INDEPENDENT REVIEW:

# SkyTrain Service Disruptions on July 17 and July 21, 2014

McNeil Management Services
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## EXECUTIVE SUMMARY

There were two major, unprecedented service disruptions of the SkyTrain system in July of 2014, which impacted the commute of thousands of passengers. The delays lasted 5 to 6 hours. The root causes of the delay incidents were not related. However, the reason for the extended delay period was related. The loss of communication between the train command computers in the SkyTrain Control Centre and the computers on the trains caused the trains to stop. Once the cause of each failure was repaired, it took many hours to manually re-enter each train into the SELTRAC automatic control system.

Because of the duration of the delay, unauthorized self-evacuation from the trains occurred. Severe pedestrian and vehicle congestion was experienced around stations. Customers were stranded in unfamiliar locations and found it necessary to search out alternate transportation options. Customer communication was limited. The overall customer experience was poor.

These delay incidents prompted TransLink to review its operating, maintenance, and customer service and communications protocols. As part of its review, TransLink requested an Independent Review of its practices to assist them in improving the SkyTrain service for Metro Vancouver.

## SAFE, RELIABLE SYSTEM

SkyTrain has been operating a safe, reliable and cost-effective service since it began operating in 1986. The SkyTrain system has maintained an on-time performance level comparable to a number of its operating peers. However, SkyTrain measures performance for reliability at a more stringent level than a number of its peer operating systems, which makes relevant comparisons difficult. SkyTrain measures performance within 2 minutes of its operating schedule; most of its peers use higher time variables (such as 3 minutes or more), and some exclude periods of planned maintenance.

Given the differing measurements of reliability, SkyTrain's overall service has performed well. In most years, SkyTrain has maintained on-time performance at a level of approximately 95% when measured to within 2 minutes of its scheduled headway of operation. This means that, for 95% of its operating time, trains functioned on or within 2 minutes of their operating headway.

In analyzing the July incidents, it is important to note that SkyTrain is a safe system. Very few "accidents" occur on the overall system, and none have been related to the train control system. As a driverless service, SkyTrain relies upon SELTRAC, a computerized Automatic Train Control and Operations technology, to manage and control train movements. The SELTRAC train control system is designed to stop all trains in a safe mode. A walkway along the length of the system is available for passengers, if evacuation from trains is required. It is also used for access by SkyTrain personnel in recovering service.

The fact that these two major delay/evacuation events occurred, without any injury occurring to staff and the public, attests to the safety focus of the system. The various system elements performed in a safe mode, as intended. Trains stopped as soon as operating-command communication was lost. Unauthorized self-evacuation by passengers and supervised evacuation occurred in a relatively calm and respectful manner. The passengers stayed on the walkways and moved to the refuge of station areas.

## GUIDEWAY INTRUSION AND ON-TIME PERFORMANCE

The system could perform at an even higher level of reliability than 95% on-time performance, if improved technology were used for the guideway intrusion system at the stations of SkyTrain. Because SkyTrain is a driverless system, it relies upon various guideway intrusion technologies to warn the train control system of potential hazards on the track in the station areas. The current technology is designed to detect very small intrusions or small articles on the sensor panels at track level in stations.

Guideway intrusion represents approximately 50% of all delay events and 50% of delay event times. The individual time period of train delay for guideway intrusion is relatively low, usually taking 3 minutes to 15 minutes to clear an incident. The delay duration is typically related to the time that it takes for a SkyTrain Attendant to reach the platform, scan the area and clear the alarm.

However, the frequency of the delays must be aggravating to customers. Most of the intrusions are "false" alarms, detecting inanimate objects. The frequency of alarm activations has also increased over the past few years due to safety-related adjustments to the sensitivity elements of the detection devices. Before adjusting the guideway intrusion sensitivity, there were approximately 275 – 300 intrusion alarms a month, resulting in almost 125 emergency brake situations each month. Since November 2013, there have been approximately 450 guideway intrusion alarms a month (50% increase) and almost 275 emergency brake situations each month (over a 100% increase in emergency braking).

This increase in delay events may give the public a general perception that the system is aging and more maintenance issues are present than reality would attest. Increasing frequency of minor delays may also tend to make the public less tolerant of major delays.

## SUGGESTED IMPROVEMENTS

When significant delay events occur such as the two incidents in July, there are always opportunities to learn from what transpired, and to follow through on identified improvements. A number of improvements to the operations, safety, customer service and communications practices of SkyTrain can be made.

The major recommendations are summarized as follows:

## IMPROVEMENTS IN OPERATIONS

1. **Install an auto re-start component to the SELTRAC technology package.** If a major failure occurs that impacts the command and control communication between the trains and the Control Centre (as happened on July 17 and 21), the current SELTRAC technology on the Expo and Millennium Lines requires 3 to 5 hours to get service back to normal operation due to manual re-entry of trains into the system. An auto re-entry system component is available, which could significantly reduce the duration of the delay events associated with the kind of service disruptions of July 17 and July 21. TransLink should assess the SELTRAC technology options available to reduce the train re-entry time.

2. **Modify the Line of Sight Operating Rule to allow multiple, manual train movements.** The current policy restricts multiple train movements during manual operation. Therefore, if a major delay event occurs and SkyTrain Attendants reach the trains, only one train at a time can be manually driven to the closest station, before any other train is moved. This encourages self-evacuation, as customers can be waiting on trains for a very long time before each train gets moved to a station. Once self-evacuation occurs, traction power must be dropped on that affected section of guideway and trains can no longer move, forcing complete evacuation. The line of sight operating rule should be changed to allow multiple train movements under manual operation. This would discourage self-evacuation from occurring and significantly reduce the recovery time of the system.

3. **Install system continuity redundancies for critical system elements**. For critical system elements, redundancies for system continuity should be considered so the critical functions remain active, even if in a non-fully functional mode. For example, an individual Uninterruptible Power Supply for system-critical train control components would mean that, even if the main UPS system for the Control Centre fails for a few seconds, the train service may not be significantly disrupted.

4. **Work on system-critical control components should only be allowed during non-revenue operating hours.** With this restriction in place, if a failure occurs on a component being repaired/replaced, it will not have significant impacts on the travelling-public.

5. **Update and create new operating and maintenance manuals, and procedures.** Some processes are unwritten. Also, as long term SkyTrain operating and maintenance employees retire (many of whom have been working with SkyTrain since its early days of operation), much of the "hands-on" expertise and understanding of the specific SkyTrain system elements departs with them. This knowledge needs to be captured and synthesized for transfer to new hires.

6. **Decouple important systems and develop an Asset Management Plan.** By decoupling systems, if one system fails, it does not impact other systems. As an example, when the Uninterruptible Power Supply failed on July 21, it took out all communication channels (emails, Public Address, phone lines and radio communication) at the Control Centre. A comprehensive Asset Management Plan that deals with maintenance and refurbishment cycles of various system elements, and also recognizes dependencies on other system elements for its effective operation, needs to be developed.

7. **Upgrade the guideway intrusion system.** More intelligent systems, using latest technology advances in laser and/or video surveillance are available. Reducing the unnecessary delays created by the guideway intrusion system will generate a more responsive delay recovery system (SkyTrain response staff may be suffering from a "Cry Wolf" syndrome due to the high number of false or non-critical guideway intrusion alarms). Reducing the frequency of minor delays will also resonate well with the public. TransLink should assess options to improve the current guideway intrusion system.

8. **Introduce a single emergency radio band for all TransLink Operating groups**. A single communication channel will facilitate communication between BCRTC, Canada Line, West Coast Express, Coast Mountain Bus Company and Transit Police. Communicating through a single channel avoids time delays and potential confusion in re-packaged messages to staff across the different operating groups.

9. **Establish an "alarm-based" warning system for appropriate management and supervisory staff.** Systems are available that alert staff of an emergency situation in a proactive manner by way of an audio alarm on their smart phone. This alarm assures a quicker response by management and designated supervisory personnel than relying upon staff to look for an email or text message (or even a telephone call) that can be caught up in a hundred other messages received that day.

10. **Set frontline staffing levels and their service area locations so qualified staff can respond within a specified period of time.** Staff need to be able to quickly get to stations to deal with guideway intrusion alarms and stopped trains on the guideway. A response time of approximately 10 minutes to get staff to a station and clear an alarm is suggested to deal with the guideway intrusion alarms and crowding issues that may occur at the station. A target response time to access a stopped train of approximately 20 minutes is suggested so the train can be attended by staff. (There may be situations where station spacing may limit the ability to access a train within 20 minutes.) This response time target is important, until improvements to the system are introduced (such as the upgrade SELTRAC module and new guideway intrusion technology).

11. **Install system-wide CCTV coverage.** It is desirable for the Control Centre to visually be able to see train locations, guideway activity or other intrusion/security matters when system failures or intrusion alarms occur. This is especially important if staff cannot get to trains in a responsive time period. However, if a reasonable response time to delays occurs (as referenced in Item 10), this investment could be deferred.

## IMPROVEMENTS TO SAFETY

12. **Install platform edge CCTV coverage.** CCTV cameras would also be helpful in dealing with guideway intrusion, both inside and just outside of station areas, reducing the delay events associated with guideway intrusion alarms, as well as providing added safety at stations. If other improvements referenced in this report occur (response time improvements and replacing the intrusion technology), this investment could be deferred.

13. **Communicate during lengthy delays that windows can be opened on some trains.** Customers may not be aware that it is possible to open the windows on the non-air conditioned Mark I vehicles. Opening of windows will allow better air circulation in a vehicle if a train is stopped for a long period of time, and will reduce the internal heat build-up on sunny, warm days. This may also reduce the sense of claustrophobia for passengers in the vehicle.

14. **Install a low profile, lighting system along the walkway edge.** There is a need to improve delineation of the walkway edge, especially when poor lighting conditions exist. As an example, surface level lights along the edge of the walkway will better define the walking path area

when background light levels are low, and will assist evacuating passengers, especially those with depth perception or limited peripheral vision. This walkway delineation system can be tied-in with the power system (activates when power is turned off and when ambient lighting levels are at a defined luminance level).

## IMPROVEMENTS TO CUSTOMER SERVICE AND COMMUNICATION

Customer Service and Communications are intrinsically linked. One cannot have good customer service without good communication systems and processes.

15. **Increase visibility of frontline staff.** As referenced under the Operational recommendations, a quicker response time by SkyTrain staff will go a long way to enhancing customer service. However, it is also important that staff in the field be quickly recognized as SkyTrain employees even when there is normal operating service. All frontline staff should wear high visibility vests over their clothing. This will make them easily recognizable in times of minor or major crisis.

16. **Improve the quality of the Passenger Address System.** The quality of the Passenger Address System on many trains and at a number of stations is poor. Announcements can be easily missed. During times of major disruptions, when crowding and confusion is happening, it is relatively easy to miss important messages. TransLink should assess each train and station and determine the best audio technology enhancements.

17. **Introduce programmable-messaging signboards, fixed signage and PA speakers at the entrances to all stations.** In conjunction with a review of wayfinding signage within each station, there is a need for service-related information just outside of the station entrances. When the stations are closed, important communication should still be able to be conveyed to waiting customers outside of the security gates. This is also an added customer service feature when the system is operating in a normal mode.

18. **Strengthen the resiliency of the Call Centre phone system and webpage.** Customers need to get information on the time for the system's recovery and alternative travel choices, during the time of a major delay event.

19. **Establish protocols and communication links with local municipalities.** In emergencies, local municipalities and their first responders can assist in managing traffic, pedestrian crowding and decimation of communication messages to the public. By having closer ties with municipal partners, TransLink can tap into a large group of interested communication and crowd management personnel.

20. **Introduce a bus scrolling message advising of major delays.** When a major delay event is occurring on the Expo, Millennium or Canada Line, a pre-programmed message on the front of each bus serving the stations on the impacted section can inform customers of the delay before they get on the bus feeder service. With this advance knowledge, some customers can consider alternative travel options.

The above recommendations represent a number of improvements that can be individually, or could be completely, introduced into the SkyTrain system recovery protocols. Each element will improve how the system recovers. Some improvements can be quickly and readily implemented as they are operational in nature, or low cost. Other enhancements may take a number of years as they are large scale projects that will take time to study and implement.

TransLink wants to improve SkyTrain, and it is improving. After the July incidents, management and staff have undertaken a concerted effort to isolate system weaknesses and strengthen operating and communication procedures. For nearly 30 years, SkyTrain has maintained a vital transportation service for Metro Vancouver. It will continue to do this for decades to come. By implementing some or all of these recommendations, TransLink will continue to enhance the customer service aspects of SkyTrain.

**SECTION 1:**

# Mandate of Study

As a result of two major failures of the SkyTrain system (July 17 and July 21, 2014), TransLink requested that an independent review of the response to the failures be undertaken, specifically to:

- *evaluate TransLink's response plan for major system outages from operational, customer safety, customer service, and public communications perspectives;*
- *consider how TransLink's response plan can be improved; and*
- *determine what can be done, going forward, to prevent a reoccurrence or speed up system recovery.*

This Report highlights the various measures that could be considered to improve Emergency Responses on the SkyTrain transit system.

## SECTION 2:

# The History of SkyTrain Service in Metro Vancouver

### THE EXPO LINE

Since its start of operations in 1986, the SkyTrain service in Metro Vancouver has been a leading example of Canadian technology, at the forefront of automated transit systems. Conceived as a low operating cost rapid transit service for the Greater Vancouver Regional District, SkyTrain has more than lived up to its expectations of providing reliable transportation services for the region. It has also encouraged a significant amount of transit-oriented development around its stations, which was also one of the original visions for rapid transit in Metro Vancouver.

SkyTrain is an automated, "driverless" rapid transit system. Operating Control is maintained through computerized SELTRAC automated technology, developed in the late 1970s/early 1980s. Fail-safe elements in the system ensure that the train control of the transit service operates with the highest degree of safety. Vehicle Control Centre computers (VCCs) control individual segments of train operation along track sections. The VCC "talk" to each train in its control area, connecting through the train's Vehicle Onboard Control computer (VOBC). The automated operational/ communication control occurs through a System Management Centre (SMC). Three (3) VCCs controlled the Expo Line on the original SkyTrain system.

The technology available in the 1980s required that each train had to initially be manually entered into the command and control system – an exercise that could take up to 10 minutes per vehicle. However, once trains have been recognized by the SELTRAC system, and provided the various command and control systems remain powered and functional, the SMC/VCC system is always aware of where each train is. If a failure occurs, the system stops all trains affected in a safe mode. Manual re-entry of trains typically only happens after a train/car is taken out-of-service, in a controlled manner, for special maintenance.

In 1986, SkyTrain operated approximately 20 four-car trainsets, serving 15 stations, from an underground section in downtown Vancouver along an at-grade/elevated guideway to New Westminster Station. Excluding the Operations and Maintenance Centre in Burnaby, each train travelled 21 kilometres per trip. On an average weekday, 65,000 passengers were carried. On a distance-travelled basis, the 114 individual vehicle fleet operated 12.9 million kilometres in a year with 2.5 minute headways between trains. There were approximately 300 employees.

The annual operating budget of SkyTrain was $26 million in 1986, or approximately $55 million in 2014 dollars when adjusted by the Consumer Price Index (CPI). The CPI inflation rate from 1986 to 2014 has been approximately 213%. Energy prices have increased at a much higher rate (274%) than CPI, and SkyTrain is energy-dependent. Therefore, the CPI is a conservative inflation factor to use when looking at inflated dollar comparisons.

## THE EXPO AND MILLENNIUM LINES

Today, the Expo and Millennium Lines of SkyTrain operate with up to 58 trains during the day, typically as four-car trainsets. The two lines have 33 stations, along corridors that are 49 kilometres in length. The Operations and Maintenance Centre (OMC) of SkyTrain in Burnaby, although slightly expanded and modified for growth since 1986, continues to be the sole facility for SkyTrain maintenance activities. When the Millennium Line was constructed, an additional VCC was added to the control system to incorporate the expanded service area.

Although the SELTRAC system was upgraded to the 2nd generation of software in 1994, the version that was installed for SkyTrain did not incorporate a vehicle auto-restart function, which was available at the time.

In 2014, the Expo and Millennium Lines are serving 250,000 customers on an average weekday. The 258 vehicle fleet operates 45 million kilometres per year, with a train every 108 seconds (1.8 minutes). There are approximately 660 employees employed by SkyTrain. The annual operating budget is now $107 million.

## THE EVERGREEN LINE

In 2016, the Evergreen Line will be added to the Control System of the Expo/Millennium Lines. This will add 28 individual vehicles to the fleet, 6 more stations and 11 more kilometres of additional SkyTrain service corridor length. Train maintenance will continue to occur at the OMC in Burnaby and two additional VCCs will be added to the current SkyTrain SELTRAC technology in the Control Centre of the OMC. As part of the Evergreen Line project, some vehicle storage, vehicle light cleaning and repairs, and guideway/wayside maintenance facilities are being constructed in Coquitlam, so some OMC activity will be diversified after 2016.

## THE CANADA LINE

In 2009, the Canada Line was opened for service. It was constructed, and is operated, under a public/private partnership arrangement. The Canada Line is a self-contained transit service connecting downtown Vancouver to Vancouver International Airport (YVR) and Richmond. Like the Expo and Millennium Lines of SkyTrain, it is also an automated, driverless transit system using SELTRAC technology. However, the Canada Line command and control system incorporates a module that reduces the complexity of entering trains into service by incorporating an auto-restart functionality feature. Therefore, when a VCC-impact system failure occurs on the Canada Line, it should be more quickly brought back to normal operation.

## DOING MORE WITH LESS

From an overall system perspective, SkyTrain is doing a lot more with less. The operating/maintenance budget and staffing of SkyTrain has doubled since 1986, which is consistent with the total system distance and number of stations. However, in 1986:

- passenger volumes were relatively low;
- the system was new, so the resiliency of the myriad of system components was greater;
- the cost of energy was relatively low;
- the cost of labour was relatively low (hourly rates and position of new hires in salary bands); and
- Warranties were applied to all components of SkyTrain operations.

The 1986 Operating Budget reflected the relatively low level of maintenance and use of a new transit service.

Since 1986, the number of passengers handled by SkyTrain, and the number of vehicle miles travelled has increased almost four-fold. Therefore, although staffing levels have increased consistent with asset elements (stations and length of track), the operating budget has not kept up with the number of passengers handled, or miles driven by the vehicles. Increasing vehicle miles equates to a parallel increase in energy consumption and vehicle/wayside equipment maintenance, which puts pressure on other parts of the operating budget. Likewise, higher passenger volumes equate to increases in cleaning and station maintenance demands at a higher rate than "twice" the operating budget of 1986.

| YEAR | LENGTH (KM) | FLEET | STATIONS | PASSENGERS/ DAY | OPERATING (KM) | STAFF LEVELS | OPERATING BUDGET (2014 $) |
|---|---|---|---|---|---|---|---|
| 1986 | 21 | 114 | 15 | 65,000 | 12.9 Million | 300 | $55 Million |
| 2014 | 49 | 258 | 33 | 250,000 | 45 Million | 660 | $107 Million |
| % | 233% | 226% | 220% | 385% | 349% | 220% | 195% |

## SECTION 3:

# On-Time Performance (OTP)

The On-time Performance (OTP) of the SkyTrain service has been reasonably good for the past decade.  SkyTrain measures reliability based upon a 2 minute delay from scheduled headways. Measured from 92% to 95% in a given year, within 2 minutes of the service schedule, the vast majority of train trips are on-time, or less than two minutes late getting to a designated station area.

## GUIDEWAY INTRUSIONS

For recorded delay events, one of the major reasons for delays on SkyTrain is due to guideway intrusion alarms. As a driverless system, SkyTrain chose to introduce intrusion technology devices in its station areas to ensure that the automatic train operation system is aware of persons or large objects on the track in station areas. This is accomplished by pressure sensors in the track area on the Expo line, and optical sensors on the Millennium Line. In the first 8 months of 2014, there were over 4,500 delay events associated with guideway intrusion on the SkyTrain system.

Many of these intrusions were "false" in nature, as they were related to such non-descript activities as birds flying through, or a section of newspaper blowing past, optical sensors. Also, small objects falling on the pressure plates at stations can trigger alarms. The limit of pressure sensitivity is 10 pounds of pressure before the pressure sensors activates the alarm/braking. This pressure level can be reached when a train passes over a soft drink can.

When these incidents happen at a station, an approaching train goes into emergency brake, and vehicles behind the stopped train also stop. From this one braked train, a complete ripple effect can occur down the line.

The cause of the guideway intrusion alarm has to be investigated by SkyTrain personnel, before train service can re-continue at the impacted station. Depending upon the location of an available SkyTrain Attendant (STA), it can take anywhere from 3 minutes to over 15 minutes to verify that the intrusion event does not pose a risk to the travelling public. A concerted effort to reduce the number of delays related to non-critical guideway intrusions will significantly improve the overall performance perception of SkyTrain.

The frequency of guideway intrusion alarms has increased over the past few years due to safety-related adjustments to the sensitivity elements of the detection devices and the age of the detection devices on the Expo Line. The pressure plates are in need of extensive maintenance due to their age, and they are prone to false alarms or small sections of failure because of their age. Before adjusting the detection plate sensitivity, there were approximately 275 – 300 intrusion alarms a month, resulting in almost 125 emergency brake situations per month. Since November 2013, there have been approximately 450 guideway intrusion alarms (50% increase) and almost 275 emergency brake situations (over a 100% increase in emergency braking) per month.

This increase in delay events may give the public a general perception that the system is aging and more maintenance issues are present than reality would attest. It could also mean that the public may be less tolerant to major delays, as the frequency of minor delays increases.

## OTP STATISTICS

On-time Performance is just one measurement tool to show how well the system is performing relative to past measurement periods. However, using on-time performance as a measure of service to the customer can create a deceptive perception of the quality of service, especially when measured as train availability within 2 minutes of its normal headway. If most delayed trains are less than (say) 3 minutes late, customers might be mildly inconvenienced. However, if a large number of those delayed trains are 10 minutes late, customers would be more greatly inconvenienced.

An example of "statistics not telling the full story" can be illustrated using SkyTrain data between 2012 and 2013. In 2012, the average OTP was 93.6%. In 2013, the average OTP was 94.7%. This gives the overall appearance that service is improving. From the customers' perspective, there may have been fewer delays in 2013; however, the delays were longer and more significant. In 2012, there were 173 extended delays over 10 minutes in duration representing 2,748 minutes (average delay of 15.9 minutes). In 2013, there were 207 extended delays over 10 minutes in duration representing 3,626 minutes (average delay of 17.5 minutes). OTP may have improved by 1 percentage point but the number of significant delays had increased by 20%, and the average delay time of these events had grown by 10%.

## PEER COMPARISONS

Comparing OTP from one transit system to another transit system does not always provide customers and stakeholders with the answer that they want, which usually relates to *why their service has been impacted.* All systems in different cities:

- are at a different age,
- use differing technology,
- measure OTP using different time limits, deal with different weather conditions, and
- use different exclusions for their Key Performance Indicators (KPI), such as excluding "Acts of God" and planned maintenance.

Peer comparators can be misleading as the transit systems operate differently. As an example, the London Docklands Railway excludes contractual maintenance periods from their delay statistics. Also, even though the train control system uses automatic control technology, each train is manned by an employee, increasing the operating costs dramatically. Dedicated staff on the trains of SkyTrain could cost TransLink (and the public) almost $20 million more in additional operating budget each year.

A comparison to other transit systems shows a myriad of variances:

- The Toronto Transit Commission (TTC) Scarborough Rapid Transit line, that uses the same vehicle and SELTRAC technology as SkyTrain, had an April OTP of 89%, as measured to within 3 minutes of regularly scheduled headways. A 98% OTP level was achieved in August.
- The Miami Metrorail had a 95% OTP for 2013, as measured to within 5 minutes of scheduled headway for each vehicle (not total delay event).
- Bay Area Rapid Transit (BART) has a monthly OTP of 91%-94% as measured to within 5 minutes of schedule.
- Chicago Transit Authority (CTA) does not appear to post OTP; it measures the number of trains delayed for longer than 10 minutes, with a target of not more than 78 trains per month. Actual "over 10 minute delays" range from 40 to 71 trains.
- London's Dockland Light Railway (DLR) has a 99.7% OTP as measured at 3 minutes beyond train scheduled departure and arrival at terminals. However, it is also allowed 50 consecutive hours of closure every two months to facilitate wayside and system maintenance. The system closure time is not included in their posted OTP.

Most rapid transit systems have significant service delays. In Toronto, for example, the downtown section of the subway has been frequently closed on weekends to accommodate their train signal upgrade program. (In the past few years, a number of emergency signal system failures on the TTC subway have caused shut downs.) In a December 2013 ice storm, the Scarborough Rapid Transit system (SkyTrain technology) was shut down, as were some outdoor sections of the TTC Subway. When these failures occur, congestion at stations, frustration of passengers and media coverage is prevalent.

| TRANSIT SYSTEM | LENGTH (KM) | STATIONS | PASSENGERS /DAY | OTP MEASURE |
|---|---|---|---|---|
| Vancouver SkyTrain | 49 | 33 | 250,000 | 93% – 95% (2 min. over schedule) |
| London DLR | 34 | 40 | 275,000 | 97% – 99% depending upon quarter (3 min. over scheduled departure or terminal arrival, excluding major maintenance cycles) |
| Toronto SRT | 6.5 | 6 | 40,000 | 89% – 98% depending upon month (3 min. over schedule) |
| Miami Metrorail | 40 | 23 | 70,000 | 95% (5 min. over schedule/train) |
| San Francisco BART | 167 | 44 | 400,000 | 92% (5 min. over schedule) |
| Chicago CTA | 360 | 145 | 700,000 | Target of 78 trains not later than 10 min |

In other words, the major delays on SkyTrain and the public's reaction to them are not unique to the Vancouver area. All major transit agencies have to deal with the issues raised by the public and media when major delays occur.

***In the case of major service delays, the differentiator amongst most transit systems, from a general public perspective, is how quickly the agency responds to the failure (recovery time) and the communications to its customers during the event (the waiting time).***

The SkyTrain customer likely wants to know what to expect from its own service, not necessarily what is happening on mass transit systems elsewhere in the world. If the SkyTrain service performs consistently at a high level of OTP, customers will tolerate occasional delays. This is how SkyTrain has been perceived by the public for many years.

As one customer commented following the July 21 delay, *"I have always been very grateful over the last two decades as a SkyTrain user to be able to rely upon the consistency of service over the years..... "*.

On July 17 and July 21, the 5 – 6 hour service delays were unacceptable to customers. They expect more from SkyTrain. The delays, which were definitely a major disruption and inconvenience to the people of Metro Vancouver, were in some ways a wake-up call for TransLink (a number of staff used this phrase). The disruptions showed vulnerability in some of the system elements, and highlighted customer service issues that needed to be rectified. Improvements in these areas will not only enhance the reliability of the system, but they will also enhance the customer experience on a daily basis.

## SECTION 4:

# Vulnerability to Major Delays on SkyTrain

The SELTRAC technology of the 1980s has been upgraded with new control and software elements. SkyTrain was upgraded to the 2nd generation of the SELTRAC technology in 1994. However, SkyTrain did not include the auto-restart module that was available. Therefore, in a temporary loss of communication from the VCCs or VOBCs, SkyTrain SELTRAC technology still requires each train to be manually introduced into the control computer system. Averaging 5-10 minutes per train to enter the necessary data, this equates to approximately 5 hours to fully recover operations, as there are approximately 40-58 trains operating depending upon when a service delay related to a train control communication failure occurs.

Therefore, any weakness of infrastructure that exposes the VCC computers to a shut down mode (so command and control communication links to the on-train VOBCs are disconnected) exposes the system to a major service delay. A hardware/software recovery can occur in a few minutes, but it takes hours to fully recover and get the system back to normal operations. Trains must be manually verified as to location (safety concern), track-way must be visually swept to ensure no blockages or passengers are present (safety), and trains must be manually brought back into service one at a time (current system requirements).

Although not contributing to major delay events, the platform intrusion detection systems do contribute significantly to overall delays. The number of delay events associated with the guideway intrusions justifies mention in this report. Although the guideway intrusion systems are important safety elements at stations, they provide numerous "false" alarms, as they are primarily detecting inanimate small objects or birds in the guideway at station areas. Because these detections cause emergency braking or blockage of the train control block in the station area, and cannot be cleared until a SkyTrain employee has verified the intrusion is "safe", a large number of delay events occur, and vary in duration from 3 minutes to over 15 minutes. Guideway intrusions can represent up to 50% of all delay events and delay times. This may give the impression to passengers that the overall system is having problems.

The resiliency of the SkyTrain system is recognized by the lack of a major shut down over the past decade or longer. However, as infrastructure ages, it does become more vulnerable to failures.

SECTION 5:

# Events of July 17, 2014

1. At 4:38 pm, the SkyTrain Control Centre received notification messages on the monitors that trains were stopping due to lost ATC communications. At almost the same time, TransLink Customer Communications became aware of a system disruption, as a result of a "tweet" from a customer that a train had stopped functioning. Within a few seconds, another passenger report was received of a train stopped at another location.

2. At 4:50 pm, the Operations and Maintenance Centre realized that all trains in the zone covered by VCC2 (Royal Oak/Edmonds to King George Stations and Columbia to Braid/Lougheed Stations) had stopped running. Maintenance staff immediately began checking VCC2 for status.

3. No cause for failure was immediately apparent. A slower than usual blinking light eventually was seen as an indication of a failure of a circuit board in VCC2. The 20+ year circuit board was removed but the newer circuit board spares had different connector interfaces, so it was not possible to insert the new circuit board.

4. A circuit board in a training simulator was used as a temporary replacement, and the VCC2 came back to normal operation at 7:50 pm (more than 3 hours after the system shut down in that section of SkyTrain).

5. Re-connecting the SMC, VCC2 and each trains' VOBC started at 8:15 pm; trains were ready to be re-entered into the ATC system. However, each train had to be manually driven to a defined location of the various track sections to allow the VCC to re-enter the train in a managed process. By 10:33 pm, the system was back to normal operation.

The train operation on the VCC2 section of guideway was down for 6 hours. It took 3 hours to diagnose and resolve the technical problem, and 3 hours to get trains back into service.

During this delay, the public experienced severe delays while "trapped" in their trains. Some trains were at stations and de-boarding was relatively easy. However, for those trains stopped on the guideway, customers experienced very poor conditions.

Many issues happened during that day, but two issues standout the most.

## EVACUATION

Self-evacuation is perceived to be relatively easy by some anxious passengers, but it has a major impact on the SkyTrain system. A minor 5 to 10 minute delay can extend to hours if self-evacuation occurs. For safety reasons, self-evacuation requires that the power must be shut down on the section of track where the vehicle is located, and the guideway must be determined to be safe before power can be restored. Therefore, in periods of major delays, it is critical that SkyTrain staff attend the stranded vehicles on the guideway so passengers on trains can feel assured that recovery of service is imminent.

On July 17, approximately 30 minutes after the delay commenced, people did start to self-evacuate from some trains without authorization from the Control Centre. The outside ambient air temperature was over $20^{C}$. Although the Mark I vehicles had some air circulation, they are not equipped with Air Conditioning (AC). Temperatures increased dramatically in the Mark I vehicles. While power was on, the Mark II vehicles still retained AC and air circulation.

When the on-board vehicle monitoring system provided an indication that doors had been opened on a number of vehicles, power was shut off in that area of the guideway. Without video or direct observation, there was no way to confirm if passengers were evacuating from a train. When doors are opened, it has to be assumed that self-evacuation is occurring from a safety perspective and power to that area of the SkyTrain service has to be shut down. Once power has to be cut to the various sections of the guideway, air circulation to the inside of all vehicles on the shut down section is shut off, further exacerbating the air temperature issues. For those people who remained onboard trains, some waited nearly 2 hours before being evacuated by SkyTrain Attendants.

SkyTrain staff was rallied to attend affected trains. There were approximately 40+ SkyTrain Attendants and Field Supervisors on-duty across the entire SkyTrain service area. This is the typical staffing level on the system during the day shift. The first train was attended at 5:02 pm. (24 minutes after the delay started). However, under the current Line of Sight Operating Rule, only one train can be manually operated at a time. Therefore, even though all trains may have been attended by a SkyTrain Attendant, they each had to wait to be moved one at a time. At 6:38 pm, all passengers were off affected trains. It took two hours to fully evacuate the guideway area under control of VCC 2.

Following evacuation, and after VCC2 had been brought back into service, each train was manually driven to the next communication loop so it could be recognized by the system.

## STATION-AREA CONGESTION

Mass transit systems such as SkyTrain are designed to carry heavy loads of passengers. A single train has a maximum capacity of up to 500 people per trip, doing the job of 10 buses. Because of the dedicated right-of-way, it also functions more effectively in moving people above (or below) congested streets. It is impractical to anticipate that the bus system can match the carrying capacity and demands of the SkyTrain service.

Coast Mountain Bus Company (CMBC) operates approximately 1,045 buses (excluding trolley buses) across the Metro Vancouver area. It typically would only have anywhere from 20 (peak hour) to 50 (off-peak hour) road-ready spare buses available. However, these spare buses are usually spread across three bus storage facilities. CMBC also has a limited pool of spare drivers available, as drivers are being used for normal daily operation, or are off-duty elsewhere as their work shift has finished. Getting some of these buses to the area of SkyTrain service disruption is very difficult and can take over an hour in rush hour periods.

When a major failure occurs on SkyTrain, a complex “bus bridge” response occurs, taking people in between stations (if only one short segment of guideway is impacted) or taking people to/from destinations (for a broader impact area). The primary bus service available for bus bridges are buses normally serving the stations, and buses that have been taken off other less critical bus routes in the surrounding station area.

When passengers did arrive at stations from evacuated trains, there was limited signage or communication available to direct them to the emergency “bus bridge” area. Most passengers arriving from street level, or on bus to the affected stations, were not aware that the system was down. This only added to the confusion and congestion at stations.

## SECTION 6:

# Events of July 21, 2014

At 12:12 pm on July 21, power to the Control Centre Room in the Operations and Maintenance Centre (OMC) was instantaneously lost on a number of critical systems. This impacted operating systems that supported the system-wide radio and public address system, the remote monitoring camera system, as well as all telephones into/out of the OMC, and lights and most computer monitors in the Control Room. In essence, the Control Room became fully disabled. (Because of a recent addition of an individual uninterruptible power supply unit, an Automatic Train Control monitor was still active, and it showed that trains were still operating. This meant that communication between the VOBC, VCC and SMC was still occurring, and passengers were continuing to use SkyTrain.)

At 12:25 pm, the OMC lost power to the four VCCs and the SMC. When the VCCs and SMC shut down, the system safeguards automatically stopped all SkyTrain vehicles in their position at that time. This is a fail-safe response designed into the automatic control system. It took almost 5 hours for the system to get back to normal operation.

### HOW DID THE CONTROL ROOM OF THE OMC LOSE POWER?

In simple terms, power is supplied to the Control Room directly through an Uninterruptible Power System (UPS). A UPS is essential for critical electrical systems which require continuous power. Standard for most UPS architectures, outside power is fed through the UPS (diesel backup generator that instantaneously powers up and continually supplies power when the external power supply is cut-off, or through continuously charging lithium batteries that supply power for a limited time period, or combinations of both). The UPS power then goes through a UPS Breaker Panel to feed the various system elements through sub-panels in the Control Room. In this way, if an external main power failure occurs (i.e. a power cable is cut in the immediate area, or a local hydro blackout happens), power continues to be fed directly from the UPS, through the UPS panel, to critical system elements until external power is restored. If maintenance or retrofit work occurs on the last step of the power supply system – the UPS Circuit Breaker Panel – it is downstream from all power feed elements, including the UPS. When the UPS circuit breaker trips, it is like pulling the plug on your computer.

There has to be a circuit breaker panel for the UPS. The Circuit Breaker Panel distributes the power properly to all system elements to which it is connected. Sub-panels in the Control Room allow power circuits to be shut off for individual system elements for maintenance activities.

The complete power failure in the Control Room occurred as a result of a number of events aligning at one time:

1. For expediency, a qualified Power Technician (electrician) was allowed to work on a system critical power panel, during regular passenger-operating hours. The work was being done to accommodate the new Evergreen Line. The work was not schedule-critical. The work activity presented a manageable risk to passenger service. Although standard operating procedures did not restrict this from occurring during operating hours, they also did not state that it could occur during operating hours.

2. The electrician was allowed to work alone and unsupervised. This was a personal judgment call by the Supervisor who chose to leave the work site and proceed to another building where other work activities were occurring. Again, this was deemed to be a manageable risk and was procedurally acceptable.

3. The electrician was using a non-insulated screwdriver while working on the electrical panel. This caused the initial power failure to the Control Centre at 12:12 pm, when a small voltage arc happened between the screwdriver and the ground circuit. The use of an improperly insulated screwdriver by the electrician was in violation of WorkSafe Regulation 19.10(2).

4. As it was noon, a number of staff were on lunch, including the Vice President of Maintenance who was most familiar with the system. When the initial power failure occurred, it caused phone communication to fail. As a result, he could not be reached to be informed of the emergency situation.

5. When the screwdriver short-circuited the one breaker switch of the UPS, power continued to flow to critical train operating systems like the VCC and SMC through the other UPS circuit breaker switch. Therefore, although the Control Room was "blind", the core elements of the train service were still functional, but no-one really knew that service continued to run. Because communication lines had failed, there was no quick way to verify what was happening across the system. The staff at OMC involved in the emergency assumed that the SkyTrain system had stopped functioning.

6. The UPS Panel, where the circuit breaker failed, is strongly functional. It works as intended, but it is rudimentary in nature. It does not have indicator lights, or a visual way of discerning what circuit has tripped. A loud noise (bang) occurs when the circuit trips but there is no way to easily discern which circuit or, if nobody is there, even if a circuit has tripped. Likewise, there is not an easy way to identify what systems are on what circuit. At home, where one may have each circuit/fuse marked to show which circuit powers the kitchen lights, or the stove, or hot water tank, the panel in the Control Centre Power Room is blank. Circuit illustrations are posted on a door remote from the panel, but they do not show what individual systems run off each circuit. Therefore, when someone said that there was no power to the lights, monitors or PA system, nobody quickly knew what power circuit to check.

7. It took 13 minutes to assess the situation and determine that resetting the main power switch in the UPS Panel was the "best" way to quickly bring back the system. Because staff thought that the entire SkyTrain system was down, they felt that this measure would not have any additional impact to service. (In retrospect, if staff had known that the trains were still operating, there is a software operating protocol that allows the system to come to a controlled stop, where all vehicles are moved to a station and the passengers on trains can self-evacuate at the stations.)

8. When the UPS Panel was de-energized at 12:25 pm, and then reset, power to the VCC and SMC had been temporarily cut. Even though it was shut-down for only a short period of time, the command and control communication link between the Control Room and the trains was cut, and the trains stopped running. Power to the trains continued to be provided but they could not be moved unless manually operated. By 1:13 pm, the computers were operating and system elements were up and running.

9. Because all of the nearly 60 trains had to be manually driven to a designated VCC entry point to allow VCC identification and manual re-entry, it took nearly 4 hours to get the system back to normal operation (5:17 pm).

The entire SkyTrain system was shut down for nearly 5 hours. It took 1 hour to diagnose and "reboot" the system, and 4 hours to get the trains back into service.

Many issues happened during July 21, but three issues standout the most.

## EVACUATION

There was over 45+ SkyTrain Attendants (STAs) and Field Supervisors on-duty across the entire SkyTrain service area. There were also approximately 20 Transit Police on duty, increasing to 40 Transit Police halfway through the delay event.

Because of the loss of communication through the Public Address system, and the length of the delay, passengers either self-evacuated or were assisted in evacuation by available STAs over the next 2.5 hours. Approximately 30 minutes after the delay commenced, people had started to self-evacuate from some trains without authorization from the Control Centre. It took 3 hours to fully evacuate the system (remove passengers from trains and walk the entire system to confirm that no passenger was still on the guideway area). Following evacuation, each train was manually driven to the next communication loop so it could be recognized by the system.

All communications, including door and passenger alarms, had failed between the trains and the Control Centre, so there were no indication that self-evacuation was/was not occurring. Because of this uncertainty, power to all guideway sections was cut off. The outside ambient air temperature was over $20^{C}$. The Mark I vehicles had some air circulation, but are not equipped with AC. Temperatures increased dramatically in the Mark I vehicles. While power was on, the Mark II vehicles still retained AC and air circulation. Once power was cut to the various sections of the guideway, air circulation to the inside of all vehicles was discontinued.

## STATION-AREA CONGESTION

Mass transit systems such as SkyTrain are designed to carry heavy loads of passengers. A single train carries a maximum volume of 500 people, doing the job of 10 buses. Because of the dedicated right-of-way, it also functions more effectively in moving people above (or below) congested streets. It is impractical to anticipate that the bus system can match the carrying capacity and demands of the SkyTrain service.

Coast Mountain Bus Company (CMBC) operates approximately 1,045 buses (excluding trolley buses) across the Metro Vancouver area. It typically will only have anywhere from 20 (peak hour) to 50 (off-peak hour) road-ready spare buses available for service replacement. These spare buses are spread across Metro Vancouver in three bus storage areas. CMBC also only has a limited spare driver pool available, as drivers are being used for normal daily operation or have finished their work shifts and are elsewhere. Therefore, it may take over an hour before these spare buses reach impacted stations during a delay, especially in rush hours.

When a major failure occurs on SkyTrain, a complex "bus bridge" response occurs, taking people in between stations (if only one short segment of guideway is impacted) or taking people to/from destinations (if broader system outages occur). Most bus service in major delays comes from buses already serving the impacted stations or from buses on less critical routes in the area surrounding the stations.

In station areas for passengers who evacuated from trains, there was limited signage or communication available to direct passengers to the "bus bridge" area. Most passengers arriving from street level or on bus to the affected stations were not aware that the system was not operating. This only added to the confusion and congestion around stations.

When the decision was made to close all stations, after they were deemed clear of passengers, this meant that both detrained passengers and newly arriving bus/pedestrian passengers were in an area where PA announcements and bus service route signing was not available. All bus routing information and PA systems were inside the sealed area of the station, so passengers outside of the station area had no source of information.

In many instances, hand-written, paper signs were stuck to posts and on the station-closure grills. Passengers could not see or decipher the signs unless they were right in front of them. This type of signing does not work in crowding, and confusing situations.

## COMMUNICATIONS

The loss of voice and radio communication to the train and the entire SkyTrain system was an extreme limitation on passenger control and system/crowd control. As well, as the general public became aware of the extended delay, telephone calls and webpage enquiries into the TransLink Customer Communication portals overwhelmed the systems. Although the Customer Call Centre valiantly attempted to answer public enquiries, and deal with alternative bus service options, there was a finite number of staff available to answer the telephone calls. Customers waited for many minutes, queued to talk to a call centre staff person, and eventually their calls were dropped. Webpage enquiries were re-directed to "Error" pages, or it took so long for a page to load that the public gave up trying.

## SECTION 7:

# How the System and Recovery Plan Performed During these Major Events

### OPERATIONS

As a result of the system shut downs, TransLink has been reviewing all of its operating and maintenance procedures to reinforce the resiliency of the system. During discussions with management and staff at all levels, a sense of urgency was obvious. System weaknesses are being investigated, risk management scenarios are being developed, emergency evacuation and crowd control protocols are being refreshed based upon the lessons-learned, and all aspects of day-to-day operation are being assessed to improve the reliability of the system, and manage failures in a more effective way.

### EMPLOYEE AND CUSTOMER SAFETY

Most of the technology and system elements functioned as intended during the two major events. Safety was not compromised, as the complete lack of injuries to staff or the public attest. When the ATO system communication was cut, the SELTRAC system stopped all trains in a safe mode in their current position at the time of communication dysfunction. When unauthorized self-evacuation occurred, the Control Centre closed down train service on the affected guideway. The evacuating passengers used the guideway walkways and exits from stations as they were envisioned to be used. Although congestion and inconvenience occurred at station areas, the general public acted in a rational and safe manner. Transit Security and Transit Police were at most of the major stations.

## CUSTOMER SERVICE

SkyTrain operates as a driverless system, with limited frontline staff available to respond to day-to-day customer needs. In a major service disruption, the ability to deal with customer issues is critical but limited by lack of resources and adequate technology options. Staffing levels have been developed to accommodate short-term, low volume service disruptions, but not major service disruptions. In major service disruptions, all available staff are directed to recover trains or attend affected stations. Current staffing levels are not sufficient to attend both all trains and all stations in a timely manner. Therefore, during these major delay events, SkyTrain frontline personnel were conspicuous by their absence and a poor customer service experience took place.

## COMMUNICATIONS

Direct communication to customers during these service disruptions was inadequate and limited. When the delay occurred, the public was informed that updates on the delay would be provided in 15 minutes, and then another 15 minutes, and another, etc. (On July 21, when the PA system came back into service, communications were also limited in their information to customers). The PA system on most of the trains and in many stations was very ineffective due to its quality and volume level. In a major crowding situation, it is even harder to hear the public announcements. Bus drivers on various bus routes to the stations were not aware of the SkyTrain delays and found out about the delays from customers. The Connectivity Call Protocol allowed most senior staff to connect when the delay event became apparent, but not all of management was aware, as they were away from their smartphones, their phones were on silent mode, or they were not constantly checking their emails on a minute-by-minute basis.

## SECTION 8:

# Recommendations for Consideration

### TO MINIMIZE THE LIKELIHOOD OF MAJOR SERVICE DELAYS:

**Identify critical infrastructure elements and verify segregation and redundancy:** Most elements of the SkyTrain system, when they fail, do not have catastrophic system-wide impacts. A cracked rail, misaligned switch, or even an activation of the passenger intrusion system will cause a delay, but the overall system quickly recovers after the repair is made. However, there is a need to isolate and more effectively protect elements of the train control system. It is this control system which, when it fails even for a minute, requires hours to recover through the manual verification of each train. To protect this functionality, the following is suggested:

a. Any non-emergency work that is undertaken on the UPS power supply or command and control system should only occur outside of revenue operating hours (i.e. between 2 am to 4:30 am).

b. If any system needs to be strengthened, it is the supply power to the command and control system. A quick solution would be an independent UPS dedicated for the VCCs. Ideally it would be located between the large UPS circuit panel and the VCCs. In that way, when the UPS panel requires maintenance, the VCCs will continue to function even if the power is accidently shut-off. (It is noted that, during the power loss of the UPS on July 21, a self-contained UPS for the SMC maintained power to that system and its computer monitor).

c. Another area of protection is the incoming power supply to the OMC in Burnaby. With only one power feed coming into the yard, the "heart and brains" of SkyTrain would be stopped if, as an example, a contractor accidentally used a backhoe in the wrong location. A secondary source of power for the yard is essential, so if one fails, power is still supplied from another source. TransLink should investigate additional power redundancy for its yard and control system operations.

d. Another area is to clearly identify the various elements of the UPS (and other circuit panels) so quick recovery can be affected. By separating the circuitry schematic from the UPS panel box (the schematic was on the back of the door to the room), and not even identifying what system elements were on each circuit, meant that the overall Control Centre power supply was exposed to mistakes and errors. The UPS panel should be modified to introduce circuit indicators (an indicator light or a clearly displayed setting to show when a circuit breaker is tripped) and a list of what system elements are running off each circuit breaker. In the case of July 21, if each system element was listed above each of the two UPS circuits, knowing that the lights, monitors, PA, Radio, and phones were not working would have clearly indicated which circuit was tripped.

**Update and fully document procedures for maintenance and operations:** There is a need for more detailed and complete operational procedures and maintenance manuals (trouble-shooting). The SkyTrain system has expanded since 1986 but the document trail has not kept up with changes. Operational procedures appear to be more clearly defined, but Maintenance Procedures do not have the depth necessary for the complexity of the system elements that control train operation. The generation of technologists and maintenance personnel/managers, that started working with SkyTrain since its inception, is well versed in troubleshooting and maintenance knowledge. However, as this generation retires, new hires do not have the same level of experience and knowledge of the specific SkyTrain system elements. Therefore, processes and troubleshooting guidelines need to be prepared now, while the knowledge is readily available. A concerted effort is now underway in the OMC to clearly map out and develop a long list of maintenance procedures.

**Decouple systems to provide greater resiliency:** The opening of the circuit in the UPS panel that controlled a large number of critical system communication elements illustrated a need for additional UPS redundancy and independence. The loss of all communication to/from the OMC, during a major system outage, had a significant impact on the ability to recover. Although there is a tendency to link systems together, it does create a weakness when they are all tied in through one circuit. The loss of that circuit proved to be catastrophic to the overall communication system. There needs to be a systematic risk assessment undertaken for all of the communication media, so the loss of one circuit does not completely shut off all communication channels. As a minimum, it is recommended that a fully dedicated and independent land line (red phone) be established between the Control Centre and CMBC Control Centre so a communication link is maintained at all times, in all but the most catastrophic of emergencies.

**Develop an Asset Management Plan:** There is a need to expedite the development of an Asset Management Plan that documents infrastructure, criticality of infrastructure, age of infrastructure, maintenance/replacement cycle, monitoring program, etc. for all system elements of SkyTrain from the macro to the micro level. Elements of this comprehensive Plan already exist in rail equipment maintenance manuals and individual system maintenance manuals. However, until a comprehensive Plan is developed, current Asset Management occurs in an uncontrolled manner and inter-dependencies are not identified. This Plan is in its early stages of development but should be expedited, with focus on priority, critical infrastructure.

## TO DEAL WITH INEVITABLE, MAJOR DELAY EVENTS:

In all transit systems, no matter how much resiliency is built into the system, failures occur. Anything that is electrical or mechanical will one day fail. Even a replacement item can sometimes fail upon activation. Therefore, in any failure recovery plan, there is a need to prioritize steps that must be taken. When a major system-wide failure occurs that impacts communication to/from trains by the VCCs (July 17 and 21 are examples), staff know that it will take anywhere from 3-5 hours to fully recover the system to normal operation.

Therefore, the first priority in any major service disruption is managing the expectations of onboard passengers; the second priority is station closure, if necessary; the third priority is crowd control at stations, especially key interchange stations. If staffing and technology permits, all of these events should be managed at the same time. Any steps that can be taken to reduce time in a major service disruption will be beneficial.

## RECOGNITION PHASE

The first step is to quickly identify and recognize the potential severity of the situation.

**Replace the guideway intrusion technology:** For almost 50% of the delays, guideway intrusion of some nature has triggered a delay event. These are usually short term delays. New technologies are available using enhanced video camera systems. With intelligent image processing software, it is also possible to differentiate between persons and objects falling into the track area. Changing the current guideway intrusion technology should substantially reduce the frequency of unnecessary delays caused by small object intrusion into the guideway area at stations.

**Notification of necessary staff:** Once the magnitude of the delay has been assessed, there is an immediate need to mobilize senior management and SkyTrain response personnel. The present callout system can be streamlined for instantaneous notification. Depending upon the severity of the incident, messaging can be broadcast using smart phone technology to who needs to know. Presently, TransLink relies upon a somewhat cumbersome text/email/callout system to individual smart phones. However, if one does not look at a phone for messages, it is easy to be unaware of a major incident for some time. There are Warning System Apps/technologies available that can instantaneously send an audio alarm signal to one's smart phone, so those who need to know of an incident, are aware of it.

**Deploy a single emergency radio frequency:** TransLink should have a single radio frequency, so all transit system elements of TransLink (including the Transit Police and the Canada Line) can communicate during a major emergency. Presently, each element of TransLink services has its own radio frequency for day-to-day operation. When an emergency occurs, all communication occurs through the CMBC Connectivity Call Procedure. Connectivity Calls are an effective tool for some aspects of emergency management. However, passing one message from one radio frequency to another can be time and information-consuming in those critical moments when decisions and direction must occur fast.

**Inform bus drivers of major service delays:** During a SkyTrain emergency, it is important that messaging get out to all bus drivers feeding the SkyTrain stations so they can notify bus passengers immediately of the service disruption.

## EVACUATION PHASE

In both incidents, self-evacuation occurred in approximately 30 minutes after the trains service stopped. Self-evacuation triggers an instantaneous signal in the Control Centre and power is cut to the section of guideway where passengers could be evacuating from a train. This is done for safety reasons. When this occurs, power is cut to the impacted train and any other train in that section of de-energized guideway. Power to the lighting and air circulation elements are also cut-off on the affected trains. This further aggravates the situation on the train(s), and a full self-evacuation can be anticipated. When self-evacuation occurs on only one train, it can take over an hour to get train service back to normal operation.

By recognizing the magnitude of the delay earlier, response personnel can be called in to assist with prioritizing the movement of trains or evacuation of passengers. In a major delay event, when power to major sections of SkyTrain is shut down, additional staff should be used in the train evacuation process. In the two delay events under investigation, many of the STAs who arrived at stations, assisted with the removal of passengers from trains at the stations, rather than dealing with stranded trains on the guideway. Transit Security personnel were assigned to the bus loop areas of the various stations, rather than focusing on evacuating passengers from stranded trains. Although crowding and concerns were present in station and bus loop areas, the immediate need was for evacuating trains so the system could be brought back to normal operation as quickly as possible.

The Transit Police were present to deal with rowdiness or property damage matters. The Transit Police also assisted in securing and closing approximately 13 stations, and assisted in crowd management at 7 bus loop areas. It is noted that the Transit Police are currently assessing their ability to help in train evacuations. These are operational areas that they have traditionally avoided. It is now understood that major shut downs create situations of panic and confrontation. Therefore, the Transit Police are looking at proactive policing, rather than a reactive approach. A full assessment of the actions of Transit Police during the July 21 event is being undertaken by them.

**Prioritize STA activities:** The first priority is to access passengers on stranded trains on the guideway. Passengers can evacuate themselves from trains at stations (during a major delay, the close headways of each train means that nearly 50% of all trains are at platforms).

**Manual train operation with onboard passengers:** If the communication from the VCC(s) to the trains has been compromised, the Control Centre has to recognize that many hours will lapse before normal operation recommences. Therefore, a priority action needs to be manually driving the impacted trains with passengers onboard to stations, using all available qualified STAs. This means a change in the Line of Sight Operating Rule. The current Line of Sight Operating Rule only allows one vehicle to be manually driven at a time. Therefore, even though a train may be attended by a SkyTrain Attendant, it may have to wait a very long time before it is allowed to move, as another train may be under manual operation elsewhere. The Line of Sight Operating Rule is being assessed and modified to permit manual operation of multiple trains, under various defined operating scenarios. This will significantly improve the system recovery time.

**Use more staff to deal with passenger evacuation:** When a major delay occurs that requires evacuation, power needs to be shut-off to the effected guideway area as soon as practical. This will allow all available TransLink staff (STAs and others) to assist in evacuation of passengers from trains (especially in hot weather conditions). Presently, only STAs are allowed to assist passengers with evacuation. This limits the ability to quickly access stranded trains.

**Walkway delineation:** During evacuation (whether controlled or not), there is a need for better identification of the walkway area of the guideway when lighting levels are low, or to assist individuals with poor peripheral vision or depth perception. Lighting is a common feature of most emergency evacuation routes in buildings and other confined spaces. On July 17 and 21, evacuation occurred during daylight hours; however, if it had been early evening or in the winter months, the evacuation could have been more complicated. A reasonable-spaced array of low profile, surface-mounted lights (such as LED lights) at the edge of the walkway would aid passengers as they walk along the guideway. If the lights were half-shielded, they would also indicate the direction to the closest station (depending upon where the train is positioned, the path to the closest station would only be visible by the illuminated portion of the light). It may also be possible to have the circuits for the lights tied-in with the power circuitry of the guideway section so, when the power is cut on an individual guideway section, the lights only become illuminated on that section. TransLink should investigate ways of improving the visibility of the walkway edge.

## RECOVER PHASE

Once passengers have been cleared from the track area and the system has been secured, the time-consuming process of re-entering trains begins. Each train has to be physically located and manually entered back into the VCC system by driving each train over an inductive loop, one train at a time. Between July 17 and July 21, personnel of SkyTrain identified ways to reduce vehicle manual input time from 10 minutes to 5 minutes. However, even at 5 minutes per vehicle, it can take many hours to recover all impacted trains.

**Upgrade SELTRAC technology:** The existing SELTRAC train control system is based upon 30 year old logic and technology. Although it was upgraded in 1994 to the 2nd generation of SELTRAC, an upgrade to the auto-restart feature was not included. This new technology feature could allow trains to be quickly detected after a power outage has been corrected. TransLink currently has identified the need to go to a 3rd generation of SELTRAC technology. The upgrade to an auto-restart feature has not been included. Due to the severe impact created by manual re-entering of vehicles into the system in times of a failure of the train communication system, it is recommended that TransLink expedite investigation of the auto vehicle re-start feature. The long delays created by the need to re-enter trains into the command computer system are very impactful to the customer and the station areas.

**Install guideway CCTV coverage:** To reduce the manual (and time consuming) process of identifying train location and guideway status with the current SELTRAC system, CCTV coverage of the guideway could be considered. High profile, good quality cameras pointed down the guideway would assist in identifying vehicle numbers/train locations, as well as discerning if passengers are on the guideway during self-evacuation. CCTV cameras are now available for both day and night-time use, and are relatively inexpensive to purchase. (It is noted that, if other improvements are implemented, which reduce tendencies for self-evacuation, this infrastructure investment could be deferred.)

**Install platform edge CCTV coverage:** CCTV cameras would also be helpful in dealing with guideway intrusion, both inside and outside of station areas, reducing the delay events associated with guideway intrusion alarms.

**Improve onboard announcements:** In order to reduce the probability of self-evacuation, SkyTrain has introduced a protocol for onboard announcements to be broadcast immediately upon a delay occurring and every 2-3 minutes during the delay. A cautionary comment is made here to ensure that the message is not repetitive and is informative. The public has a limited patience for repeat, "canned" messaging; they are looking for facts and updates so they can plan their actions or advise others of what is happening.

**Improve the quality of PA announcements:** The Passenger Announcement (PA) audio quality is inconsistent across vehicles and stations. The clarity of message can be very poor on a number of SkyTrain vehicles and in a number of the station areas. This is a common problem throughout most of the transit world, and in most public areas where PAs have to operate in outdoor environs.

Improvements in audio technology are available. The PA system on new TTC subway vehicles allow audio messages to be easily discernible, as does the new PA system on the retrofit GO Transit bi-level rail fleet. With a concerted effort, it is possible to upgrade amplifier systems and speakers to improve the quality of the message. It is recommended that a study be undertaken to take the necessary steps to upgrade these vital public communication channels. It should start with the vehicle audio system, where passengers are most vulnerable in times of emergency, and expand to station areas (most stations will have to be individually customized for amplification and speaker location). It is an upgrade project that can span 3-5 years.

**Improve visibility of staff:** Transit systems have entered the world of high public expectations when it comes to customer service. The public perceive that they pay a high price for regular transit use, and expect good quality service in return (nearly 30% of comments related to the July 17 and 21 incidents from the public dealt with issues of compensation due to the delay). When the system is operating well, the public very seldom needs to see a transit representative, and technological changes have made this need for staff to be even more prevalent – smart card fare systems and automated fare dispenser machines eliminate the need for ticket sellers and automated train control eliminates the need for a driver. However, when a failure or system breakdown occurs, the need for a human interface becomes very important. As service frequencies increase along with passenger volumes, the need for a few "staff" to assist the many "customers" looking for help increases at the same time.

It is important that transit staff be highly visible during an emergency. STAs traditionally wear white shirts and dark pants; on a crowded platform they blend in with the crowd. If all SkyTrain frontline employees wore highly reflective, brightly coloured vests (a similar approach was taken by Transport for London, and the Canada Line), there would be a greater sense of presence of the "operators" of the system, a perception that there are more staff around the system, and a clearly highlighted individual to reach out to for help, when it is needed.

**Adequately allocate staff for quick response:** Frontline staffing levels and their service area locations should be established and allocated so qualified staff can, at any time, assess a guideway intrusion alarm at a station in not more than 10 minutes. A staff response time of approximately 20 minutes is suggested to access a stopped train, so the train can be either manually driven to a station or controlled evacuation of the train can occur before self-evacuation starts. These response times are essential until other elements of the system are introduced (SELTRAC module and new guideway intrusion technology). This may, depending upon available resources, necessitate the temporary hiring of additional complement.

**Improve visual communications at stations:** Over 25% of customer comments during the July 17 and July 21 delay events were related to poor communication. When any minor or major interruption occurs, effective communication is what retains calm and control. The need for an improved and informative audio message has previously been mentioned.

However, imagine that you have just been evacuated off a train and you have been brought to a station in a neighbourhood that you have never visited. Imagine as a customer what is going through your mind – Where am I? Am I safe? How do I get home from here? Do I have to pay to get on the bus? All of these questions are flowing through the stranded passenger's mind, and the only way to relieve the angst is through communication.

Each station needs to be reviewed for the effectiveness of its wayfinding signs. Signs should clearly indicate the various destination points at each exit, and where the bus pickup location is, as well as the emergency bus bridge location. At a number of stations, the signage is poor. Although "emergency exit" signs are displayed on the platforms, actual street exits and exit directions for bus areas are not prominently displayed. Wayfinding at station areas is important for stranded passengers, and for regular customer service considerations.

When an STA arrives to initiate evacuation, they should not only focus on telling passengers how to safely walk down the guideway, they should also inform passengers of what to expect when they get to the station. A helpful statement could be useful, such as, *"When you get to the station, a bus bridge is being developed. The buses will take passengers to various destination points, but expect large crowds and delays. Look for and follow the signs with a bus image on them"*.

**Inform passengers about what is around a station area:** A clear map could be made available at each station, showing what attractions, streets or restaurants are available within a 10 minute walk of the station. The City of Vancouver has this type of signing in parts of its downtown for tourism purposes. Expanding this signage to all SkyTrain stations, and to encompass a 10 minute walk area from the station, could help to disperse a small element of crowding in station areas. (Partnerships with the local business community could be explored to reduce the cost of this signage by advertising destination names and locations on the signs.) Waiting passengers, who are unfamiliar with the neighbourhood around the station, could be subliminally encouraged to wait elsewhere. By knowing what is available in the area, some passengers could meet their spouse/partner at a restaurant rather than the station. The station area will be crowded and hard to access by car, so anything to remove people from the crowded area should be attempted.

**Extend passenger information systems to station entrances:** When stations are closed due to system failures, all of the audio and visual communication mechanisms are locked inside the station area. On July 21, passengers were left to fend for themselves when stations were closed. Some SkyTrain staff were available and attempted to direct people to bus loading areas over the din of the milling crowd, but this proved ineffective in dealing with the large crowds across the dispersed area of the station. (A sufficient number of battery-operated bullhorns should be available at all stations for use by a number of SkyTrain personnel). SkyTrain should aggressively expand its passenger information systems to the exterior of 80+ entrances to/from the SkyTrain stations. A system of static and programmable signage (electronic display boards) should be located at the entrances. Static signs/maps should be placed to indicate what regular bus stops are available and where the bus bridge stops are located (permanent, pole mounted "bus bridge" signs are presently being considered by CMBC so emergency stop locations can be prominently seen). Also at the entrances, strategically located electronic monitors should be installed to inform customers of the system status and other station-related information. This can be an expensive and lengthy project to undertake, but it can be undertaken in a phased manner, either by station or by priority entrance.

**Improve responsiveness of the TransLink Customer Call Centre:** On July 17 and 21, the demand for information from customers overwhelmed both the incoming public telephone lines, as well as the website. As many customers had access to smart phones, stranded passengers attempted to access the Call Centre of TransLink. Phone lines and Call Centre Operators could only respond to so many calls, and many calls were "dropped" by the phone system. TransLink should investigate staffing levels in its Call Centre, or investigate options for increasing staff availability during major delay events.

**Improve responsiveness of the TransLink webpage:** Many telephone callers also reverted to the TransLink webpage to get status updates. The webpage was, of course, already overloaded from people trying to access the site for service updates and alternative travel choices. With smart phone technology, customers on stranded trains attempted to access the TransLink website, as did passengers waiting at home, office or elsewhere.

To increase customer service during outages, there may be an opportunity to handle more webpage inquiries by answering obvious questions quicker, and thereby keeping an individual on the website for a shorter period of time. Because the Service Status and Alternative Route features are embedded within the main homepage of TransLink, the public is forced to stay on the website longer than normal. In the future, when a major event happens, TransLink could automatically upload the SkyTrain Service Status page and *prominently* display it on the first page of its website, or temporarily divert all incoming "hits" on the TransLink homepage to the SkyTrain service status webpage. TransLink should investigate options to save response time for inquiring passengers and reduce the duration of visit times on the website during major delay events.

TransLink is upgrading the resiliency of the website to deal with higher levels of contact volumes. The current contract is set to expire in early 2015, so this increase in website capacity may not occur until 2015.

**Expand delay messaging to bus scrolling screens:** When a major service disruption occurs, all efforts need to be explored to stop prospective passengers from coming to the SkyTrain stations when the system is in failure mode. Many of these customers are located at remote bus stops waiting to be taken to the SkyTrain station. If these customers had up-to-date information on service disruptions on the SkyTrain, they may consider an alternative bus route (i.e. staying on the 41st Avenue bus to get over to the Canada Line instead) or delaying/deferring their trip. It is possible, using the existing bus scrolling technology, to scroll SkyTrain service disruption information along with regular bus route information. Provided the bus drivers have the information (see earlier comments on communications to bus drivers), they can start to scroll the service status message by pulling up the message from the pre-programmed portfolio.

**Reach out to the media and local municipalities:** During a major emergency event, these groups can act as heroes for crowd management and information dissemination. The public want to hear a message from them, and look to them for leadership. Their message can have a calming influence, and they can act as a conveyor of "what to do". During a major delay event, all focus must be on recovery and passenger needs. By providing timely and direct information to the media during an emergency, the media can pass this information out to a broader audience. Likewise, local municipalities, if contacted early, can assist in information decimation through their social media channels, and arrange for emergency response agencies to assist in traffic control and crowd management in station areas. TransLink and the local municipalities should convene regular meetings to identify and explore opportunities for cross-jurisdictional assistance. The City of Vancouver has tabled a number of supportive and cooperative suggestions. TransLink is proactively reviewing the ideas suggested by the City.

**SECTION 9:**

# Staffing Needs of System

SkyTrain is an automated, driverless system. Although frontline staff are roaming the trains, stations and bus loop areas of the transit system (SkyTrain Attendants and Transit Security), it is a very low number of employees compared to the length of the system, the number of stations, and the number of trains in service. As indicated on the July 17 and 21 delay events, there were approximately 40-45 frontline staff stretched across the entire system. They had to deal with evacuation from trains, train location identification, guideway clearance, manual operation of the trains and crowd-management issues at stations.

When all of its components are working, SkyTrain works exceptionally well – better than many large, rail-based transit systems in North America. With headways less than 2 minutes in rush hour, most passengers seldom wait for a train.  However, with its 22 hour/7 day a week operation, high passenger load levels and its transportation importance to the Metro Vancouver economic and social fabric, it needs additional frontline staff available for its day-to-day operation. SkyTrain can then be more-readily available to deal effectively with emergency situations.

When a major service delay occurs today, there is not enough STA staff available to effectively deal with evacuation. At the same time, there is a daily need for more human interaction at stations as more passengers equate to more needs related to customer service. Manpower reduces the risk, provides better customer service and, if tied in with other improvements to the system, enhances the overall customer experience. TransLink should gain from this more positive public perception.

In 1986, SkyTrain's budget was approximately $55 million (2014$). At that time, the system was new, warranties applied to many of the components, and passenger loads were low. By 2014, the operating budget has doubled from its 1986 level, but operating needs have increased significantly higher.

The present operating budget has to deal with:

- a four-fold increase in passengers,
- a four-fold increase in kilometres driven by the trains,
- 30 year old fleet and infrastructure, and
- high expectations from the public on customer service.

SkyTrain needs more operating dollars to serve their growing passenger base.

In dealing with minor and major service delays, the roaming area of frontline staff service should be established, and/or appropriate staffing levels allocated, so qualified staff are not at any time more than 10 minutes from a station (to deal with the guideway intrusion alarms and the crowding that may occur at any time at a station), or a target of 20 minutes from a stopped train (so the train can either be manually driven to a station or for controlled evacuation). It is recognized that it may be difficult to access trains within this period of time at all locations, because of the distance from adjacent stations or access points. However, if most trains are accessed within this reasonable time period, improved customer service will be achieved. This response time length is essential until other elements of the system are introduced (SELTRAC module and new guideway intrusion technology). This may, depending upon available resources, necessitate the temporary hiring of additional complement.

Additional frontline staff will provide a significant customer service benefit. Additional staff at stations would be available to aid in minor system recovery events (guideway intrusion verification is just one example), and would provide a perception of additional security for passengers. They would also be available to assist passengers who are new to the system and are attempting to understand its complexities.

TransLink has an opportunity, through its new Compass Card and Fare Gate project, to re-define roles and responsibilities of STAs and Transit Security. This could provide a broader base of perceived safety and service coverage across the system. There is some consideration to utilize temporary staff for assistance at all stations for the new fare gate activation period. These staff could also be trained to assist with investigation of guideway intrusion alarms, freeing up STAs to deal with other system needs.

SECTION 10:

# Conclusion

In analyzing the July incidents, it is important to note that SkyTrain is a safe system. The SELTRAC train control is designed to stop all trains in a safe mode, and a guideway walkway is available for SkyTrain personnel, and for passengers to evacuate from trains. The fact that these two major delay/ evacuation incidents occurred, without any injury occurring to staff and the public, attests to its safety focus. The system performed as intended. Trains stopped as soon as operating command communication was lost. Self-evacuation and supervised evacuation was relatively calm and respectful of the system. The passengers stayed on the walkways and moved to the refuge of station areas.

When significant incidents such as the two incidents in July occur, there are always opportunities to learn from what transpired and follow through on improvements. A number of improvements are available to improve the operations, safety, customer service and communications practices of SkyTrain.

Key to these elements is modifications to the re-start protocol of the SELTRAC technology, so an automatic train reload can occur after system recovery. Also required is a new guideway intrusion technology to remove the high occurrence of unnecessary alarms causing delays on a daily basis to the system. Other elements, related to operating and maintenance procedures, staffing resource capabilities, customer service enhancements and new technology applications, will improve the capability of SkyTrain to respond to major delays.

Some of the recommendations can be undertaken quickly, as they are operational in nature, and do not require major studies or capital cost outlays. Other recommendations have to be studied to determine the best options available and then, because of their scale, some recommendations may take a number of years to fully implement (i.e. major signage and PA improvements at stations). The critical action is starting the assessment and moving toward improvement. It may also be possible to defer a recommendation, if other actions are taken. For example, if improvements to staff response times can occur, it may be possible to forego full guideway CCTV coverage. Likewise, if CCTV coverage of the platform edge is enhanced, so guideway intrusions can be remotely assessed, it may be possible to defer replacing the guideway intrusion. In moving forward with improvements, the intent should always be to enhance the day-to-day customer service experience of all passengers using the service.

The following chart highlights the suggested improvements. It should be noted that the costs are order of magnitude. Aside from the cost associated with increasing staff to improve response times, all budget estimates are capital costs and do not include increases in operating costs which may be introduced with the new infrastructure elements.

| IMPROVEMENTS IN OPERATIONS: | BENEFIT | ESTIMATED BUDGET ALLOCATION | FULL IMPLEMENTATION |
|---|---|---|---|
| Install an auto re-start component to the SELTRAC technology package. | If a major failure occurs which impacts the command and control communication between the trains and Control Centre, the current SELTRAC technology on the Expo and Millennium Lines require 3 to 5 hours to get service back to normal operation due to manual re-entry of trains into the system. An auto re-start component could allow system recovery in a significantly shorter period of time. | **$5,000,000 (include in 3rd generation upgrade for SELTRAC)** | **36 months** |
| Modify the Line of Sight Operating Rule to allow manual operation of multiple trains at one time. | Allows a SkyTrain Attendant to quickly drive a train to the closest station, if the train is operable, reducing the probability of self-evacuation. | **Nominal** | **2 months** |
| Install system continuity redundancies for critical system elements. | If critical systems fail, basic train service is not significantly disrupted. | **$5,000,000** | **30 months** |
| Work on system-critical control components should only be allowed during non-revenue operating hours. | If failures occur, they do not have significant impacts on the travelling-public. | **Nominal** | **Complete** |
| Update and create new operating and maintenance manuals, and procedures. | As long term employees retire, much of the wisdom of the system departs with them. There should be a knowledge transfer to new hires. | **$2,000,000** | **24 months** |
| Decouple important systems and develop an Asset Management Plan. | If one system fails, it does not completely impact other systems (detailed Asset Management Plan that recognizes dependencies on other system elements). | **$6,000,000** | **48 months** |
| Upgrade the guideway intrusion system. | Reduces the unnecessary delays created by the guideway intrusion system and creates a more responsive alarm recovery process. | **$10,000,000** | **24 months** |
| Introduce a single emergency radio band for all TransLink Operating groups. | Allows BCRTC, Canada Line, West Coast Express, Coast Mountain Bus and Transit Police to communicate through a single channel, avoiding time delays and potential confusion in re-packaged messages to staff in differing operating divisions. | **$1,000,000** | **8 months** |
| Establish an "alarm-based" warning system for appropriate management and supervisory staff. | Appropriate supervisory staff can be more proactively advised of an emergency situation through an audio alarm to their smart phone. | **$500,000** | **6 months** |
| Set frontline staffing levels and their service area locations so qualified staff can respond within a specified period of time. | This will more quickly deal with alarms from non-critical guideway intrusions and the management of stopped trains. | **$1,000,000/year** | **6 months** |
| Install system-wide CCTV coverage. | The Control Centre could see train location data, guideway activity or other intrusion/security matters when system failures or alarms occur. This could be deferred if improved response times to delays occur. | **$5,000,000 (if necessary)** | **24 months** |

| IMPROVEMENTS IN SAFETY: | BENEFIT | ESTIMATED BUDGET ALLOCATION | FULL IMPLEMENTATION |
|---|---|---|---|
| Install platform edge CCTV coverage. | Increased station CCTV coverage of the platform edge and surface of the guideway will assist in responding to guideway intrusion alarms. This could be deferred if improved response times to delays occur. | **Included in previous recommendation** | **24 months** |
| Communicate during lengthy delays that windows can be opened on some trains. | This will reduce the sense of claustrophobia in the vehicle, and reduce the internal heat build-up on sunny, warm days. | **Nominal** | **Complete** |
| Install a low profile lighting system along the walkway edge. | This will better define the walking path area when light levels are low, and assist evacuating passengers, especially those with depth perception or limited peripheral vision. | **$5,000,000** | **30 months** |

| IMPROVEMENTS TO CUSTOMER SERVICE AND COMMUNICATION | BENEFIT | ESTIMATED BUDGET ALLOCATION | FULL IMPLEMENTATION |
|---|---|---|---|
| Increase visibility of frontline staff. | This will make staff easily recognizable in times of minor or major crisis. | **Nominal** | **2 months** |
| Improve the quality of the Passenger Address System. | The quality of the current Passenger Address system on most trains and stations is at a low level. Announcements can be easily missed. | **$15,000,000** | **60 months** |
| Introduce programmable-messaging signboards, fixed signage and PA speakers at the entrances to all stations. | When the system is closed, important communication can be conveyed to waiting customers. This should be done in conjunction with a complete review of wayfinding signs at stations. This is also an added customer service feature when the system is operating in a normal mode. | **$15,000,000** | **48 months** |
| Strengthen the resiliency of the Call Centre phone system and webpage. | Customers need to get information in a time of a major delay event. | **$500,000** | **12 months** |
| Establish protocols and communication links with local municipalities. | In emergencies, local municipalities and their first responders can assist in managing traffic, pedestrian crowding and decimation of communication messages to the public. | **Nominal** | **6 months** |
| Introduce a bus scrolling message advising of major delays. | Customers can be informed before getting on the bus feeder service and make alternative choices. This capability already exists on Coast Mountain buses. | **Nominal** | **3 months** |