital costs for procurement of gondola system
	Operating Cost	High	○	Burnaby Mountain fleet operating cost premium ($125/hr). Subject to potential fuel price volatility	◐	Annual operating costs less than Base Case	◐	Annual operating cost less than Base Case. ($3.4M / yr refer to O&M Costs)
TRANSPORTATION	Travel Time	High	○	Current one-way travel time for Route 145 (Production Way-University Station to SFU Bus Exchange) is 13 to 16 minutes	●	Assuming direct routing, aerial solutions can cut travel time by 50%	●	Assuming direct routing, aerial solutions can cut travel time by 50%
	Capacity	High	○	Current capacity using articulated buses is 2,400 pphpd	●	Can meet future demand (up to 3,600 pphpd)	●	Can meet future demand (up to 6,000 pphpd)
	System Expandability	Medium	○	Demand can be partially met by increased frequency, but limited by bus exchange capacity	◐	Cabins can be added (closer spacing) to meet future demand as warranted	●	Cabins can be added (closer spacing) to meet future demand as warranted
	Wind Tolerance	Medium	n/a	n/a	◐	See Key Features table	●	See Key Features table
	Snow Tolerance	Medium	○	Transit service to Burnaby Mountain disrupted approximately 10 days each winter season due to road conditions	●	Aerial solutions can operate in snow conditions, and are not dependent on road network	●	Aerial solutions can operate in snow conditions, and are not dependent on road network
	Maintainability	High	○	Spare parts and maintenance expertise available locally	○	Local expertise with ropeways and suppliers have offices in BC. Cabins can be cycled offline with spares, but limited flexibility due to long operating hours	○	Local expertise with ropeways and suppliers have offices in BC. Cabins can be cycled offline with spares, but limited flexibility due to long operating hours
	Availability / Redundancy	High	○	Diesel buses could be pulled from alternate routes to serve peak demand	○	All options require diesel bus service as a backup in the event of unforeseen downtime	○	All options require diesel bus service as a backup in the event of unforeseen downtime
	Downtime Impact	High	○	Road closures (whether caused by accidents or adverse weather) will stop service	○	Aerial options unaffected by road closures. If roads open, diesel bus is back up when system is down (for maintenance or unexpectedly)	○	Aerial options unaffected by road closures. If roads open, diesel bus is back up when system is down (for maintenance or unexpectedly)
	Multi-modality	Medium	○	Burnaby Mountain fleet can accommodate two bicycles per bus	◐	Smaller cabins may limit capability to carry bicycles during peak periods	●	Larger cabins for 3S and Funitel increase capability to carry bicycles

Exhibit 6-1 – Burnaby Mountain Gondola Transit – Alternative Technology Secondary Screening

Secondary Screening Criteria		Importance of Criterion	Diesel Bus (Base Case)		Monocable/2S		3S/Funitel	
			Rating	Comments	Rating	Comments	Rating	Comments
ENVIRONMENTAL	Energy Consumption	Medium	○	Buses run on non-renewable fuel source. Diesel drive not ideal for long, steep grades	●	More efficient to move lighter cabins, ascending cabins and cable balanced by descending	●	More efficient to move lighter cabins, ascending cabins and cable balanced by descending, 3S more energy efficient than Funitel
	GHG Reduction	Medium	○	GHG emissions related to combustion of diesel fuel	●	GHG emissions reduction associated with avoided bus trips and electric drive. Additional benefit of shifting from mobile to point source	●	GHG emissions reduction associated with avoided bus trips and electric drive. Additional benefit of shifting from mobile to point source
	CAC Reduction	Medium	○	CAC emissions related to combustion of diesel fuel	●	CAC emissions reduction associated with avoided bus trips and electric drive. Additional benefit of shifting from mobile to point source	●	CAC emissions reduction associated with avoided bus trips and electric drive. Additional benefit of shifting from mobile to point source
	Noise	Medium	○	Noise from diesel engine adversely impacts properties adjacent to Production Way, Gaglardi Way and University Way	●	Less noise impact, concentrated at terminus stations	●	Less noise impact, concentrated at terminus stations
	Hydrologic Impact	High	○	Current operations call for use of road salts for de-icing, which would continue in the future for all options	●	Low-profile monocable gondola may require significant tree removal within the ROW - impact on groundwater recharge / retention	◐	Ground disturbance (potentially including tree removal) localized at tower sites – low overall
	Habitat Impact	Medium	○	Current operations stay within roadway ROW	●	Low-profile monocable gondola may require significant tree removal within the ROW	◐	Ground disturbance (potentially including tree removal) localized at tower sites – low overall
URBAN DEVELOPMENT	Land Use Impact	Medium	○	Existing bus loop at Production Way-University Station and SFU Bus Exchange	◑	Potential for redevelopment around terminals	◑	Potential for redevelopment around terminals
	Urban Fit	Medium	○	Existing bus loop at Production Way-University Station and SFU Bus Exchange	○	Potential impacts - location, height, design of towers and terminus buildings. To be clarified in ensuing design and consultation phases	○	Potential impacts - location, height, design of towers and terminus buildings. To be clarified in ensuing design and consultation phases
ECONOMIC DEVELOPMENT	Impacts During Construction	Medium	○	Diesel bus requires no changes to existing road network	◐	Some temporary traffic disruptions expected. Utilities crossing agreements required	◐	Some temporary traffic disruptions expected. Utilities crossing agreements required
	Economic Benefits	Low	○	Limited benefit - road reconstruction / repaving	◑	Moderate benefit from systems and civil construction	◑	Moderate benefit from systems and civil construction

Exhibit 6-1 – Burnaby Mountain Gondola Transit – Alternative Technology Secondary Screening

Secondary Screening Criteria		Importance of Criterion	Diesel Bus (Base Case)		Monocable/2S		3S/Funitel	
			Rating	Comments	Rating	Comments	Rating	Comments
SOCIAL AND COMMUNITY	Accessibility	Medium	neutral	Universal accessibility via ramp access	neutral	Universal accessibility via direct low floor access to a small cabin.	better	Universal accessibility via direct low floor access to large cabin.
	Public Safety	High	neutral	Typical near ground evacuation	neutral	Evacuation plans to be clarified with first responders, including system redundancy and rescue procedures	neutral	Evacuation plans to be clarified with first responders, including system redundancy and rescue procedures
	Security	High	neutral	Driver and passenger surveillance	neutral	Driverless system, but with attendants at terminals. Additional mitigation includes CCTV, 2-way communications	neutral	Driverless system, but with attendants at terminals and passenger surveillance. Additional mitigation includes CCTV, 2-way communications
	Privacy	High	neutral	Non-issue, buses operate on high-traffic arterial roadways	worst	Low longitudinal (vertical) profile - cabins closer to buildings	worse	High longitudinal (vertical) profile - cabins further away from buildings
DELIVERABILITY	Property Requirements	High	neutral	Utilizes existing road ROW	worst	Relatively tight spacing of monocable towers not conducive to spanning over obstacles; greatest property requirement	worse	Property requirements concentrated at terminus and tower locations
	Alignment with Policy Objectives	High	neutral	Capacity-constrained	best	Gondola solutions best meet broad-based Transport 2040 goals	best	Gondola solutions best meet broad-based Transport 2040 goals
	Constructability	High	neutral	Non-issue	worst	Challenging to erect towers and cables in conservation area. In particular monocable systems with closer spaced towers	worse	Erection of towers and cables in environmentally sensitive area

Legend				
worst	worse	neutral	better	best

6.1.1 Financial

Each alternative to the base case requires capital expenditure, both in the form of fixed infrastructure and new fleet vehicles. The alternatives require less operating expenditure, though the payback period varies.

- Trolleybus option – installation cost of poles and trolley wires on the order of $7 to $10 million per km (based on Seattle DOT estimate), and trolleybus vehicles cost approximately $1 million.
- Aerial Tram/Detachable Gondola solutions – cost includes property acquisition and construction of fixed infrastructure (terminal stations, foundations, towers, ropes, and drive systems), as well as cabins. Indicative cost estimates for detachable gondola (3S/Funitel) systems will be provided by suppliers at the end of Phase 2.

6.1.2 Transportation

Articulated trolleybuses offer the same passenger capacity as the base case, and monocable systems are similarly capacity constrained. An aerial tram solution could provide capacities that come close to opening day demand, but only 3S/Funitel systems are capable of meeting future demand of approximately 4,000 pphpd. Realization of the maximum capacity will be dependent on the efficiency of loading/unloading operations, and will be clarified in Phase 3.

Aerial Tram and 3S/Funitel provide more room for bicycles, and supports anticipated growth in recreational usage.

Each of the alternatives requires diesel buses to operate as a backup system during periods of unexpected downtime.

6.1.3 Environmental

The environmental account considers energy usage, emissions, noise, and surface impacts. All alternatives represent a shift from diesel to electric power, thereby reducing GHG and CAC emissions, and fossil fuel dependency.

The aerial solutions are quieter and concentrate the noise at the terminal stations.

Construction of the terminal stations and tower foundations has the potential to impact the environment. Of particular interest to the study area are the hydrologic effects in terms of surface runoff and groundwater recharge for fish-bearing systems. In this respect, a monocable system would have the greatest impact, requiring clearing of the vegetation within the alignment right-of-way.

6.1.4 Urban and Economic Development

The lower terminus and storage/maintenance centre will likely require purchase of the property adjacent to SkyTrain. Value from redevelopment may be captured by the project. The upper terminus could be designed to integrate with the existing plaza area.

6.1.5 Social

The Aerial Tram operator provides a level of security commensurate with that of the bus options, and greater than the other aerial solutions. For detachable systems, the presence of attendants at either terminus, short travel times, and the potential to provide additional features such as cameras/communications devices help to mitigate security concerns.

The lower cable profile of the monocable system gives rise to more severe privacy concerns than other aerial solutions. The monocable system also has frequent towers which impose a greater visual impact, not unlike constructing a network of trolley wires. Its small cabin size also reduces peer pressure and natural surveillance that would passively control anti-social behaviour.

6.1.6 Deliverability

The transportation aerial solutions best satisfy the goals of Transport 2040, but there are offsetting environmental, property, and constructability considerations.

The trolleybus option appeals mainly to the environmental goals of Transport 2040 and support for installation of wires leading to and on the mountain is unknown.

6.1.7 Overall

The 3S/funitel option performs well in the Transportation, Environmental, and Urban and Economic Development Accounts. Specific environmental surface impacts could be mitigated through careful design and construction practices. Measures could also be taken to mitigate issues within the Social account. The overall assessment is that a 3S or funitel system is the most suitable technology in the corridor relative to the base case of diesel bus service.

While trolleybus would provide environmental benefits, the limited capacity increase and marginal improvement to travel times would not justify the additional cost relative to the 3S and funitel solutions.

6.2 3S versus Funitel

As part of the lift system evaluation two suppliers, Doppelmayr and Leitner-Poma, were contacted to provide technical input and indicative pricing. The specification outlined the operating characteristics for a circulating ropeway system: the opening day and long-term capacities of the system, and its assumed hours of operation. Also included were the ground profile, as well as clearance requirements over existing buildings, roadways, and forested areas. The package did not specify the type of circulating ropeway system to be employed, but did stipulate restrictions on potential tower locations.

Both suppliers recommended 3S technology in their conceptual design. Below is a summary of the rationale for choosing this technology:

1. Relatively Long Spans – 3S and funitel are comparable in this respect.
2. Comparable Wind Performance – For the span lengths considered, 3S and funitel are comparable.
3. Greater Passenger Capacity – The greater size of 3S system cabins offer advantages.
4. Power Consumption – 3S systems consume less power than funitel systems.

6.3 Precedents for Urban Ropeway Transit

The use of gondolas and other forms of aerial ropeway to provide urban transportation is a relatively new trend but one that is developing rapidly. In the past, urban installations were often for special events such as world expositions and locally there were two gondolas as part of Expo 86 site.

In North America, aerial tramways are used for urban passenger transport in two high profile locations. The first is the Roosevelt Island Tram, connecting Roosevelt Island to Manhattan over part of the East River. Originally installed in 1976 as a temporary precursor to a subway connection (that finally opened in 1989), the aerial tram has become a well-known piece of the urban fabric and well-used for commuting and tourism, carrying over two million passengers per year. After the original tram operated for double its projected lifetime, the lift was completely rebuilt in 2010 to provide improved reliability and flexibility through the use of two independently operable cabins.

The Portland Aerial Tram opened in 2006 and connects the city's South Waterfront district and streetcar line to a major hospital complex about 1 km away and 150 m higher in elevation. The line crosses four major roadways including I-5, and runs above a residential area for close to half its length. The tram does not cross directly above any residential property, however, as the alignment is above city street right-of-way through the neighbourhood. Daily ridership is about 4,800 riders. The system has been more popular with cyclists than anticipated, leading to additional bike parking requirements at the lower station, in part to discourage transportation of bikes onboard. Tourist and recreational ridership has also been higher than predicted.

The popularity of gondolas for urban transportation has been growing in recent years, particularly in South America, where cities with steep hillside neighbourhoods and poor transportation networks serving them have implemented monocable gondolas. Medellin, Colombia was the pioneer system, opening its first Metrocable line in 2006, as a feeder to their metro system. The first line was so successful that two others are now in operation. Following Medellin's lead, urban gondolas have opened in Caracas, Venezuela (2010, second line under construction) and Rio de Janeiro (2011). In Europe, gondola systems in urban areas but targeted more to recreational markets have recently opened in Portugal, Turkey, and Romania. Most recently, Transport for London has awarded contracts for a 1.1-km gondola across the Thames from North Greenwich to the Royal Docks area. This gondola, locally called a cable car, is planned to open as early as summer 2012.

3S gondolas are a relatively new technological advancement and thus are rare in urban use with installations in Koblenz, Germany and Bolzano, Italy being the best precedents. The Koblenz installation uses the same supplier and system as the Peak 2 Peak at Whistler but in an urban environment. It features an 890 m long route starting from the west bank of the Rhine River, crossing the river and a major rail line on the opposite bank before climbing above forest to a castle that is part of a UNESCO world heritage site. The system was opened in 2010 on a three-year temporary basis to link the main sites of the major BUGA 2011 garden show and offers a very high capacity of 3,750 pphpd. The lift has been designed to demonstrate the potential for gondolas as urban transport through, for example, transit-like cabin interiors.

The Bolzano 3S is a much lower capacity installation being capable of moving only 550 pphpd based on local need. This 4.5 km long lift opened in May 2009 and replaced an aerial tramway in linking the city centre to mountaintop villages and a short rail line. It features architecturally impressive terminals and a lower section that crosses over and adjacent to several buildings.

While there are relatively few examples of gondolas in urban operation, those that are in place have operated very successfully, as have thousands of ski and other recreational lifts worldwide. The latter often operate in demanding conditions with difficult access, and extreme cold and wind. While urban systems will have longer hours, their locations can provide a much less severe operating environment. In summary, there are no fundamental barriers to the use of gondolas for urban transportation and benefit from attracting additional tourist and recreational riders based on the technology.

7. ALTERNATIVE ALIGNMENT ASSESSMENT

Based on the conclusions of the technology alternatives assessment, a review of potential alignments was developed with the assumption of a 3S system. The key objective of this assessment was to identify alignment(s) that:

- Minimize conservation area impacts
- Minimize neighbourhood impacts
- Minimize length of route – (reduce cost and travel time, avoiding kinked alignments)
- Minimize impacts of tower locations
- Maximize transit integration – with SkyTrain and SFU/UniverCity

7.1 Alignment Options

Four alignments linking Burnaby Mountain with the existing SkyTrain network were considered in some detail. The alignments can be described as follows:

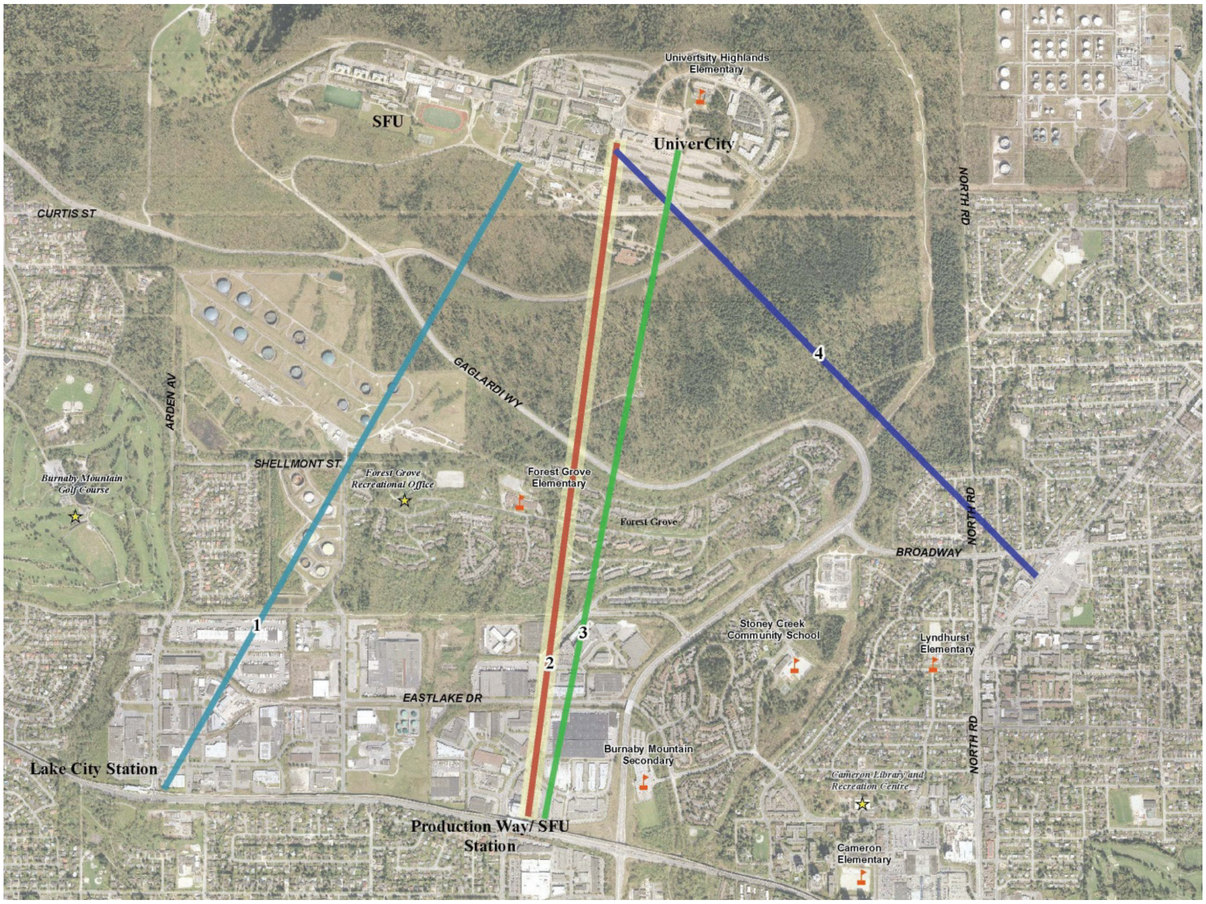
1. Lake City Way Station to South Campus Road (across from the South Sciences Building)
2. Production Way – University Station to SFU Bus Exchange
3. Production Way – University Station to intersection of Highland Court and Tower Road
4. Burquitlam Station (on the Evergreen Line) to SFU Bus Exchange

The route alignment alternatives are shown in Exhibit 7-1. Alignments with mid-stations were initially also considered but ruled out for the following reasons:

- If a midstation were used to allow an alignment to avoid crossing over residential areas, the midstation would be in the Conservation Area, greatly increasing surface impacts due to additional clearing for the building and to allow the gondola to descend to it and ascend from it.
- A mid-station would ideally be located where there would be significant passenger demand to board or alight but the prospective locations would not be proximate to demand generators or network connections.
- Midstations require the gondola to slow down and so would generate an increase in travel time, particularly since the intent is that they would make the route less direct. Added travel time would result in less diversion of trips to the gondola from other modes, reducing environmental and economic benefits.
- Midstations (and a longer route) would increase project costs and so reduce the benefit to cost ratio as benefits would decrease while costs increased.

All alignments assume that full advantage of the 3S technology is made to avoid tree removal under the alignment, except at tower locations, and to locate towers in locations that minimise residential and conservation area impacts.

Exhibit 7-1 – BMGT Alignment Alternatives



7.2 Alignment Evaluation

The alignments are evaluated on a basis similar to that utilized for the technological alternatives. The chart following (Exhibit 7-2) summarizes the results of the evaluation with the reasons for the evaluation results described following:

Exhibit 7-2 – Alignment Evaluation Summary

Criteria	Route			
	1: Lake City – South Campus Road	2: Production Way – SFU Bus Exchange	3: Production Way – Tower Road	4: Burquitlam – SFU Bus Exchange
Length	2.8 km	2.7 km	2.7 km	2.4 km
Conservation Area Impact	◕	◔	◔	○
Residential Impact	◕	◑	○	◔
SkyTrain/Transit Integration	◔	●	◕	◔
SFU Campus & UniverCity Integration	◔	●	◔	◔
Property Acquisition Risk	○	◕	◔	◕
Safety & Approvals	○	◕	◕	◕
Cost (including property)	○	◕	◔	◔

Worse ◄————► Better

○ ◔ ◑ ◕ ●

7.2.1 Route 1: Lake City – South Campus Road

This alignment travels the shortest distance over the conservation area and avoids crossing residential neighbourhoods and so performs highly on these accounts. However, the lower terminus at Lake City skews the ridership catchment to the west, reducing the potential to attract ridership from the south and east, thus its poor showing on SkyTrain/transit integration. Building a convenient connection at Lake City Way station would also be difficult since the station is on the west side of Lake City Way close to the road, suggesting the station need either be at a higher level on the west side, to allow the gondola to cross above Lake City Way, or on the east side of the street where it would be less convenient to the SkyTrain station.

At the upper end of the route, the terminus would be across South Campus Road from the South Sciences Building as crossing above the university buildings to reach the transit hub would be challenging. The net effect of the upper and lower terminal locations is a reduction in ridership with this alternative such that it is approximately one-fifth that of alignment 2, based on initial model results. Integrating bus services, including replacement bus services when the gondola is not operating, at this upper terminal would be challenging due to the a lack of an existing facility and little available land to build one.

Notwithstanding the above, the most fundamental challenges with this alternative result from its crossing the tank farm properties on the slopes of Burnaby Mountain. The tanks on these sites store refined petroleum products and the consequences of any incident at them for the gondola are such that the BC Safety Authority has indicated that they could not approve operation of a gondola above them. Furthermore, this alignment would require the purchase of aerial rights-of-way over the tank farms and the tank farm owners have indicated they would not agree to this. As the tank farms are owned by inter-provincial utilities and thus are federally regulated, TransLink has no authority to acquire property from them. This alignment is therefore not viable.

7.2.2 Route 2: Production Way – SFU Bus Exchange

This alignment was recommended in the initial feasibility study and continues to be the most promising. It connects directly to existing transit nodes at the upper and lower terminals and takes a direct route up the mountain, serving travel demand well from most directions, including the north-east once the Evergreen Line is in place.

The main challenge with this route is the crossing of the Forest Grove residential neighbourhood, with approximately 40 residential units below the alignment. Residents have indicated concerns about noise, safety, privacy, and visual impacts. The number of directly crossed residential properties is minimized to the extent possible as the alignment crosses part of this area above a ravine in the Burnaby 200 Conservation Area. The choice of 3S technology also permits an alignment that is about 30 m above rooftops and well above the tree canopy, which would remain intact and offer some visual screening. Potential tower locations have been identified that are at least 100 m from dwellings and minimize conservation area impacts.

The lower part of the alignment, through the industrial area, is largely above the Production Way street right-of-way and so limits property requirements. The upper part of the alignment is compatible with the street network at SFU/UniverCity and so would have little negative impact on current or future development there.

While some property would need to be acquired for this alignment, for terminals, towers, and aerial rights-of-way, none of the required activities are considered a high risk given experience with precedent projects in the region, such as SkyTrain.

Preliminary discussions with the BC Safety Authority indicate that the alignment is approvable as there are precedents for ropeways over streets and buildings of the type found on this route. Some special operational measures would be required when performing maintenance activities above buildings and public areas.

7.2.3 Route 3: Production Way – Tower Road

This alignment is similar to alignment 2 except that the upper terminal is further east, placing it further from the SFU campus and the destinations of most riders. Because it is less effective at following existing street right-of-ways in its upper and lower sections, it offers inferior integration with SFU/UniverCity and crosses more industrial properties. Compared to alignment 2, it crosses a similar number of residential units and there are fewer trees to provide visual screening in this segment. Overall, this alignment offers no benefits and many drawbacks relative to alignment 2.

7.2.4 Route 4: Burquitlam – SFU Bus Exchange

This alignment would have a lower terminal on the west side of Clark Road, opposite the planned Burquitlam station on the Evergreen Line. The design of the Evergreen Line station at this location is for a side platform station with no mezzanine level making a high-quality connection across the road challenging. It is assumed all passengers would need to cross Clark Road at street level or make multiple changes in grade to access the gondola terminal. For this reason this alignment scores poorly on integration. While this alignment is effective at capturing ridership originating in the east, much of the travel demand is destined to and from other directions.

The lower part of this route would cross about 500 m of single-family housing with private backyards. Approximately 30 properties would be crossed directly overhead. As a result, the alignment scores poorly on residential impacts.

The alignment then makes a long crossing of the Burnaby Mountain Conservation Area for a distance of about 1,400 m. Given the topography and existing BC Hydro lines, it is likely that one or more towers would be needed in the Conservation Area in areas remote from existing road access. Given the likely level of disturbance and the high recreational use of this section of the Conservation Area, this alignment was considered inferior to the others in terms of impact on conservation lands.

On arrival at the mountain, this alignment cuts diagonally across the UniverCity development area and is to likely have a negative impact on future development since it would require establishing a new right-of-way. Other alignments could take advantage of existing right-of-ways.

While this alignment is considered to be viable from an approvals perspective, it is less desirable than alignment 2 given its inferior transportation connections and higher land use and environmental impacts.

7.3 Conclusion

On the basis of this secondary screening, summarized in Exhibit 7-2, Route 2 is identified as the preferred alignment because it:

- Minimizes impacts on the conservation areas;
- Minimizes residential property crossings;
- Minimizes travel time (6.5 minutes versus 15 minutes by bus);
- Maximizes integration with transit facilities and SFU/UniverCity;
- Limits conflict with utilities; and
- Has good potential for low impact tower locations.

8. TECHNOLOGY AND ALIGNMENT CONCLUSION

Based on the foregoing analysis, the combination of a 3S gondola on Route 2: Production Way – SFU Bus Exchange stands out as the most promising combination of technology and alignment to carry forward to more detailed evaluation in the business case. This combination is expected to show the highest transportation benefit with lower and more manageable surface impacts relative to other options.