Evaluation of Joint Operations in the Downtown Seattle Transit Tunnel

August 21, 2001
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EXECUTIVE SUMMARY

This report documents the findings of studies performed by Sound Transit, in cooperation with King County Metro, concerning the modifications needed to operate both light rail and buses in the Downtown Seattle Transit Tunnel (DSTT).

As a result of these studies, this report concludes:

- With modifications, advances in equipment and operational changes it is feasible to operate both trains and buses in the transit tunnel.
- Downtown surface streets will not be clogged with increased bus volumes. Under joint operations, bus volumes on downtown surface streets are projected to remain at or below the estimated 2002 surface bus volumes until at least 2016 when rail might be extended past Northgate or to the Eastside.
- Until the light rail system is extended, joint operations will allow the most efficient use of the transit tunnel. Joint operations will provide flexibility for the transit tunnel to serve commuters who come into downtown from the east, north, and south. Joint operations will maximize use of the transit tunnel until the rail system is built further north and other downtown capacity issues like the Alaskan Way viaduct are addressed.
- In the long term, the most efficient use of the transit tunnel is rail-only. As a rail-only tunnel, it can ultimately carry three times the number of passengers as a bus-only tunnel.

Downtown Seattle is the transportation hub of Central Puget Sound and its continued vitality depends on easy access to jobs, stores, housing and cultural and sporting events. As Seattle continues to grow, transit buses and trains will provide an increasingly important transportation alternative for those living, shopping, working or visiting downtown.

The 1.3-mile DSTT is already helping keep downtown Seattle moving. The tunnel was opened in 1990 to enable transit buses to operate through downtown free of surface street congestion. Today there are 25 bus routes running through the tunnel with more than 23,000 boardings every day.

But the transit tunnel was also built with the idea of someday running light rail trains. This report, which builds upon the information presented in the 1998 Downtown Seattle Transit Tunnel Report, shows that with modifications, advances in equipment and operational changes it is feasible to operate both trains and buses in the transit tunnel. The 1998 report’s major concerns about the joint operation of trains and buses have been answered.

For instance, a new tunnel signal system has been developed that would maintain a safe distance between buses and trains. With that system in place, trains and buses would not be allowed to operate in the same tunnel section or be in a station at the same time.

Joint operations can continue until after the Central Link light rail system expands past Northgate, which is likely past 2015 or beyond.

Under joint operations the afternoon peak-hour rail and bus passenger capacity (two-way) in the tunnel is estimated at 16,480 passengers.
There is an increased interest in studying joint bus/rail operations in the transit tunnel. While the entire Central Link light rail segment is envisioned from Northgate to South 200th Station past Seattle-Tacoma International Airport, the Sound Transit Board is currently considering starting with a smaller initial segment. The smaller segment would run from about the airport to an interim north terminus at either the Royal Brougham Station or the Convention Place Station located inside the transit tunnel.

As part of the study of that initial segment, the Board is also interested in the possibility of joint operations in the transit tunnel. This report looks at some of those issues.

**Bus Volumes**
- Today there about 470 buses operating on the surface streets in downtown Seattle and 140 buses running in the transit tunnel during the afternoon peak-hour. Following the two-year period it will take to retrofit the transit tunnel for light rail, the surface bus volumes are expected to return to levels similar to today with joint operations.
- With joint operations, bus volumes on downtown surface streets are projected to remain at or below the estimated 2002 surface bus volumes until at least 2016 when rail might be extended past Northgate or to the Eastside.

**Transit Tunnel Capacity**
- A computer simulation model estimates that with light rail trains arriving about every six minutes, up to 60 buses and 10 trains could operate in each direction in the transit tunnel during the afternoon peak hour.
- The one-way, peak-hour capacity for light rail only in the transit tunnel is estimated at 16,440 passengers per hour. The one-way, peak-hour capacity for buses only in the transit tunnel is estimated at 5,700.
- Under joint operations, the one-way peak-hour rail and bus capacity in the transit tunnel is estimated at 8,240 passengers.

**Ridership**
- With an interim north terminus at Convention Place and service to South 200th Station in SeaTac, the 2020 daily ridership for joint operations is estimated at 50,000 total daily rail boardings, with 27,600 of these boardings taking place in the DSTT. Rail-only use of the DSTT with bus intercept terminals at Convention Place, International District and Lander results in 64,200 daily rail boardings, however, most of the increase in daily boardings are related to the forced bus to rail transfer at Convention Place, International District and Lander.

**Speed**
- Under joint operations, rail speeds would be reduced to better match bus speeds. This will not significantly change the travel time.
- Bus riders will experience an average 1.5 minutes of delay as buses wait to merge between trains in the transit tunnel.
New Bus Technology

- King County Metro and Sound Transit plan to begin testing a low-floor hybrid diesel-electric bus which would eliminate the need to operate tunnel buses that use trolley poles and would increase operating flexibility and reliability in the transit tunnel.

- This hybrid bus will also allow level boarding at the stations by using a ramp instead of a lift for riders in wheelchairs.

- King County Metro and Sound Transit plan to have a fleet of these hybrid buses in place starting in 2004 as replacements for the current Breda dual mode coaches.

- Testing later this year will determine whether these buses will be able to operate through the tunnel exclusively on stored electric power or if some use of the diesel motor will be required.

- Joint operation in the transit tunnel is still feasible even if Metro decides to replace its fleet with conventional buses using electric trolley poles. A solution for buses with poles crossing the light rail overhead system has been developed, but additional design and testing will be required.

Cost

- The retrofit of the transit tunnel for rail use only is estimated at $25 million (YOE). The additional cost to retrofit the transit tunnel for joint operations is estimated at $43 million and covers such items as trackwork, the overhead electrical contact system, communications and signal systems, emergency ventilation system and the fire suppression system.
1. INTRODUCTION

1.1 Purpose
This paper describes the issues surrounding the potential of operating both light rail trains and buses in the Downtown Seattle Transit Tunnel (DSTT) when rail operations opens in 2008 or 2009. The information provided is intended to give the Sound Transit Board sufficient information to determine if staff should be directed to further evaluate and refine a joint operating plan for the DSTT.

1.2 Downtown Seattle Transit Tunnel (DSTT)
The DSTT was opened in 1990 to enable bus transit service to operate through downtown Seattle free of surface street congestion. Today 25 routes operate in the transit tunnel, providing 1,200 weekday bus trips.

The DSTT is 1.3 miles long and extends from a southern portal under Airport Way and Fifth Avenue to a northern entrance at Olive Way and Terry Avenue. There are five stations in the DSTT as described below.

- **Convention Place Station** – This open-air station is located at Ninth Avenue just northwest of Pine Street at the north entrance to the DSTT. Buses traveling to and from Interstate 5 and the Eastside via SR520 as well as areas north of downtown Seattle enter and leave the DSTT through this station.

- **Westlake Station** – Located under Pine Street between Third and Sixth avenues, this station is in the heart of downtown Seattle’s retail core. From the station mezzanine there is access to the Bon Marche, Westlake Center, and Nordstrom.

- **University Street Station** – This station serves the downtown financial district and is located under Third Avenue between Union and Seneca streets. The station has entrances in the Cobb Building parking garage, the Washington Mutual Tower, and the Benaroya Concert Hall.

- **Pioneer Square Station** – Located under Third Avenue between Cherry Street and Jefferson Street, this station is in Seattle’s government center and is within a few blocks of the historic Pioneer Square. The station has entrances in the Public Safety and Lyon buildings and is next to City Hall Park.

- **International District Station** – Located at Fifth Avenue South and South Jackson Street, the International District Station is the south entrance to the DSTT. It serves buses traveling to and from the areas south of downtown Seattle and areas to the east via Interstate 90. From this station, riders can reach Safeco Field, the new football stadium, buses serving Rainier
Valley and Beacon Hill, the Waterfront Streetcar and King Street Station which serves both Amtrak and Sounder commuter rail service.

1.3 Past Joint Operation Studies & Decisions

The issue of joint operations has been discussed and studied since the decision was first made to construct the DSTT in the early 1980s. Early studies identified technical and operational issues associated with running both buses and rail in the transit tunnel, but none that would make joint operations infeasible.

Sound Transit, in cooperation with King County Metro and the City of Seattle prepared the Downtown Seattle Transit Tunnel (DSTT) Report in September 1998 to examine the feasibility and impacts of joint bus/rail operations in the DSTT. The results were incorporated into the Central Link Draft and Final Environmental Impact Statement (EIS). Key findings of the 1998 report were:

- **Limited time** – Depending on the growth in rail ridership and the timing of future rail extensions, joint operations might be possible for no more than 2 to 10 years. This was based on the assumption that additional rail corridors would be added at a faster rate than now appears likely.
- **Fewer buses** – Currently 70 buses per hour per direction operate in the transit tunnel during the peak hour. Due to operational constraints, under joint operation with trains operating every four minutes, a maximum of 30 buses per hour would be able to operate in each direction.
- **Safety concerns** – The system must depend on operator judgement to maintain a safe stopping distance due to lack of a fail safe signal system when combining bus and rail operation.
- **Slower** – With joint operation, light rail vehicles would operate an average of two minutes slower and buses would operate two to four minutes slower than they do today.
- **Less reliable** – Buses could not pass other buses or light rail trains and there would be additional conflicts in the staging areas, resulting in less reliable service for both buses and rail.
- **Replace buses** – To maintain joint operation, King County Metro would need to replace a portion of their tunnel bus fleet with higher cost dual mode bus technology.

The cost of the transit tunnel modifications, need to purchase a new dual mode bus fleet, and potential for only operating 30 buses in each direction for 2-10 years led to the conclusion that joint operations, while feasible, was not desirable.

In February 1999, based largely on the findings of the 1998 report, the Sound Transit Board and the Seattle City Council made a preliminary recommendation that the existing transit tunnel be converted to light rail only operation.

In November 1999, after completion of the Central Link Final EIS, the Sound Transit Board reconfirmed its decision to retrofit the transit tunnel for light rail only operations as part of the locally preferred alternative (LPA). In addition, the Board committed to working with King County Metro and City of Seattle to provide surface improvements on downtown Seattle streets to accommodate displaced buses. Prior to the Board action, the Seattle City Council made the same recommendation.
1.4 Downtown Seattle Transit Tunnel Transfer Agreement

In June 2000, the King County Council, the Seattle City Council and the Sound Transit Board approved the Downtown Seattle Transit Tunnel Transfer Agreement that transfers the 1.3-mile tunnel to Sound Transit. Under the agreement, Sound Transit would pay the outstanding debt service on the transit tunnel totaling $130 million as well pay $11 million of a $13.5 million program of surface improvements to mitigate the impact during the tunnel closure period when buses are moved to the surface.

The delay in schedule for the start of Link light rail has resulted in the need to modify the approved. In addition, if the Sound Transit Board recommends joint operations in the DSTT, the agreement will need to be renegotiated and issues regarding tunnel ownership, control of the tunnel systems, liability for operations and other factors will need to be determined.

1.5 Scope

The scope of this report covers a review of various operating plans and scenarios to safely and reliably accommodate passenger service by both buses and light rail trains in the transit tunnel. In addition, it describes the physical changes that would be required to accommodate both rail and bus given the current baseline assumption of a rail only tunnel. The various elements of the report are listed below:

1. Introduction
2. Operations analysis
3. Downtown Seattle transit service
4. Vehicle assumptions (light rail and bus)
5. Station platforms
6. Trackwork/roadway
7. Overhead contact system/traction power substations
8. Signal systems
9. Communication system
10. Fire/life/safety issues
11. Cost estimates
12. Report findings
2. OPERATIONS ANALYSIS

This section reviews the existing use of the DSTT and outlines the proposed Link light rail use, discusses bus and rail service levels, presents the results of the joint operations computer simulation modeling for the various north terminus scenarios, and discusses possible system operations under abnormal conditions.

2.1 Existing Bus Use of the DSTT

Currently, bus service in the transit tunnel consists of 25 routes, operating over 1,200 weekday bus trips. During the afternoon peak hour (4:30-5:30 p.m.), about 70 bus trips operate in each direction through the transit tunnel. In fall 2000, these routes together carried almost 55,000 weekday daily riders, with about 23,700 daily boardings in the transit tunnel. Four route groups serve the transit tunnel:

- **North Corridor Routes:** These routes operate from the north King County area and northeast Seattle/University District and enter and exit the station via the I-5 reversible lanes when available, and the I-5 mainline at other times. When the I-5 mainline is used, inbound buses exit the freeway at Stewart Street, and continue on Stewart Street and Ninth Avenue before entering the Convention Place Station (CPS) staging area. Outbound buses exit CPS via the Terry Avenue ramp to Olive Way, then enter the I-5 mainline.
  
  **Routes:** 41, 71, 72, 73, 301, 306, 307, and 312.

- **South Corridor Routes:** These routes serve the south King County area and enter and exit the tunnel at International District Station (IDS) via the E-3 busway between Fourth Avenue South and Sixth Avenue South.
  
  **Routes:** 101, 106, 150, 176, 177, 178, 190, 194, and 196.

- **East Corridor Routes (North):** These routes serve the northern portion of the Eastside via SR-520 and I-5, and access and exit CPS on the same routings used by the north corridor routes via the I-5 mainline.
  
  **Routes:** 255, 256 and 266.

- **East Corridor Routes (South):** These routes serve the southern portion of the Eastside via I-90, and enter and exit IDS via the D-2 HOV roadway.
  
  **Routes:** 212, 225, 229 and 550 (Sound Transit Express).

2.2 Link Use of the DSTT

The Central Link Locally Preferred Alignment (LPA) is expected to run from Northgate and the University District through downtown Seattle via Capitol Hill and First Hill. The current adopted route travels through the North Duwamish, under Beacon Hill through the Rainier Valley and Tukwila to South 200th Street with a stop at Sea-Tac Airport. The alignment consists of a mix of at-grade, tunnel, elevated, street median and gate-protected semi-exclusive sections. The Sound Transit Board is in the process of reviewing options for going north in the future which may result in changes to the adopted LPA.

Initially, Link may be constructed and provide service between downtown Seattle and either Tukwila or SeaTac, via Beacon Hill and the Rainier Valley. There are three alternatives under consideration for joint operations as described below and shown in Figure 2.1.
Convention Place Rail Terminus: There would be no passenger facilities at Convention Place. Trains would use a special track to turnback at Convention Place. Buses would use Convention Place to stage and merge into joint operations. Westlake would be the first/last station for passenger activity.

Convention Place Bus/Rail Intercept Station: There would be a passenger facility for both buses and rail with a special track to turnback trains at Convention Place. Some bus routes would use Convention Place to provide transfers to and from rail and stage prior to merging into joint operations.

Pine Street Rail Terminus: Rail would terminate in a new tunnel under Pine Street, 600 feet east of Eighth Avenue. Buses would use Convention Place to stage and merge into joint operations at Eighth Avenue. Westlake would be the first/last station for passenger activity.

Figure 2.1
North Terminus Joint Bus/Rail Operating Alternatives

2.3 Special Trackwork

Special trackwork will be provided at the northern terminus and south of the Royal Brougham Station. At the northend, a scissors-type double crossover will accommodate the crossover and turnaround of trains both at Convention Place and under Pine Street just east of Westlake Station. Just south of Royal Brougham Station, a 600-foot long center pocket track with entry and exit arrangements to the northbound and southbound tracks will provide temporary storage and/or movement of trains from one mainline track to the other. The special trackwork will permit single tracking of trains between Westlake Station or Convention Place Station and Royal Brougham Station.
2.4 Hours of Revenue Service

Currently, King County Metro service operates in the DSTT from 5:00 AM to 7:00 PM weekdays and between 10:00AM and 6:00 PM Saturdays, with no service on Sundays. This would be expected to change in the future with rail and bus operating in the DSTT during much the same hours.

Link will operate seven days per week, approximately 20 hours per day. For planning purposes, Monday through Saturday service will begin at approximately 5:00 AM and end at approximately 1:00 AM. Sunday and holiday service will begin at approximately 6:00 AM and end at midnight.

2.5 Rail Service Levels

Figure 2.3 shows the peak hour ridership projections for Link service in 2010 and 2020 with joint bus/rail operation in the DSTT, Convention Place Station as the north terminus and three potential south terminus points. It should be noted that the maximum line loads to the north are significantly higher.

Figure 2.3
Maximum Peak Hour Line Loads

<table>
<thead>
<tr>
<th>South Terminus</th>
<th>2010 Maximum Line Load</th>
<th>2020 Maximum Line Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPS to Henderson</td>
<td>1,400 passengers per hour</td>
<td>1,800 passengers per hour</td>
</tr>
<tr>
<td>CPS to South 154th</td>
<td>1,800 passengers per hour</td>
<td>2,200 passengers per hour</td>
</tr>
<tr>
<td>CPS to South 200th</td>
<td>2,000 passengers per hour</td>
<td>2,700 passengers per hour</td>
</tr>
</tbody>
</table>

The maximum load will be experienced southbound between the Pioneer Square Station and the International District Station. With each light rail vehicle assumed to carry 137 passengers or more, projected demand could be met in several ways through various combinations of headways and train length. However, Sound Transit is considering headways of 5, 6 or 7.5 minutes, while early morning and late night headways will be 15 minutes. This is shown in Figure 2.4.


### Figure 2.4

**Weekday Rail Service Periods**

<table>
<thead>
<tr>
<th>Service Period</th>
<th>Time Period</th>
<th>Headways</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early morning</td>
<td>5:00 AM to 6:00 AM</td>
<td>15</td>
</tr>
<tr>
<td>Morning peak</td>
<td>6:00 AM to 8:30 AM</td>
<td>5 or 6 or 7.5</td>
</tr>
<tr>
<td>Midday</td>
<td>8:30 AM to 3:00 PM</td>
<td>7.5</td>
</tr>
<tr>
<td>Afternoon peak</td>
<td>3:00 PM to 6:30 PM</td>
<td>5 or 6 or 7.5</td>
</tr>
<tr>
<td>Evening</td>
<td>6:30 PM to 10:00 PM</td>
<td>7.5</td>
</tr>
<tr>
<td>Late night</td>
<td>10:00 PM to 1:00 AM</td>
<td>15</td>
</tr>
</tbody>
</table>

### 2.6 Bus Service Levels

There are many possible bus route and assignment options for joint operations. King County Metro applied the following guidelines to identify which routes to include in the analysis:

- Balances access to the transit tunnel among King County Metro service subareas;
- Concentrates all-day regional trunk services in the transit tunnel, supporting intermodal connections;
- Assigns routes that have good access to the transit tunnel entrance and exit points and connecting transit-priority facilities;
- Assigns routes that have or are expected to have strong daily ridership;
- Balances the northbound and southbound bus volumes; and
- Supports consistent operator training and coordination by limiting bus operations to King County Metro-operated routes.

Figure 2.5 shows the nine routes which King County Metro selected for the joint operations analysis, assuming light rail service from NE 45th Station in the University District to South 200th Station in SeaTac. The actual number of routes will depend on the capacity parameters suggested by the simulation work.

### Figure 2.5

**Potential Bus Routes in DSTT under Joint Operations**

*(NE 45th to South 200th (LPA))*

<table>
<thead>
<tr>
<th>Route</th>
<th>Corridor</th>
<th>Serving</th>
<th>Projected 2010 Hourly Bus Volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>AM Peak Hr</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NB</td>
</tr>
<tr>
<td>41/307</td>
<td>I-5 North</td>
<td>Northgate TC/P&amp;R</td>
<td>4</td>
</tr>
<tr>
<td>255</td>
<td>SR-520</td>
<td>Kirkland/S Kirkland P&amp;R</td>
<td>2</td>
</tr>
<tr>
<td>545</td>
<td>SR-520</td>
<td>Redmond/Overlake</td>
<td>4</td>
</tr>
<tr>
<td>550</td>
<td>I-90</td>
<td>Bellevue/Mercer Island</td>
<td>12</td>
</tr>
<tr>
<td>554</td>
<td>I-90</td>
<td>Eastgate/Issaquah</td>
<td>2</td>
</tr>
<tr>
<td>174*</td>
<td>Pacific Hwy</td>
<td>Duwamish/SeaTac/Federal Way</td>
<td>4</td>
</tr>
<tr>
<td>194**</td>
<td>I-5 South</td>
<td>SeaTac/Federal Way</td>
<td>4</td>
</tr>
<tr>
<td>150</td>
<td>I-5 South</td>
<td>Tukwila/Kent</td>
<td>4</td>
</tr>
<tr>
<td>101</td>
<td>I-5 South</td>
<td>Renton</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>44</td>
</tr>
</tbody>
</table>

*Does not currently operate in the DSTT*
In addition, King County Metro has identified the following routes that could operate in the DSTT under joint operating conditions (see Figure 2.6) assuming the existing rail line start starts at Convention Place Station and ends at either South 154th Station or South 200th Station.

**  Eliminate if Airport Link is implemented

** Eliminate if rail is extended to South 200th

### Figure 2.6

**Potential Bus Routes in DSTT under Joint Operations**

(Convention Place to South 154th or South 200th)

<table>
<thead>
<tr>
<th>Route</th>
<th>Corridor</th>
<th>Serving</th>
<th>AM Peak Hr</th>
<th>Midday</th>
<th>PM Peak Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>NB</td>
<td>SB</td>
<td>NB</td>
</tr>
<tr>
<td>41/307</td>
<td>I-5 North</td>
<td>Northgate; SR-522</td>
<td>4</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>71/72/73</td>
<td>I-5 North</td>
<td>U District</td>
<td>8</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>101</td>
<td>I-5 South</td>
<td>Renton</td>
<td>8</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>150</td>
<td>I-5 South</td>
<td>Tukwila; Kent</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>174*</td>
<td>Pacific Hwy</td>
<td>SODO; SeaTac</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>194**</td>
<td>I-5 South</td>
<td>SeaTac</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>255/256</td>
<td>SR-520</td>
<td>Kirkland/Kingsgate/Overlake</td>
<td>4</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>545+</td>
<td>SR-520</td>
<td>Overlake; Redmond</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>550</td>
<td>I-90</td>
<td>Mercer Island; Bellevue</td>
<td>12</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>554+</td>
<td>I-90</td>
<td>Eastgate; Issaquah</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>56</td>
<td>64</td>
<td>42</td>
</tr>
</tbody>
</table>

*  Not currently assigned to the DSTT
** Eliminate if rail is extended to South 200th

### 2.7 Simulation of DSTT Joint Operations

Different models have been used over the years to simulate bus/rail operation in the DSTT. In 1998, a *General Purpose Simulation System* (GPSS) software was used to simulate train and bus movements through the transit tunnel. Given a set of inputs, the GPSS program estimated the amount of time it took for each mode to travel through the simulation area. The findings of the 1998 study were discussed in Chapter 1.

The current effort used an event and process-oriented simulation program called *Arena* that was used to build a computer model of a given system. The GPSS model used in 1998 and the *Arena* program are similar, but the Arena program features full animation of simulation functions.

The *Arena* program requires the following inputs:

- Rail and bus operating schedules
- Travel times through the DSTT
- Dwell times by mode
- Logic for the operation of the staging and merge areas
- An assumed signal system
- Operating rules for buses and trains

The simulation modeling was performed for the following options:

- A turnback/terminus at Convention Place Station
• A turnback under Pine Street in an exclusive tunnel section east of Westlake Station
• The current adopted route NE 45th to South 200th (LPA)

The simulation results offer insight into the volume of buses that can be safely operated in the DSTT under joint operations. The outcomes of each model run depend on the light rail interim northern terminus, rail headway, bus operating schedules and proposed operating rules for joint operations.

**Key Assumptions**

The simulations were performed for the area depicted in Figure 2.7. Northbound trains enter the simulation at the Lander Station platform to begin their dwell. In the LPA scenario, southbound trains enter the simulation at the First Hill Station. Northbound buses, with the exception of southbound buses that turnaround at IDS, enter the simulation either merging at Royal Brougham via the E-3 busway or the northbound IDS staging area from I-90. All southbound buses enter the simulation at CPS.

**Arrival and Dwell Variability**

The affect of on-time train performance was considered during the model testing. One test assumed all trains run exactly on schedule. A second test assumed trains randomly were as much as 30 seconds early and as late as one minute. The final test assumed trains could be up to two minutes late.

All of the models assigned on-time probabilities to passenger bus arrivals. The result was buses could be as much as 5 minutes early or as late as 10 minutes (based on automatic passenger count (APC) data supplied by King County Metro). Buses originating from layover locations or garages were assumed to arrive within one minute (+ or -) of their schedule.

Train and bus dwell times were simulated with random variability. For trains at DSTT stations, dwell times vary between 20 and 40 seconds, with an assumed average of 30 seconds. Bus dwell times vary between 10 and 40 seconds, with an average of 22 seconds. The average dwell time for buses are based on the current dwell times and the assumption that low floor buses will be operated in the tunnel to speed loading (see Section 4.2 for description of buses). In addition, King County Metro is considering the use of precision guidance technology at the stations and is investigating the potential of only securing boarding wheelchair passengers when they reach the last outbound tunnel station. These factors would speed bus loading and reduce dwell times. The dwell time assumptions were made for modeling purposes only and will be refined in the future.

**Operating Rule**

To address fire/life/safety concerns, an operating rule was established whereby trains and buses are not allowed to be in the same tunnel or ventilation zone simultaneously. To maintain this
separation, the model assumes the use of a signal system to govern all merge and crossing points (see Chapter 8 for details). This rule is important because it places restrictions on operations that had not been assumed in previous DSTT joint operations analysis.

**Station-to-Station Travel**

Station-to-station running times, for both bus and rail, are based on year 2000 automatic passenger count data provided by King County Metro. Although rail vehicles can travel faster than buses in the DSTT, the modeling was based on slower scheduled travel times for trains. Train speeds were reduced by about one minute in each direction to optimize the use of the transit tunnel for both buses and rail. This resulted in a larger operating window for buses. The result is that total travel times through the DSTT increased for both trains and buses. However, because light rail service will be starting for the first time, rail riders will not perceive the change in travel time.

**Rail and Bus Operation Schedules**

As discussed in Section 2.3 (Rail Service Hours), rail headways were tested at 5, 6 and 7.5 minutes. The bus routes and associated PM peak hour volumes shown in figures 2.5 (NE 45th to South 200th) and 2.6 (Convention Place to South 154th or South 200th) were assumed in the modeling work.

**Staging/Dispatching Assumptions for Northbound Buses at International District Station**

The addition of tracks in the bus staging area at IDS reduces the number of bus lanes in the northbound mode change area. Each lane is 240 feet long. Figure 2.8 displays the IDS staging area in diagram form. While four 60-foot buses could technically fit in each lane, the buses would literally be lined up tip-to-tail with no gap between them.

To allow a margin of safety so that all buses could move off the tracks prior to a train’s arrival, it was assumed the staging would not operate at capacity with four buses per lane. Instead, the simulations assumed three buses per lane or nine buses total for the northbound staging area at IDS. Sound Transit is working with King County Metro to determine if adding an additional lane would increase the bus throughput at IDS.

It was also assumed the signal control system would hold all northbound (NB) buses in the staging area for two minutes prior to a train arrival from Lander Station.

The majority of northbound buses arrive at IDS via the E-3 busway and for a brief stretch leading to the staging area, these buses would occupy the NB tracks. Moreover, train operators rely on line-of-sight for bus detection as they approach IDS.

The proposed signal controls would hold in the staging area southbound (SB) buses from the E-3 busway and those turning around to go north, prior to a southbound train’s scheduled departure from IDS.
Another assumption in the models was the formation of bus platoons. Given the loss of staging capacity and the limited time between train arrivals, it is important that buses move to the platforms as orderly as possible. As such, a dispatching sub-model was introduced in each of the models to facilitate the formation of bus platoons.

Initial model logic gives E-3 bus arrivals priority over both I-90 arrivals and southbound turnaround buses. I-90 arrivals have priority over southbound turnaround buses. Upon arrival, any passenger bus would proceed to one of the front three lane positions if possible.

Otherwise the model assigned buses to one of the three lanes using the following logic:

- Arriving E-3 buses move to the left lane (Figure 2.8). If the left lane is full (i.e. three buses) or the last position is occupied, the arriving E-3 bus moves to the center lane. If the center lane is full or the last position is occupied, the bus moves to the right lane. If the right lane is full, the model scenario is considered unworkable.

- Arriving I-90 buses move to the center lane. If the center lane is full (i.e. three buses) or the last position is occupied, the bus moves to the right lane. If the right lane is full, the bus is held on the I-90 ramp until a position becomes available. I-90 buses are not assigned to the left lane to avoid additional conflicts with E-3 bus arrivals.

- Southbound turnaround buses move to the right lane if there is an open position. If not, these buses stay in the southbound turnaround lane until a far right lane position becomes available.

Model logic randomly assigns a mode change time for each bus upon arriving at the staging area. The duration of the mode change is anywhere between 50 and 70 seconds. Southbound turnaround buses switch to diesel power prior to making the turnaround maneuver and then do a second mode change once in the northbound staging area.

The sub-model dispatches buses from the three front positions. The model also moves buses in the rear positions forward as leading buses leave for the platform. When a bus reaches a front position and can proceed to the platforms (i.e. a NB train is not approaching the station), the dispatching sub-model scans the staging area in an attempt to form a platoon. A signal control system is being designed so the dispatching of buses is automated to the extent possible. Signals positioned at the head of each staging lane would dispatch buses by bay order.

However, the model does not hold buses to form a platoon. For example, if there is only one bus present, then the bus will be dispatched to the platform. The only time the model holds buses in the staging area is when the platform capacity is exceeded. For example, if three Bay A buses are ready to move to the platform, model logic will hold one of the three until the other two pull to the platform, dwell and depart. Passenger buses have priority over a non-passenger bus.

Model Assumptions at Convention Place Station
At Convention Place, a dispatching sub-model was used to form southbound bus platoons similar to the logic used for northbound buses at International District Station. Southbound platoon sizes were limited to four buses with a 30-second separation between platoon departures. The model only attempts to form platoons when there are two or more buses ready to depart for Westlake Station.
In the NE 45th to South 200th light rail (LPA) scenario, southbound buses were not allowed to enter the transit tunnel until a train had finished boarding and alighting passengers at First Hill Station. Northbound buses could proceed as far as the Convention Place tunnel merge in the event of a southbound train departure from First Hill Station.

In the scenario with Convention Place as the northern terminus, the signal to halt southbound bus departures was issued one minute prior to a train’s departure schedule. Northbound buses were not delayed in the event of a train departure, as northbound buses did not conflict with trains. In addition, all trains were assigned layovers at Convention Place to aid in maintaining schedules. In the event a train was too late to maintain schedule, a minimum two-minute time was assumed for completing the turnback (i.e. powering down, walking to the front of the train and powering up).

With the rail terminus at Pine Street, southbound bus departures from Convention Place were halted one minute prior to a train’s scheduled departure. Northbound buses were also stopped one minute since this scenario requires buses to cross both sets of tracks. Northbound buses could proceed only as far as the Convention Place tunnel entrance in the event of a southbound train departure from the Pine Street terminus.

**Simulation Results**

For each of the three scenarios, theoretical single-mode runs were made to serve as a baseline for measuring delays caused by joint operations. The simulation was run with trains and no buses to serve as a benchmark for measuring train times, and the model was run with buses and no trains to serve as a benchmark for measuring the effect on bus times.

Although all of the models simulate PM peak period conditions (3:00 to 6:30 PM), model statistics are only accumulated for the peak hour (4:30 to 5:30 PM). When accumulating statistics, the models are run several times and the results reflect the averages of those runs.

In all cases, with a 5-minute train headway, the maximum number of buses that could operate through the transit tunnel in the peak hour were 42 northbound and 40 southbound assuming all the trains were on time. When trains were simulated with one or two minutes delay, the 40 bus schedule failed as the total number of buses in the northbound International District Station staging area exceeded nine buses at some point in the simulations.

The simulation results for the three scenarios are shown on the following pages.
Results with Rail Locally Preferred Alternative

Figure 2.9 summarizes simulation results for the LPA scenario. Using a 6-minute rail headway and assuming all trains are within two minutes of schedule, the simulation with joint operations allowed 60 NB buses. The simulation showed joint operations adds about one minute of travel time to NB trains and buses. In addition, NB bus passenger delays at the IDS staging area average about two minutes or about one and one-half minutes more than the base measurement.

Simulations with a 7.5-minute rail headway resulted in travel times and delays similar to those of the 6-minute headway. This scenario successfully tested having 64 northbound buses and 56 southbound buses in joint operations.

Figure 2.9
Simulation Results - Locally Preferred Alternative
Joint Operations

<table>
<thead>
<tr>
<th>Mode</th>
<th>Direction</th>
<th>Segments</th>
<th>Average Times</th>
<th>5-Minute Headway</th>
<th>6-Minute Headway</th>
<th>7.5-Minute Headway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Base 1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Rail</td>
<td>Northbound</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lander to First Hill</td>
<td>11:30</td>
<td>12:08</td>
<td>12:13</td>
<td>12:00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passenger Delays</td>
<td>none</td>
<td>0:38</td>
<td>0:43</td>
<td>0:30</td>
</tr>
<tr>
<td>Bus</td>
<td>DSTT</td>
<td></td>
<td>8:00</td>
<td>8:40</td>
<td>9:03</td>
<td>8:54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passenger Delays</td>
<td>0:36</td>
<td>2:40</td>
<td>1:53</td>
<td>1:55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scheduled # of Buses</td>
<td>64</td>
<td>42</td>
<td>60</td>
<td>64</td>
</tr>
<tr>
<td>Rail</td>
<td>Southbound</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lander to First Hill</td>
<td>11:30</td>
<td>no change</td>
<td>no change</td>
<td>no change</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passenger Delays</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Bus</td>
<td>DSTT</td>
<td></td>
<td>7:20</td>
<td>8:05</td>
<td>8:12</td>
<td>8:19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passenger Delays</td>
<td>0:22</td>
<td>1:18</td>
<td>1:28</td>
<td>1:31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scheduled # of Buses</td>
<td>56</td>
<td>40</td>
<td>52</td>
<td>56</td>
</tr>
</tbody>
</table>

Notes:
1) Base travel times reflect single mode model runs.
2) Results: 5-minute light rail headway reflect all trains running exactly on time.
3) Results: 6-minute light rail headway reflect all trains running within two minutes of schedule.
4) Results: 7.5-minute light rail headway reflect all trains running within two minutes of schedule.
5) NB bus passengers delays are for the IDS staging area only. SB bus passenger delays reflect delays departing CPS.
Results with a North Rail Terminus at Convention Place Station
Simulations of the Convention Place terminal scenario assume NB buses loop around the train turnback tracks and crossover without interfering with the train movements. The CPS terminus results appear in Figure 2.10.

Results found that trains running in either direction would not encounter significant changes in running times under any of the tested headways (i.e. 5, 6 and 7.5 minutes). Bus passenger delays at the NB International District staging area were consistent with the LPA results with NB buses experiencing almost two minutes delay and SB buses averaging just over one minute delay. Results also suggest no difference between this scenario and the LPA scenario regarding the volume of buses that can be accommodated under the given rail headway assumptions.

**Figure 2.10**
Simulation Results - North Rail Terminus at Convention Place Joint Operations

<table>
<thead>
<tr>
<th>Mode</th>
<th>Direction</th>
<th>Segments</th>
<th>Average Times</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Base $^1$</td>
</tr>
<tr>
<td>Rail</td>
<td>Northbound</td>
<td>Lander to CPS</td>
<td>10:40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passenger Delays</td>
<td>none</td>
</tr>
<tr>
<td>Bus</td>
<td>DSTT</td>
<td>8:00</td>
<td>no change</td>
</tr>
<tr>
<td></td>
<td>Passenger Delays $^5$</td>
<td>0:36</td>
<td>2:49</td>
</tr>
<tr>
<td></td>
<td>Scheduled # of Buses</td>
<td>64</td>
<td>42</td>
</tr>
<tr>
<td>Rail</td>
<td>Southbound</td>
<td>Lander to CPS</td>
<td>10:40</td>
</tr>
<tr>
<td></td>
<td>Passenger Delays</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Bus</td>
<td>DSTT</td>
<td>7:20</td>
<td>7:36</td>
</tr>
<tr>
<td></td>
<td>Passenger Delays $^5$</td>
<td>0:22</td>
<td>0:43</td>
</tr>
<tr>
<td></td>
<td>Scheduled # of Buses</td>
<td>56</td>
<td>40</td>
</tr>
</tbody>
</table>

Notes:  
1) Base travel times reflect single mode model runs.  
2) Results: 5-minute LRT headway reflect all trains running exactly on time.  
3) Results: 6-minute light rail headway reflect all trains running within two minutes of schedule.  
4) Results: 7.5-minute light rail headway reflect all trains running within two minutes of schedule.  
5) NB bus passenger delays are for the IDS staging area only. SB bus passenger delays reflect delays departing CPS.
Results with a North Rail Terminus under Pine Street
With respect to bus access at Convention Place, having the north rail terminus located under Pine Street creates conditions similar to those of the LPA scenario. NB buses wait at the merge to the CPS tunnel turnout, while SB trains depart from the Pine Street terminal for Westlake Station. Both NB bus arrivals and SB bus departures at CPS are stopped one-minute prior to a train’s scheduled departure.

Results of the Pine Street simulations show travel times for northbound trains increasing by an average of one-half minute. The train delays occur at Westlake Station as trains wait for NB buses queues at the CPS tunnel merge to clear. There would no train passengers on board at this point to experience the delays. Bus passenger delays at the NB International District staging areas show results similar to the other scenarios (almost two minutes delay), as do the delays measured for SB passenger buses departing CPS (just over one minute delay).

<table>
<thead>
<tr>
<th>Mode</th>
<th>Direction</th>
<th>Segment</th>
<th>Base 1</th>
<th>5-Minute 2 Headway</th>
<th>6-Minute 3 Headway</th>
<th>7.5-Minute 4 Headway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail</td>
<td>Northbound</td>
<td>Lander to CPS</td>
<td>10:20</td>
<td>10:54</td>
<td>10:58</td>
<td>10:46</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passenger Delays</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Rail</td>
<td>Southbound</td>
<td>Lander to CPS</td>
<td>10:20</td>
<td>no change</td>
<td>no change</td>
<td>no change</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passenger Delays</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Bus</td>
<td>DSTT</td>
<td>Passenger Delays 5</td>
<td>0:36</td>
<td>2:44</td>
<td>1:50</td>
<td>1:55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scheduled # of Buses</td>
<td>64</td>
<td>42</td>
<td>60</td>
<td>64</td>
</tr>
<tr>
<td>Bus</td>
<td>DSTT</td>
<td>Passenger Delays 5</td>
<td>0:22</td>
<td>0:51</td>
<td>1:10</td>
<td>1:15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scheduled # of Buses</td>
<td>56</td>
<td>40</td>
<td>52</td>
<td>56</td>
</tr>
</tbody>
</table>

Notes: 1) Base travel times reflect single mode model runs.
2) Results: 5-minute LRT headway reflect all trains running exactly on time.
3) Results: 6-minute light rail headway reflect all trains running within two minutes of schedule.
4) Results: 7.5-minute light rail headway reflect all trains running within two minutes of schedule.
5) NB bus passenger delays are for the IDS staging area only. SB bus passengers delays reflect delays departing CPS.

Summary of Simulation Model Results
The current modeling effort builds upon past work to simulate joint operations in the DSTT. This model, as with all models, depends upon a set of assumptions to perform the analysis. The assumptions used are based on the best judgement and technical work that has been completed to-date by both Sound Transit and King County Metro. These assumptions include bus and rail separation in the tunnel sections and stations through a signal system, travel times by mode, dwell times in the stations and constraints at the staging areas.
Using these assumptions, a 5-minute train headway results in a maximum of 42 peak hour buses per direction but only if all trains operate on time. The biggest limitation is the amount of space in the International District staging area.

At a 6-minute train headway, the model was able to simulate 60 northbound and 52 southbound bus trips in the peak hour (assuming trains could be off schedule by up to two minutes, with an average bus passenger delay of 1.5 minutes and minimal train passenger delay). At a 7.5-minute train headway, the average bus passenger delay was the same; however, the number of buses increased to 64 northbound and 56 southbound bus trips in the peak hour (assuming trains could be off schedule by up to two minutes).

These model runs would indicate that between 50 and 60 buses in each direction could travel through the DSTT in joint operations during the PM peak hour with train headways of 6 to 7.5 minutes.

2.8 Abnormal System Operation

The simulation modeling was performed under typical operating conditions. This section provides a discussion of operation under abnormal conditions. The system is designed to ensure that if facility and systems components fail, service can continue, consistent with operational safety. A comprehensive Failure Management Plan and Standard Operating Procedures will be developed during later stages of design to identify failures and the operational responses to various failure conditions.

Causes of Abnormal Operations

Events will occasionally occur during joint train and bus operations that disrupt scheduled service to an extent that requires implementation of service management techniques. When emergencies of a more serious nature occur, coordinated responses by several departments within the Link and King County Metro operating groups and, under certain circumstances, emergency services external to Link are required. Some examples of causes resulting in abnormal operations include:

a) Tunnel track out of service due to blockage or for repair
b) Disabled train in station or between stations
c) Disabled bus in station or between stations
d) Loss of traction power
e) Loss of wayside signals
f) Accident involving personal injury or loss of life
g) Fire on train, bus or in tunnel
h) Major seismic event.

Operational Strategies

A variety of strategies will be used to manage delays and return the line to its scheduled operation. The appropriate strategy will depend on the location, type, and duration of the delay and the time of day. These include:

a) Ability to de-energize a selected section of OCS,
b) Ability to single-track,
c) Ability to power a section of track from an second substation if the primary substation is out of service, and
d) Provisions for special trackwork (i.e. crossovers).
Operational strategies also will be used to adjust service to unusual conditions and to recover from service delays. These actions include modifying the operating schedule, turning a train back short of its scheduled destination, and operating trains in both directions using a single track (single-tracking). For bus service, an additional operating strategy will be for buses to be rerouted to surface streets as they are today, using predetermined routings common with periods when the tunnel is closed to bus use (evenings, Sundays).

In a single-track operation, trains will be held at interlockings at both ends of the single-track segment (for the DSTT, these interlockings are at Westlake Station and Royal Brougham) and will be released to proceed first in one direction and then in the other. Each train will clear the interlocking at the exit end of the single-track segment before the next train can be authorized to enter the single-track segment. Bus operations in the DSTT will be rerouted to the surface during single-tracking operations.

Figure 2.12 provides potential responses to typical abnormal operating conditions. In some cases trains may be held outside the tunnel and buses allowed to continue operation. Detailed operating procedures will be developed prior to initiation of joint tunnel operation.

### Figure 2-12

**Potential Responses to Abnormal Tunnel Operations**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Train</th>
<th>Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>One tunnel track out of service due to blockage or for repair</td>
<td>• Single tracking of service using the other track</td>
<td>• Surface operation during period of disruption</td>
</tr>
</tbody>
</table>
| Disabled train in station or between stations | • Another train will push or pull the disabled train out of the way.  
• Prolonged delays (due, for instance, to re-railing, etc.) would result in single tracking of service using the other track. | • Surface operation during period of disruption.  
• If train is disabled in station, buses could use bypass lane with OCC authorization. |
| Disabled bus in station or between stations | • Train service delayed until bus is removed from tunnel segment.  
• Prolonged delays may require switching to single-track service | • KCM to arrange towing of bus  
• Prolonged delays may result in surface operation during period of disruption |
| Loss of traction power | • Train service suspended until power restored. | • Buses rerouted to surface. |
| Loss of signals | • Train service continues using line-of-sight mode. | • Buses rerouted to surface for duration of interruption.  
• Very limited bus operations possible based on station to station working. |
| Accident involving personal injury or loss of life | • Single tracking may be required.  
• Service may be suspended depending on circumstances. | • Buses rerouted to surface during period of disruption. |
| Fire on train or bus in tunnel | • Service suspended until us of tunnel and stations authorized by the Fire Department. | • Buses rerouted to surface during period of disruption. |
| Major seismic event | • Service may be temporarily suspended until tunnel safety approved by appropriate authorities. | • Buses rerouted to surface during inspection of tunnel. |
2.9 Findings

- Currently, bus service in the tunnel consists of 25 routes, operating over 1,200 weekday bus trips. During the afternoon peak hour (4:30-5:30 p.m.), about 70 bus trips operate in each direction through the tunnel. Together, these routes carried almost 55,000 weekday daily riders in fall 2000, with about 23,700 daily boardings in the tunnel.

- The current adopted light rail route would run from NE 45th Station in the University District to South 200th Station in SeaTac, and extend to Northgate subject to available funding. However, the Sound Transit Board is currently considering identifying an interim north terminus at either the Royal Brougham Station or the Convention Place Station to begin construction south first.

- Using a computer simulation model to evaluate the LPA route and the CPS terminus options it has been estimated that between 50 and 60 buses in each direction could travel through the DSTT in joint operations during the PM peak hour with train headways of 6 to 7.5 minutes.
3. DOWNTOWN SEATTLE TRANSIT SERVICE

Downtown Seattle is the transportation hub of the Puget Sound region. The continued vitality of downtown is dependent upon the ability to provide easy access to the employment opportunities, retail businesses, housing and the cultural and sporting events. By 2010, downtown is expected to have 224,000 jobs (an increase of 38,000), 35 million square feet of office space (21 percent increase), 8 million square feet of retail space (25 percent increase), 15,000 hotel rooms (67 percent increase) and almost a doubling of residents to 30,000. To meet the transportation needs of these activities, a range of transportation options needs be provided. Transit is an important part of the transportation mix for providing access to downtown.

Today, in the afternoon rush hour, buses account for only two percent of the vehicles on downtown streets, but carry 40 percent of the people traveling. With the start-up of the Sounder commuter rail service and the regional express service, downtown transit usage will continue to increase. The introduction of light rail will further increase accessibility to downtown, and overtime increase the usage of the downtown tunnel.

3.1 Downtown Surface Bus Volumes

The analysis for transit usage in downtown Seattle has concentrated on the PM peak hour (4:30 p.m. to 5:30 p.m.) An analysis of bus volumes and potential surface improvements to accommodate bus and auto traffic both during the period the DSTT is closed for retrofit and after light rail is operational was analyzed in the Downtown Seattle Surface Street Report, Alternatives to Improve Transit Operations, April 14, 1999. Based on the report findings, $13.5 million (2000$) of physical and operational improvements were identified to help maintain bus travel times and general mobility. The DSTT Transfer Agreement (see Section 1.4) commits Sound Transit, King County Metro and the City of Seattle to implement these improvements.

Currently, there are about 470 buses operating on the surface streets and 140 buses operating in the DSTT, for a total of 610 buses operating in downtown during the PM peak hour. The current projection is that between now and 2006 when the tunnel closes for retrofit, the number of tunnel bus trips is expected to remain about the same as today. Surface bus trips in the peak hour will increase due to growth but other trips will be eliminated due to route restructuring around the Sounder commuter rail line that will be extended to Everett in Snohomish County and Lakewood in Pierce County. The result will be only a slight increase in surface trips between now and 2006. During the two-year period the tunnel is closed for retrofit, just over 600 buses will be operating on the surface streets during the PM peak hour.

3.2 Downtown Surface Bus Volumes after Rail is Operational

The degree to which downtown Seattle hourly bus volumes will change over time is influenced by many variables, including potential Sound Transit actions. What follows is a brief description of the variables affecting downtown bus traffic:

- **Response to downtown Seattle employment, commercial and residential growth and increasing transit demand.** Downtown jobs, employment and business activities are expected to continue to grow over time. Public transit services are a cornerstone of the region’s strategy for accommodating the transportation demand that will come with that growth. Bus trips will need to be added to serve new riders over time, but the level of new demand cannot be known exactly.
- **Level of bus service restructure around Sound Transit services.** Some bus trips may be eliminated from downtown Seattle streets if they can be re-routed to feed Sound Transit light rail, commuter rail and/or regional express bus services outside of downtown. The local transit operators’ ability to restructure is highly dependent on the extent and levels of service of Sound Transit’s rail and bus routes and the size and configuration of the transfer facilities. Bus rider acceptance of transfers and travel time impacts and community acceptance of bus re-routes to make Sound Transit connections have a great impact on the level of restructuring and subsequent downtown bus traffic reduction that can occur.

- **Level of bus service restructure independent of Sound Transit.** The transit operators providing bus services to downtown Seattle may have opportunities over time to restructure services independent of Sound Transit. Some of those service changes might result in reductions to peak hour downtown bus volumes, but they could also result in increases.

- **Improved utilization of existing services.** Some bus trips might be eliminated due to low ridership, but the level of acceptance of lost transit access and convenience, resulting crowding on surrounding trips, and congestion impacts will have to be weighed carefully against the benefits of fewer buses on downtown streets.

King County Metro in conjunction with Sound Transit has developed estimates of future surface bus volumes for an interim rail terminus at Convention Place and the following options under consideration by the Sound Transit Board:

- Joint bus/rail operations in the DSTT
- Rail only in the DSTT with bus intercept terminals at Convention Place, International District, and Lander.

Surface bus volumes have been estimated for the period from 2002 through 2030 based on a series of assumptions. These assumptions include an estimated annual growth in transit usage to downtown, the restructuring of transit routes around light rail and future extensions of light rail, the restructuring of bus routes around commuter rail service, and future extensions of the light rail system. Figure 3.1 summarizes these assumptions.

These assumptions differ from previous published work in several ways. First, the *Downtown Seattle Surface Report* provided estimates of the growth in future transit trips by trying to determine the growth rate of individual routes. The assumptions being used now are that transit trips will grow by a steady rate of one percent per year, which fits better with projections of future service additions. The current assumptions also assume aggressive route restructuring around Sounder commuter rail service, which should be at full service levels prior to the opening of light rail.
### Figure 3.1
Assumption Used to Estimate Future Surface Bus Volumes

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline Volumes</strong></td>
<td>- 2002 starting volumes are based on Spring 2001 King County Metro, ST’s Regional Express, Community Transit schedules plus adopted King County changes through Spring 2002</td>
</tr>
<tr>
<td><strong>Trip Growth</strong></td>
<td>- Assumes 1% per year through the time rail is extended to Lynnwood, Federal Way and Redmond, to meet anticipated new rider demand over time.</td>
</tr>
<tr>
<td></td>
<td>- Annual growth drops to 0.5% per year thereafter to reflect absorption of most new demand by rail.</td>
</tr>
<tr>
<td><strong>Trip Management &amp; Non-Rail Restructures</strong></td>
<td>- Assumes approved 2001 changes, plus trip reductions every 6 years at 1% of total hourly Downtown Seattle bus volumes through the time rail is extended to Lynnwood, Federal Way and Redmond.</td>
</tr>
<tr>
<td></td>
<td>- Reductions drop to 0.5% every 6 years thereafter to reflect reduced set of routes that might be considered for trip reduction.</td>
</tr>
<tr>
<td><strong>Commuter Rail Restructures</strong></td>
<td>- Assumes projected &quot;moderate&quot; bus service restructures as commuter rail service is increased and extended as follows:</td>
</tr>
<tr>
<td></td>
<td>- By end of 2005: Seattle-Everett line built, with full Phase I service between Tacoma and Everett (18 trips/day south; 12 trips/day north)</td>
</tr>
<tr>
<td></td>
<td>- By end of 2005: Full commuter rail service from Tacoma to Lakewood</td>
</tr>
<tr>
<td><strong>Light Rail Restructures</strong></td>
<td>- Assumes projected &quot;moderate&quot; bus service restructures as rail is built and extended as follows, per current Sound Transit plans:</td>
</tr>
<tr>
<td></td>
<td>- 2006: tunnel closes and tunnel routes come to surface streets</td>
</tr>
<tr>
<td></td>
<td>- 2008: tunnel re-opens and light rail service begins Convention Place to Henderson; = 6 min. peak headway</td>
</tr>
<tr>
<td></td>
<td>- 2009: Light rail extended from Convention Place to North 200th; = 6 min. peak headway</td>
</tr>
<tr>
<td></td>
<td>- 2012: Light rail extended from Convention Place to Northgate; = 6 min. headway</td>
</tr>
<tr>
<td></td>
<td>- 2016: Light rail extended from Downtown Seattle to Bellevue via I-90; &lt; 4 min. headway</td>
</tr>
<tr>
<td></td>
<td>- 2020: Light rail extended South 200th to Federal Way, Northgate to Lynnwood, Bellevue to Redmond; &lt; 4 min. headway</td>
</tr>
<tr>
<td></td>
<td>- 2030: Light rail extended Federal Way to Tacoma, Lynnwood to Everett, Bellevue to Totem Lake; &lt; 4 min. headway</td>
</tr>
<tr>
<td><strong>DSTT Line Capacity</strong></td>
<td>- Based on King County operating experience and ST/KCM joint operations simulation modeling</td>
</tr>
<tr>
<td></td>
<td><strong>Joint Operations:</strong> 6 min. light rail headway: 50-60 buses/hr/direction</td>
</tr>
<tr>
<td></td>
<td><strong>Bus Only:</strong>                                                                  Up to 125 buses/hour/direction (250 total)</td>
</tr>
<tr>
<td><strong>Intercept Terminals</strong></td>
<td>- Assumes facilities at CPS (60 buses), IDS (40 buses) &amp; Lander (60 buses)</td>
</tr>
</tbody>
</table>

As shown in Figure 3.2, surface bus volumes are projected to reach about 600 buses in the PM peak hour during the 24-month period the tunnel is closed for retrofit. During tunnel closure, a $13.5 million mitigation plan has been developed and approved by the Sound Transit Board, King County Council and the City of City to accommodate this increase in bus volumes. From 2008 through 2016, the PM peak hour surface bus volumes are expected to be at or below the estimated 2002 bus volumes under the two DSTT rail options. Under joint operations, the surface volumes would increase sometime after 2016 when light rail is extended and ridership increases to the point where rail headways are reduced to 5 minutes or less and buses would no longer operate in the DSTT.
Rail only use of the DSTT with peak period bus intercept terminals would also reduce surface bus volumes both from what they are today and into the future as rail is extended throughout the region. However, intercept terminals would require bus riders to transfer to rail when they are within a short distance of their final destination. This transfer potentially impacts ridership increasing travel time and providing less convenient service.

**Figure 3.2**  
*Projected Surface Bus Volumes under Alternative DSTT Operations (2002 - 2030)*

![Graph showing projected surface bus volumes under alternative DSTT operations.](image)

### 3.3 Transit Ridership

The ridership model was revised to evaluate 2020 light rail ridership between an interim north terminus at Convention Place and South 200th Station for both rail only use of the DSTT with bus intercept terminals at Convention Place, International District and Lander and with joint operations. Figure 3.3 shows the 2020 ridership under these two options. With an interim north terminus at Convention Place and service to South 200th Station in SeaTac, the 2020 daily ridership for joint operations is estimated at 50,000 daily rail boardings, with 27,600 boardings taking place in the DSTT. With joint operations, it is assumed 10 bus routes would operate in the transit tunnel from origins in the north, east and south, which results in 37,600 daily bus boardings in the tunnel. Also shown in Figure 3.3 are the 2020 daily ridership figures for rail only use of the DSTT with bus intercept terminals at Convention Place, International District and Lander. Under this alternative, the total daily boardings are estimated to be 64,200 versus 50,000 in the joint operations alternative. However, almost 13,000 of the daily boardings are related to the forced bus to rail transfer at Convention Place, International District and Lander. This also results in the higher rail boardings in the transit tunnel as compared to the rail boardings under
joint operations. This transfer would increase both waiting time and travel time for bus passengers. The remaining difference in daily boardings between the two options is attributed to the slightly faster speeds assumed with rail only operation in the DSTT.

**Figure 3.3**

2020 Transit Ridership - Joint Operations and Rail only in the DSTT
Interim North Terminus at Convention Place to South 200th Station

<table>
<thead>
<tr>
<th>Boardings</th>
<th>DSTT Rail only with Bus Intercept</th>
<th>DSTT Joint Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus Boardings in the Tunnel</td>
<td>N/A</td>
<td>37,600</td>
</tr>
<tr>
<td>Rail Boardings in the Tunnel</td>
<td>36,200</td>
<td>27,600</td>
</tr>
<tr>
<td><strong>Total DSTT Boardings</strong></td>
<td><strong>36,200</strong></td>
<td><strong>65,200</strong></td>
</tr>
<tr>
<td><strong>Total Daily Rail Boardings</strong></td>
<td><strong>64,200</strong></td>
<td><strong>50,000</strong></td>
</tr>
</tbody>
</table>

### 3.4 DSTT Capacity

The capacity of the DSTT for either buses or rail is dependent upon the operating characteristics and design standards for each mode. When capacity figures are quoted they are based on the number of vehicles that can travel past a given point in a single hour. However, capacity is a function of both the number of vehicles and the number of passengers carried. Rail passenger capacity is a function of the following factors:

- Number of seats in the vehicle
- Number of standing passengers
- Load Factor (seated riders and standing riders)
- Number of cars in a train
- Number of trains per hour (headway)
- Dwell time at the stations
- Limits of the train signal system

Long range ridership projections for Sound Transit estimate up to 15,000 Central Link riders in the peak hour, peak direction at the peak load point (assumed to be in the DSTT). Based on the factors outlined above the peak hour, peak direction passenger capacity is estimated to be 16,440 as shown in Figure 3.4. This passenger capacity figure is based on 74 seated passengers, 63 standing passengers (5.1 sq. ft. per standee, see Figure 3.5) and 30 four car trains per hour (2-minute headway). It should be noted that this is the peak direction capacity and this capacity figure may not be achieved in both directions at the same time.

**Figure 3.4**

Light Rail One-way Passenger Capacity

<table>
<thead>
<tr>
<th>No. of Seats</th>
<th>Load Factor</th>
<th>Passengers per Car (Seats x Load Factor)</th>
<th>Cars per Train</th>
<th>Passengers per Train (Pass. x Trains)</th>
<th>Headway (Minutes)</th>
<th>Trains per Hour (Headway/60)</th>
<th>Total Passengers Per Hour in One Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>74</td>
<td>1.85</td>
<td>137</td>
<td>4</td>
<td>548</td>
<td>2</td>
<td>30</td>
<td>16,440</td>
</tr>
</tbody>
</table>
The peak hour, peak direction capacity figure of over 16,000 riders is based on full build-out of the Central Link system from Everett to Tacoma and Seattle to Bellevue. To reach this level of ridership will require the full build-out of the Link system, which is expected to take several decades to complete.

While train capacity is based on the factors listed, bus capacity is based on similar factors as listed below:

- Number of seats in the bus (mix of artic and standard)
- Number of standing passengers assumed
- Load Factor (seated riders and standing riders)
- Number of buses per hour (headway)
- Size of the staging area
- Dwell time at the station including the loading and securing of wheelchair passenger
- Service type: one-way routes versus the through routing of service.

The one-way bus passenger capacity in the DSTT is assuming to be 125 buses per hour per direction. The figure of 125 buses per hour in the peak direction is based on King County Metro’s more than ten years of experience with operating the only all bus tunnel with on-line passenger stations in the world. The size and configuration of the existing bus staging areas at IDS and CPS limit the volume of buses that can operate through the tunnel. The dwell time required at stations to load and secure wheelchair passengers will be reduced with low-floor buses (57 seats verses 63 on the Breda buses today), but there will still be an expectation for drivers to wait for late boarding passengers and answer questions.

The regional nature of the current routes using the tunnel make them poor candidates for through routing if service is to be reliable. For example, if Route 194 from Federal Way via SeaTac were through routed with Route 41 to Northgate, the schedule reliability of both routes would be compromised. The through routing of buses would result in shorter routes being assigned to the tunnel. The inability to provide through routing limits bus capacity in the DSTT. Standees should be assumed on some, but not all trips, during the peak period. King County Metro’s experience shows that planning for 80 percent average seated load usually results in periodic overloads that require some passengers to stand. Regularly exceeding this load level results in large number of complaints and may dissuade riders.

Figure 3.6 shows how the one-way bus passenger capacity in the DSTT is calculated to be 5,700 passengers per hour. Of the 5,700 passengers, 4,275 or 75 percent are making outbound trips and 1,425 (25 percent) are making inbound trips.
### Figure 3.6
One-way Bus Passenger Capacity in the DSTT

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>No. of Seats</th>
<th>Load Factor</th>
<th>Passengers per Bus (Seats x Load Factor)</th>
<th>One-way Buses per Hour</th>
<th>Inbound/Outbound Directional Split</th>
<th>Total Passengers Per Hour in One Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outbound - 75% of one-way trips</td>
<td>57</td>
<td>0.80</td>
<td>45.6</td>
<td>125</td>
<td>0.75</td>
<td>4,275</td>
</tr>
<tr>
<td>Inbound - 25% of one-way trips</td>
<td>57</td>
<td>0.80</td>
<td>45.6</td>
<td>125</td>
<td>0.25</td>
<td>1,425</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5,700</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 3.5 DSTT Bus Operations

In the PM peak, buses provide four types of passenger service in the DSTT for both the northbound direction and southbound direction. Figure 3.7 illustrates the northbound and southbound bus and passenger movements. For example, northbound buses do the following: 1) operate inbound from the E-3 Busway and drop-off passengers, 2) operate inbound from I-90 and drop-off passengers, 3) operate outbound to I-5/SR520 after picking-up passenger at the tunnel stations. In addition, passengers can use any of the northbound buses to ride within the downtown free ride zone. Similar trips are made in the southbound direction as shown in Figure 3.7.

Currently 25 routes operate in the DSTT during the PM peak period. Trips on these routes either start in the transit tunnel then travel outbound to a destination in the region, or they end their trip in the tunnel. There are no through routed trips through the transit tunnel on the existing bus system. The result is the peak load points for buses are at the ends of the transit tunnel not at some point in the middle. The one-way bus capacity of 5,700 passengers in the peak hour is a function of the trip patterns shown in Figure 3.7. Of the 5,700 one-way passengers, 75 percent are estimated to be outbound and 25 percent inbound during the peak period. That means at the peak load point leaving the transit tunnel there would be 4,275 outbound passengers plus another 1,425 inbound passengers.
3.6 Estimated Passenger Capacity of the DSTT under Joint Operations

The estimated capacity of the DSTT under joint operations is shown in Figure 3.8. The bus capacity is based on the factors described in Section 3.4 and a maximum of 60 buses per hour in each direction. Under these assumptions the one-way bus capacity would be 2,760 passengers per hour or 5,520 total in both directions. The rail capacity is based on four car trains operating every 6 minutes (10 trains per hour) with 74 seated and 63 standing passengers. This results in rail capacity of 5,480 passengers per direction or a total of 10,960 passengers. When the rail capacity and the bus capacity are combined, the total DSTT one-way peak hour capacity for rail and bus under joint operations is 8,240 passengers or 16,260 passengers per hour in total.
3.7 Findings

- Downtown Seattle is the transportation hub of the Puget Sound region, where the DSTT serves as an important part of the transportation network. Currently, there are about 470 buses operating on the surface streets and 140 buses operating in the DSTT, for a total of 610 buses operating in downtown during the PM peak hour. For the two-year period the transit tunnel is closed for retrofit, just over 600 buses will be operating on the surface streets during the PM peak hour.

- Changes in downtown bus volumes are influenced by many variables including increases in employment, commercial and residential growth, the restructuring of bus service around new services such as commuter rail, and light rail, other changes to the system over time and the improved utilization of exiting service.

- Surface bus volumes are projected to be at or below the estimated 2002 bus volumes under the various interim north terminus options until at least 2016.

- With an interim north terminus at Convention Place and light rail service to South 200th Station in SeaTac, the 2020 daily ridership for joint operations is estimated at 50,000 total daily rail boardings, with 27,600 of these boardings taking place in the DSTT. Rail-only use of the DSTT with bus intercept terminals at Convention Place, International District and Lander results in 64,200 daily rail boardings, however, most of the increase in boardings are related to the forced bus to rail transfer at Convention Place, International District and Lander.

- The one-way, peak-hour capacity for light rail only in the transit tunnel is estimated at 16,440 passengers. The one-way, peak-hour capacity for buses only in the transit tunnel is estimated at 5,700 riders.

- Under joint operations, the one-way, peak-hour rail and bus passenger capacity in the tunnel is estimated at 8,240 passengers or 16,260 passengers in both directions.
4. VEHICLE ASSUMPTIONS

4.1 Light Rail Vehicles

Central Link light rail vehicles will be 90 to 95 feet in length, double articulated, with six axles. Approximately 70 percent of the vehicle will be low floor between the end trucks and articulated sections. The vehicle will have eight passenger doorways, four per side directly opposite from one another. The doors will be arranged for passenger boarding from the station platforms. An operator’s cab will be at each end of the vehicle to permit operation in both directions.

The vehicle is designed to operate as a single unit or in trains of up to four vehicles. In emergency situations, eight vehicles can be linked together. The normal maximum operating speed is 55 mph, with a maximum design speed of 65 mph. The anticipated service life of the vehicles is 30 years.

The vehicle will have a minimum of 74 passenger seats with a crush capacity of 314 passengers. Peak hour passenger capacity is calculated at 137 (74 seated plus 63 standees) with a seated to standee ratio of 1.85. The predominant seating arrangement is transverse, bi-directional, knee-to-back, and four abreast separated an aisle of at least 25 inches wide.

The vehicle will provide full accessibility for elderly and handicapped persons, including non-ambulatory persons in wheelchairs. The vehicle is equipped with a load leveling system to meet the wayside vertical gap requirement of the Americans with Disabilities Act (ADA). The load leveling system maintains a constant floor height to facilitate boarding from station platforms without the use of bridging devices or lifts. The vehicle will accommodate a wheelchair space at each of the four door vestibules, with two spaces located on each side. The vehicle will have provision for up to two bicycles and sets of luggage.

Based on a 1999 feasibility study of 1500 Vdc traction electrification system (TES) it was determined that the vehicles should operate at 1500 Vdc rather than the 700-750 Vdc operated by trolley buses. This results in a 20-25% premium for the vehicle propulsion systems to operate on a 1500 Vdc TES, which translates into a 3 percent premium for the overall vehicle cost. It should be noted that the premium for 1500 Vdc TES could be less and insignificant because of the order size and the competitiveness in the market place. The decision to operate a 1500 Vdc system resulted in substantial cost savings in the number of traction power substations required to operate the system.

The vehicle will receive traction power via a pantograph from the overhead contact system (OCS) with a nominal voltage of 1500 Vdc. The vehicle will be equipped with headlights, taillights, and marker lights that conform to the Federal Motor Vehicle Safety Standard No. 108 of the Federal Safety Standards.

There are no design variations required to the light rail vehicles to operate jointly with buses.

4.2 Buses

The level of joint operations that would be feasible and the quality and success of that operation will be highly dependent on the type of bus that would be operated in the transit tunnel. Current Metro fleet plans call for replacing the existing Breda dual mode coaches by 2004 when they have already exceeded their useful life of 12 years by 1-2 years. Further extending the use of the Breda’s beyond 2004 is estimated to cost over $7 million per year. Replacement coaches would be low floor coaches to allow level boarding/alighting from 14-inch high joint bus/rail platforms.
in the stations. Wheelchair lifts would not be required. Sixty-foot articulated coaches would be used to accommodate anticipated bus passenger loads on routes assigned to the DSTT. The new-technology DSTT bus fleet is assumed to include 15-20 percent spares over peak coach demand to ensure an adequate number of coaches for scheduled service. It may be possible to include guidance technology on these new buses that could maintain a bus-platform gap small enough to negate the need for wheelchair ramp deployment. Diesel fuel is the only petroleum fuel allowed in DSTT. Other fuels such as gas, compressed natural gas (CNG), liquid natural gas (LNG), etc. are not allowed by the Seattle Fire Department because of their flammability. This constraint limits options for bus propulsion through the tunnel to some sort of electric power or combination of electric power and “clean” diesel operation.

King County Metro and Sound Transit are currently investigating the possibility of purchasing a diesel-electric hybrid bus that can run in the DSTT. Local transit operators are considering the procurement of such a bus to meet the rising cost of diesel fuel as well as more rigid air quality standards. In a hybrid bus, the diesel engine is much smaller and produces a constant supply of power to a computer-controlled electric propulsion system. The electricity is stored in batteries, which are recharged with energy surpluses created when the vehicle is operating below peak power demand. King County Metro plans to have a prototype 40-foot hybrid diesel-electric bus in Seattle for testing in the fall of 2001.

Both King County Metro and Sound Transit are in the process of securing low-floor 60-foot articulated diesel-electric buses that will be tested in the Spring of 2002 under various conditions. The testing will determine whether these buses will be able to operate through the transit tunnel exclusively on stored electric power or if some other use of the diesel motor will be required. As a fall back, the joint operations analysis assumes the worst case, or that trolley poles will be required for use on the buses that operate in the tunnel. Chapter 7 of this report discusses the modifications to the overhead contract system that would be required if both light rail and trolley buses operate in the DSTT together.

4.3 Findings

Sound Transit’s decision to purchase and operate low-floor 1500 Vdc light rail vehicles would not change with joint operations. King County Metro’s decision to replace their current fleet of dual mode buses in 2004 would also remain unchanged. Metro is still exploring whether or not their replacement buses will have trolley poles to be able to operate through the transit tunnel under stored electric power, or minimal use of the diesel motor will be required.
5. STATION PLATFORMS

5.1 Light Rail Only

With light rail only operation, the existing platform curbs are planned to be reconstructed in approximately the same location and elevation. The height difference between the low floor trains and the existing platform height will be accommodated within the trackway reconstruction. From the top of the new rail to the top of platform will be 14 inches. The existing trackway and surface is currently 8 inches below the platform and will be lowered 6 inches to accommodate the low floor cars. Through the station areas, a low profile rail (Ri 52) will be embedded in elastomeric grout (Figure 5.1). A security fence would have been placed between the tracks to discourage pedestrians from crossing between platforms.

Figure 5.1
Rail Profile through Station Areas

![Rail Profile through Station Areas](image)

The edge of the existing platforms was to be demolished to allow for a 2-foot tactile warning edge, which is an ADA requirement. Textured paving at the two car boarding areas will be added to all platforms as part of Link Light Rail Systems Standards.

At Westlake Station, the proposal was to widen the platforms by 5 feet and 9 inches. This will allow for the addition of another exiting stairway in the future when the light rail system is operating at a higher ridership level.

5.2 Joint Operations

The buses used in the joint operation of the transit tunnel will also be low floor and ADA-compliant with the new 14-inch platform height. The buses will drive on an embedded trackway. Additional demolition will be required to create a bus bypass zone within the 14-foot space between the trackways. Under the rail only design, there would be a 6-inch high center island between the trackways in which a mountable curb will be installed. Sound Transit and King County Metro are working together to identify how often the emergency bypass lane might be used. If such use is high enough, it might warrant the lowering of the entire existing slab between the trackways. Both the cost and convenience to passengers would need to be considered. To accommodate the bus bypass zone, the proposed security fence under rail only operation would not be installed.
The bus bypass zone is possible at all stations with the exception of Westlake. Under the current design, there will be only 5 feet of space between the northbound and southbound tracks due to the widening of the platforms. The alternative for providing a bus bypass lane at Westlake Station during the period of joint operations is to postpone widening the platforms until the tunnel is converted to light rail only. This would be both expensive and impact rail operations. Trains would have to run on one track within the tunnel while one trackway is being demolished then rebuilt to accommodate a widen platform. This would severely impact train schedules at a time when the system is running at a much higher capacity.

Sound Transit and King County Metro will continue to work through the trade-offs on the issue of widening the platform now verses in the future. At a minimum, procedures would need to be developed to allow disabled buses to be cleared from the Westlake Station area under all circumstances.

5.3 Findings

With joint operations, the roadway between the station platforms would need to be constructed with a mountable curb to allow buses to pass under emergency conditions. The planned safety fence for rail only operation would be eliminated. If buses are allowed to bypass at the Westlake Station, the planned widening of the platforms would need to be delayed until joint operation ends and rail only operation begins. This would result in significant operational delays for the trains.
6. TRACKWAY/ROADWAY

6.1 Light Rail Only

The 1998 DSTT report presented an evaluation of the existing trackwork in the DSTT in relation to noise and vibration, wheel/rail interface and corrosion and stray current control issues. The most significant issue found was the lack of stray current control. Based on the 1998 report findings and subsequent engineering studies, it was determined the most cost-effective way to handle the track issue would be to replace all the trackwork with new electrically-isolated rails. Within the station areas, a low profile Ri 52 rail would be used, thus allowing the roadbed to be lowered and the platforms to remain at their current level.

With rail only operation, the new trackway within the tunnel bores would be direct fixation on plinths. The trackway would be set in troughs created by demolishing the existing trackway and surface (see Figure 6.1). The rail transitions to Ri 52 high-strength rail would be embedded in elastomeric grout at the tunnel portals, and remain embedded through the platform areas. Ri 52 rail embedded in elastomeric grout would also be used in the south staging area of the International District Station, where the rail transitions to 115 RE rail on plinths just south of Airport Way. The south staging area is where buses currently layover just south of the platform area at International District Station.

Figure 6.1
Trackway Set in Troughs
From Airport Way to Royal Brougham, 115 RE rail would be directly fixated on plinths. Direct fixated rail would be used for several reasons, primarily because it makes the installation and maintenance of the rail and signal system easier. Direct fixated rail also has fewer drainage problems. A maintenance road alongside the southbound trackway would be required due to the fact that direct fixated rail cannot be crossed by rubber tired vehicles. The maintenance road would be a reversible one-lane road to allow deliveries and maintenance personnel access to the south staging area at International District Station.

6.2 Joint Operations

Joint operations will require all road surfaces be driveable. To make a driveable surface for buses, the track section within the tunnel bore and the E3 busway from the International District Station staging area to Royal Brougham will need to be embedded. High-strength rail embedded in elastomeric grout will be required due to the added rail wear from the transit rubber tired vehicle (See Figure 6.2).

![Figure 6.2]

6.3 Findings

Joint operations would require that all the trackway in the station areas, tunnel, International District Station staging area and the E-3 Busway between Royal Brougham Way and the International District Station staging area be embedded.
7. OVERHEAD CONTACT SYSTEM/TRACTION POWER SUBSTATIONS

In the 1998 DSTT report, questions concerning the exact configuration of the Overhead Contact System (OCS) were left to further design work. Many details were left unanswered and many assumptions may not be valid at this time. Furthermore, a crucial decision was made subsequent to the release of that report, specifically that 1500 Vdc would power the light rail vehicles. This decision was made for a number of reasons, but cost was the main driver. When the 1500 Vdc decision was made, it was also assumed that the DSTT would be exclusively a rail facility. Until now, the impact of electric trolley buses (ETB’s) and light rail vehicles (LRV’s) operating at different voltages in the DSTT has not been analyzed formally from an engineering point of view. There are three major areas of concern associated with electrically powered vehicles in the DSTT. They are: 1) overhead contact systems, 2) traction power substations, and 3) vehicles.

7.1 Overhead Contact System (OCS)

If only rail vehicles are operated in the tunnel, the existing trolley overhead system would be modified to a single wire system compatible with the chosen vehicle. The existing negative wire could be left in place and used to increase the capacity of the positive circuit. New positive and negative feeder cables would need to be installed from the manholes to the connection points at the OCS and return rails.

Several assumptions are required to proceed with any analysis of joint operations.

1. The most practical approach is to assume that all trolley bus switches for passing are removed in passenger stations, the number of staging area tracks are reduced, and the deluge system is relocated to allow room at the top of the tunnel for light rail pantograph operation.

2. Non-metallic trolley poles are practical (Metro uses metal poles today, but is testing non-metallic poles).

3. Diesel operation of buses across the light rail tracks is a preferred option but not necessarily required.

The 1998 DSTT report recognized that electrical crossings of the light rail tracks at Convention Place would be a problem. Using two voltages would make that operation more complicated and could be a concern at other locations as well.

Since track crossings will be required under any likely joint use scenario and could be a fundamental design challenge, a method for mitigating this drawback is required initially. An examination of available hardware used by North American and European properties has shown it is possible to use specially-designed crossover switches but bus and rail operations are degraded to various degrees and maintenance is a continual problem. Keeping this in mind, Sound Transit in cooperation with King County Metro has developed a new crossover method that avoids these drawbacks. These new track-crossing solutions appear to be a practical and reasonable way to allow electrical operations of buses and trains in the DSTT. There would not be dead wire spots for either vehicle nor would there be any jumps or other elevation changes. This approach would work for any combination of supply voltages. Operations would be normal or nearly normal for both types of vehicle. King County Metro has observed that speeds of the trolley buses would be slow, but no slower than they are today when travelling through the existing overhead switches and hardware.
Figure 7.1 shows both a light rail vehicle and trolley bus in a typically tunnel section. The insulator stick at the top of the tunnel section holds both the negative and positive trolley bus wires. In the center of the insulator stick is the 1500 Vdc insulator for the light rail contact wire. The light rail vehicle insulator is lower than the two trolley bus wires that straddle the insulator. The light rail pantograph makes contact with this lower single insulator. As shown in Figure 7.1, the light rail vehicles are much larger than a trolley bus and fill much more of the tunnel bore with the pantograph closer to the top of the tunnel.

**Figure 7.1**  
Joint Use Arrangement in Typical Tunnel Section

Figure 7.2 shows how the merge would work with a northbound trolley bus merging with a northbound light rail train. The pantograph on a light rail vehicle is much wider than the area covered by the trolley bus wires, so the continuous light rail vehicle wire can be split apart but still achieve electrical continuity with the pantograph at a level below the trolley bus wires. The pantograph spans the wires, keeping in contact with a portion of the light rail vehicle wire at all times. This allows the trolley bus to merge onto the track area without using a mechanical switch as is done today where two sets of trolley wires merge.

Although this design is not really new, it is more constructable because of the shallow crossing angles and the ability to use the numerous support structures available in the staging areas.

However, even with this system, there is no way to eliminate instances where a trolley bus dewires and its poles come in contact with the 1500 Vdc light rail overhead. It will be necessary to accommodate this in the specifications of the trolley bus. Ways to account for this include the use of non-conducting poles, extra insulation around the equipment at the ends of the poles and protection from overvoltage in the circuits located within the bus.
Figure 7.3 shows how the switch would work when the trolley bus must cross two sets of light rail wires. Under the LPA alignment, this movement would occur under Pine Street east of Westlake Station where light rail trains would continue straight on Pine Street to reach First Hill/Capitol Hill and trolley buses would cross the light rail vehicle wires to the existing tunnel and Convention Place Station. The same principle as shown in Figure 7.2 would be used, but a more complicated insulator stick would be needed and the pantograph would have to span three sets of light rail wires connected from above.
King County Metro is working with Sound Transit to refine the trolley/light rail interface hardware. One option being considered is the addition of a continuous protective insulated guard that would be installed between the light rail wire insulator and the vehicle contact wire.
7.2 Traction Power Substations

The most likely scenario for joint operations is to design for 1500 Vdc LRV’s and 750 Vdc ETB’s. Several assumptions are required for this analysis. The existing Metro TPSS would be used to supply the 750 VDC system presently used. No additions would be required to the Metro traction power system other than control and revenue metering functions. Sound Transit would continue with plans to supply 26 KV power to light rail facilities. Existing facilities such as emergency power and station power supplies would continue to be available for joint use. Sound Transit would still build the Pine Street TPSS as planned and budgeted. Sound Transit would also retain station underground DC feeders for Metro ETB needs.

What would be different from present plans is that a new 1500 VDC substation would be needed at the International District Station, requiring new designs and separate funds. It is speculated that this TPSS could be located in the existing staging area. This unplanned, unbudgeted facility would be necessary since there is no available space in the existing International District TPSS for two DC switchgear lineups without major civil construction. As it is, fairly complicated construction would be required to build a new substation and route necessary conduits.

A second method to accomplish the joint operations of the DSTT is the common operation of both types of vehicles at 750 Vdc similar to the concept assumed in the 1998 DSTT report. This approach would be technically feasible but involve the following elements.

- **Overhead Contact System** - The existing contact wires could be reused if the existing positive wire is lowered 6 inches using special hardware that is available. Also, all crossovers at Convention Place Station would be similar to the proposed overlap design for different system voltages.

- **Power supplies** - The power supply for joint operation of the DSTT would require significant changes from the existing estimate for 1500 Vdc LRV operation with exclusive use of the DSTT. It is assumed that Convention Place and International District TPSS would be available for upgrade and joint use. The University Street TPSS would be unavailable for Metro street trolley use and need to be replaced.

7.3 Electric Vehicle Impacts

Several options have been examined which would allow both buses and light rail vehicles to operate electrically while avoiding an OCS crossover problem and minimizing traction power changes. These options include:

1. A dual-power LRV (runs on 750Vdc and 1500 Vdc) is possible but could add several percent to the price of vehicles. This technology is unproven. There would be space and weight penalties as well.

2. A 1500 Vdc trolley bus is possible but at this time there is no proven technology. There are no known trolleys or dual mode buses in service. Also, Metro’s options for operations would be severely limited.

3. A bus with grounded wheel return has been examined with the goal of eliminating the negative contact wire, and simplifying the OCS wiring. It is speculated that there would be significant mechanical tracking problems for the current return wheel. Probable arcing problems at the rail interface are also probable. This approach would require either a 1500 Vdc...
Vdc ETB or require returning to a universal 750 Vdc system. This would also be an unproven or proprietary technology.

4. An LRV with trolley poles has been considered. There would be additional costs, space requirements and weight penalties. There would also be operational difficulties during mode change and both ETB’s and LRV’s would be locked into a 750 VDC system. A special type of OCS crossing hardware is required for this type of approach.

5. Operating LRV and ETB at 750 Vdc is feasible and technically appropriate and would reduce the estimated cost of light rail vehicles by about 3 percent. However, as discussed above, estimated incremental cost to revise the traction electrification system would be significant.

6. LRV operations at 1500 Vdc and ETB operations at 750 Vdc is also feasible and technically appropriate and is baseline cost that assumed LRV’s operating at 1500 Vdc.

7.4 Findings

The impact of electric buses and light rail vehicles operating at different voltages in the DSTT has now been analyzed and found to be feasible. A solution for buses with poles crossing the light rail OCS has been developed, but additional design and testing will be required.
8. SIGNAL SYSTEM

The signal system controls the operation of vehicles through the tunnel, signaling whether a vehicle may proceed or need to stop and providing information to vehicle operators to maintain safe separation.

8.1 Rail Only

The existing bus signal system would not be used for operations with light rail trains only. A new cab signal track circuit system consistent with rail operation would be installed. In a cab signal system, the signal information is transmitted through the rails and is displayed to the operator inside the train cab or can be acted on automatically by the train’s control systems. It would be designed to meet the expected needs of a fully expanded Link light rail system at the projected maximum capacity. This means the system would be designed to meet headway requirements estimated for the full build-out of the Sound Move long-range vision. Modification of the existing rails in the tunnel to provide the necessary isolation for corrosion reduction could also provide the necessary rail to rail isolation for a track circuit system.

8.2 Joint Operations

Bus operations through the transit tunnel currently are controlled by the tunnel traffic signal system. Under this system the tunnel is divided into traffic control blocks, whereby the signal system limits the number of buses that can be within any given block at one time. The bus operator is responsible for viewing and obeying the signals and for maintaining safe separation between buses. Operational safety is provided by the bus driver who is responsible for operating his or her vehicle such that it can be stopped short of any obstruction in the tunnel, including another bus.

Neither the traditional rail track circuit signal system with cab signals or the existing bus signal system is adequate for joint use signal system needs to control the merge point of the two transportation modes and to maintain separation between the light rail vehicle and the bus ahead. This is because the detection methods used for the rail (track circuits) are not usable for bus detection and the current bus detection and control methods are not adequate for rail operation. A highly dependable detection and logic system is important because:

- The warning lights to hold the buses at the merge points need to operate in a reliable and fail-safe manner.
- The signals used by the light rail operator must perform reliably and in a failsafe manner so that a following light rail operator can proceed to the next signal with confidence that no bus will be present. A bus stopped where the light rail operator would not expect one could create a potential hazard. A light rail operator should not attempt to follow a leading light rail vehicle as close as a bus since the light rail vehicle will have more momentum than a bus, and a longer stopping distance.

Under joint operations a hybrid signal system would provide the greatest safety. The significant points are as follows:

- Light rail vehicles would continue to be detected by track circuits since this method is both failsafe and the most reliable method of train detection.
Bus detection would be via an on-board radio tag to a wayside receiver that can only detect the onboard tag when located at the specified check-in and / or checkout location. The receiver would forward to the vital check-in / checkout logic both the bus serial number and the route number for use in the logic. To assure the bus radio tag is functioning, the system would display the bus number prior to the first bus control signal for each direction. A bus operator would need to report any failure to see his number before proceeding.

A light rail “Go” signal (vertical white bar) would mean that the track is clear of both light rail vehicles and buses and the operator is authorized to proceed at the speed limits to the next signal. If the proceeding buses have not cleared the next block zone, the light rail vehicle would be held at this signal until it becomes clear. Typically, the signals would be located at the leaving end of stations and at stopping distance from entering the next station platform.

At the points where buses merge onto (or cross) the light rail tracks, railroad type flashers would be used to signal the bus operator to hold for an approaching light rail train. This type of signal with its flashing 12-inch lenses and multiple element LED lamps will have far less chance of either becoming a dark signal through bulb failure or of being overlooked by the driver. The warning time for holding the buses should be adequate for safety and to maintain the separation for the following light rail vehicle without increasing normal light rail running times.

Bus signals would continue to have the present meanings and locations. The proceed bus signal (green) to enter a tunnel segment from a platform means that a bus driver is entering the tunnel and should be prepared to brake. The signal becomes red when the number of vehicles equals the quota allowed in that portion of the tunnel or if the light rail vehicle has not vacated the block ahead. Intermediate signals and signals at the entrance to platforms can continue to function in the present format while driven by the new logic. If additional separation is required for buses, or the signals need to automate the dispatch functions at the staging area, then the detection methods and logic are flexible enough to support it.

The control of light rail and bus signals will be from a vital processor of the same type as used for the light rail interlocking signal controls. Bus check-in / checkout logic will use the serial number of the bus to:

- Protect against a false detection.
- Allow the system to work even if buses should pass each other in a station.
- Assist in quickly identifying the bus that was not able to electronically checkout of an area so that its true location can be quickly confirmed and normal operations can be resumed.

A joint operations control center (OCC) should be considered. The SCADA system will have a display screen(s) that tracks each light rail vehicle and bus through the transit tunnel by its number. It will show the status of the signals, the vital processor health, and alarm any anomalies (such as detecting buses checking out of an area in different sequence than they entered).

A repeater screen at the bus supervisor’s booth at International District Station (which would also have the capability to act as a back up OCC) will have the same display capability as the OCC. A possible repeater screen at another location will be considered if necessary to support joint supervision functions.
In the event that a bus radio tag should fail to read, the OCC operator will have the capability to electronically advance that bus location to his confirmed actual location. This will allow normal operations to proceed with a minimum delay.

Most of the modifications that were described under the rail-only scenario above would still need to be made for joint bus/rail operations. These modifications include the installation of track circuit connections and switch machines at crossover locations. Although the track circuits would not need to apply cab signal speed commands for most of the DSTT, they still would be essential to detect the block signaling, train tracking, and traffic direction electronic locking, and to prevent the switch points from moving while a train is passing over them.

In addition to the hardware needs to operate the signal system, there will be new staffing requirements. Before staffing levels can be determined, a detailed joint operating plan must be developed with King County Metro explaining the responsibilities staging and managing of operators.

**8.3 Findings**

With joint operations, a new hybrid signal system would be required. Light rail detection would be through track circuits and cab signals, and bus detection would be via an on-board radio tag that follows a block check-in / checkout logic for both the bus serial number and the route number. This system would provide the greatest safety factor but it would not be fail-safe and the responsibility of operating the vehicle remains with the operators.
9. COMMUNICATIONS

The issue of communication systems and how they are addressed is tied to the ownership and operation of the transit tunnel. The subject of how communications will be addressed under joint operations will be part of the upcoming DSTT negotiations between King County and Sound Transit

9.1 Joint Operations

The present DSTT has several communications systems to perform various functions related to operations, security, and safety. Many of these systems would need to be replaced or modified to operate a rail only or joint operations system. These systems include:

- **Operations Control center** – Monitoring of the fire and life safety systems within the transit tunnel and the control of all vehicle movement under joint rail/bus operations would need to be coordinated at the operations control center.

- **Supervisory control and data acquisition system (SCADA)** – This system monitors and controls the functions of various systems within the transit tunnel. The existing Metro SCADA equipment would be replaced with new equipment as part of the complete Link SCADA information network with standard interfaces to subsystems such as signals, traction power, and emergency panels. Cable and other equipment connecting the existing system to the station facilities equipment, such as ventilation, fire alarm, escalator, and elevators would be retained and modified where possible. Under joint operations, the SCADA system would be equipped with the ability to monitor and control the joint signal system, which would provide the capability to track light rail vehicle and bus locations in the DSTT.

- **Station public address system** – The existing system is not ADA-compliant, because there is no text display system for the hearing impaired. The station public address system will need to be brought into compliance with ADA requirements by adding variable message signs to provide a text display of public announcements. Automatic volume control will also be added to allow the system to respond to noise from trains entering the station areas.

- **Platform and mezzanine security surveillance cameras (CCTV)** – Updates to the cameras would be the same for joint use as for the rail only operation except that eight additional cameras would be installed to allow faster identification of signal or operational problems and enable normal service to be restored more quickly. The primary destination of the video transmissions would be the OCC and the backup control center at IDS.

- **Tunnel radio system** – The existing bus radio system equipment would remain under joint operations. In addition, radio communication would be added between the buses and the light rail system at the OCC. Options for providing this coverage will be further defined during final design. Methods and costs of supplying this radio coverage vary depending on the normal and emergency operational plans and agreements between Sound Transit and Metro regarding the roles and responsibilities of each organization.

- **Emergency telephone system** – Emergency telephones are located on the mezzanine and platforms for the use of passengers requiring assistance.

- **Metro information phones** – These phones would be retained and their functions unchanged. Some phones may be moved.
- **Maintenance telephone system** – The maintenance system based on phone jacks would be deleted. At locations where a phone is necessary for rail operation, the phone jack could be replaced with a PABX phone. Sound Transit rather than King County Metro would own PABX.

- **Emergency interstation communications system** – The emergency interstation system provides voice communications between various strategic emergency locations. This system is intended for use by the fire department and operating personnel during emergency situations. The phone jack system would be integrated into a larger emergency phone system.

- **Passenger assistance phone system** – This system does not independently exist in the present transit tunnel configuration but is part of the systemwide light rail plan. A system will be created using some of the existing emergency phone locations plus additional phones to provide a direct intercom connection from the passenger needing assistance to the OCC.

Providing the radio coverage for the bus system and rail system is the largest potential communications issue with joint use.

### 9.2 Findings

The existing communication system in the DSTT has been installed to perform various functions related to operations and fire/life/safety. Before joint operations can be implemented, a number of changes and /or upgrades will be required and integrated into a new Operation Control Center.
10. FIRE/LIFE/SAFETY ISSUES

Sound Transit in cooperation with King County Metro, the Seattle Fire Department, and the Seattle Department of Design, Construction, and Land Use have been working together to identify fire/life/safety issues that need be resolved to safely accommodate joint bus/rail operations. Bus-only operation in the DSTT will continue to meet all fire/life/safety requirements established by the Seattle Fire Department. However, the introduction of light rail vehicles in the transit tunnel will significantly change the operation of the tunnel and require that fire/life/safety standards are met for both light rail and buses. The safety issues associated with joint bus/rail operation in the DSTT fall into five major categories, which are summarized below.

10.1 Collision prevention

Collision prevention involves establishing control mechanisms to avoid accidents between trains and buses. As part of collision prevention, an operating plan for joint bus/rail operations has been developed in conjunction with King County Metro (see Chapter 2). This operating plan provides controls to maintain safe separation between trains and buses, and ensure that trains and buses do not share the same station platform or the same tunnel segment. Additional traffic signaling controls to electronically communicate to buses and trains when they can safely proceed into a given section of the tunnel will need to be installed (see Chapter 8 for complete description of the signal system). The cost of these signaling controls has been included in the DSTT joint operations cost estimate.

10.2 Ventilation

With operation of light rail trains in the DSTT, the fire and smoke ventilation system must be brought into compliance with the latest National Fire Protection Association (NFPA) requirements adopted by the Seattle Fire Department. Ventilation analysis of different fire scenarios with joint bus/rail operations is underway and will be complete by the end of August. Based on preliminary information, all ventilation fans and controls may need to be replaced. In addition, other modifications may be needed.

Simulations of emergency scenarios for station fires will be modeled using a Computational Fluid Dynamics (CFD) analysis. This work will be performed using the Pioneer Square and Westlake stations. The results of the Pioneer Square Station will be applied to the University Street Station. The CFD work for the two stations is in progress.

10.3 Evacuation

Emergency evacuation facilities and procedures must meet applicable codes enforced by DCLU and the Seattle Fire Department. Calculations for safely exiting patrons have been completed and reviewed by the Seattle Fire Department and DCLU. No changes of evacuation facilities are anticipated at this time.

10.4 Fire suppression

An inventory of the existing fire suppression mechanisms has been conducted. The current recommended system calls for a new deluge system consisting of values and sprinklers on both sides of the tunnel. This is necessary to deliver a spray pattern to all sides of the light rail vehicle. Following completion of the hazards analysis, it can be determined whether installation of foam fire suppression is needed as an enhancement to the existing system.
10.5 Hazards Analysis

A hazards analysis of the facilities, equipment, and operating plan to address the safety issues listed above will be complete by the end of August. Link staff is coordinating with King County Metro and the City of Seattle to obtain concurrence on the resolution of these fire/life/safety issues. If the hazard analysis indicates that the probability of fire or collision is very low, then some of these controlling measures may not be needed.

Based on discussions with the Seattle Fire Department about the preliminary ventilation and hazards analyses, it appears the Seattle Fire Department will concur with the final recommendations once they have an opportunity to review and comment on the final reports from Sound Transit’s third party consultants.

10.6 Findings

A signal system has been developed and operating rules established that would maintain vehicle separation between trains and buses in the transit tunnel. A ventilation analysis is currently underway to determine any required changes to the existing ventilation system. A modified deluge system has been design, but final design will be dependent upon the findings from the hazard analysis.
## 11. COST ESTIMATES

The design for the retrofit of the DSTT for rail only has been advanced to a 60 percent level of design. Based on this design, the cost to retrofit of the tunnel for rail only operation is estimated at $25 million in YOE. The cost to retrofit the tunnel for joint operations is based on the cost items that would change from the rail only cost items. Figure 11.1 presents a summary of the estimated additional capital costs required to convert the DSTT to joint operations. These cost estimates are based on the D500 design package for the DSTT and only include the area just east of Westlake Station to Royal Brougham Way. The Convention Place northern terminus costs are included elsewhere. All costs are expressed in year of expenditure (YOE) dollars. The costs include a contingency as well as a factor to account for administration, design and construction management costs.

### Figure 11.1
**Additional Cost of Joint Operations in the DSTT**
*(millions in YOE dollars)*

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Description</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trackwork/roadway</td>
<td>Replace 115 lbs. direction fixation track in tunnel sections with embedded 52 lbs. Girder rail</td>
<td>$0.3</td>
</tr>
<tr>
<td>Overhead contact system/traction power substations</td>
<td>Reflects a mixed traction power system of (750/1500 volts).</td>
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<tr>
<td>Communication system</td>
<td>Communications system for joint operations</td>
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</tr>
<tr>
<td>Signal systems</td>
<td>Signaling for clearance and crossing issues with joint operations</td>
<td>$3.0</td>
</tr>
<tr>
<td>Emergency ventilation system</td>
<td>Replace existing fans and install new fans (12 total) at stations and possibly add jet fans to the portals at Pine Street and IDS.</td>
<td>$22.6</td>
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<tr>
<td>Retrofit deludge system in tunnel sections</td>
<td>Replace existing distribution lines to address vehicle clearance conflicts and incorporate a foam system</td>
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<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>$43.0</strong></td>
</tr>
</tbody>
</table>

### 11.1 Findings

The retrofit of the DSTT for rail use only is estimated at $25 million (YOE). The additional cost to retrofit the tunnel for joint operations is estimated at $43 million and includes items such as trackwork, overhead contact system, communications and signal systems, emergency ventilation system and the fire suppression system.
12. REPORT FINDINGS

The report findings by individual section are summarized and listed below:

Introduction

- The DSTT was opened in 1990 to enable bus transit service to operate through downtown Seattle free of surface street congestion. Today 25 routes are assigned to the transit tunnel, providing 1,200 weekday bus trips.

- Key findings of the 1998 DSTT report were the cost of tunnel modifications and need to purchase a new dual mode bus fleet, coupled with the potential for only operating 30 buses in each direction for 2-10 years. These findings led to the conclusion that joint operations while feasible, was not desirable.

- In February 1999, based largely on the findings of the 1998 report, the Sound Transit Board and the Seattle City Council made a preliminary recommendation that the existing downtown transit tunnel be converted to light rail only operation.

- In November 1999, after completion of the Final EIS, the Sound Transit Board selected the Locally Preferred Alternative (LPA) and reconfirmed that the DSTT be converted to exclusive rail use and that surface improvements be provided on downtown Seattle streets to accommodate the buses displaced to the surface. Prior to the Board action, the Seattle City Council made the same recommendation.

Operations analysis

- Currently, bus service in the transit tunnel consists of 25 routes, operating over 1,200 weekday bus trips. During the afternoon peak hour (4:30-5:30 p.m.), about 70 bus trips operate in each direction through the transit tunnel. In fall 2000, these routes together carried almost 55,000 weekday daily riders with about 23,700 daily boardings in the tunnel.

- The current adopted light rail route would run from NE 45th Station in the University District to South 200th Station in SeaTac, and extend to Northgate subject to available funding. However, the Sound Transit Board is currently considering identifying an interim north terminus at either the Royal Brougham Station or the Convention Place Station to begin construction south first.

- Using a computer simulation model to evaluate the LPA route and the Convention Place terminus options it has been estimated that between 50 and 60 buses in each direction could travel through the DSTT in joint operations during the PM peak hour with train headways of 6 to 7.5 minutes.

Downtown Seattle Transit Service

- Downtown Seattle is the transportation hub of the Puget Sound region. Currently, there are about 470 buses operating on the surface streets and 140 buses operating in the DTTT, for a total of 610 buses operating in downtown during the PM peak hour. For the two-year period the tunnel is closed for retrofit, just over 600 buses will be operating on the surface streets during the PM peak hour.

- Changes in downtown bus volumes are influenced by many variables including increases in employment, commercial and residential growth, the restructuring of bus service around new services such as commuter rail, and light rail, other changes to the system over time and the improved utilization of exiting service.
Downtown surface streets will not be clogged with increased bus volumes. Under joint operations, bus volumes on downtown surface streets are projected to remain at or below the estimated 2002 surface bus volumes until at least 2016 when rail might be extended past Northgate or to the Eastside.

With an interim north terminus at Convention Place and service to South 200th Station in SeaTac, the 2020 daily ridership for joint operations is estimated at 50,000 total daily rail boardings, with 27,600 of these boardings taking place in the DSTT. Rail-only use of the DSTT with bus intercept terminals at Convention Place, International District and Lander results in 64,200 daily rail boardings, however, most of the increase in boardings are related to the forced bus to rail transfer at Convention Place, International District and Lander.

The one-way, peak-hour capacity for light rail only in the transit tunnel is estimated at 16,440 passengers per hour. The one-way, peak-hour capacity for buses only in the transit tunnel is estimated at 5,700.

Under joint operations, the one-way, peak-hour rail and bus passenger capacity in the tunnel is estimated at 8,240 passengers or 16,260 passengers in both directions.

**Vehicle assumptions (light rail and bus)**
- Sound Transit’s decision to purchase and operate low-floor 1500 Vdc light rail vehicles would not change with joint operations. King County Metro’s decision to replace their current fleet of dual mode buses in 2004 would also remain unchanged. Metro is still exploring whether or not their replacement buses will have trolley poles to be able to operate through the transit tunnel under stored electric power, or minimal use of the diesel motor will be required.

**Station platforms**
- With joint operations, the roadway between the station platforms would need to be constructed with a mountable curb to allow buses to pass under emergency conditions. The planned safety fence for rail only operation would be eliminated. If buses are allowed to bypass at the Westlake Station, the planned widening of the platforms would need to be delayed until joint operation ends and rail only operation begins. This would result in significant operational delays for the trains.

**Trackwork/roadway**
- Joint operations would require that all the trackway in the station areas, tunnel, International District staging area and the E-3 Busway between Royal Brougham Way and the International District staging area be embedded.

**Overhead contact system/Traction power substations**
- The impact of electric buses and light rail vehicles operating at different voltages in the DSTT has now been analyzed and found to be feasible. A solution for buses with poles crossing the light rail OCS has been developed, but additional design and testing will be required.

**Signal systems**
- With joint operations, a new hybrid signal system would be required. Light rail detection would be through track circuits and cab signals, and bus detection would be via an on-board radio tag that follows a block check-in / checkout logic for both the bus serial number and the
route number. This system would provide the greatest safety factor but it would not be fail-safe and the responsibility of operating the vehicle remains with the operators.

**Communication system**

- The existing communication system in the DSTT has been installed to perform various functions related to operations and fire/life/safety. Before joint operations can be implemented, a number of changes and/or upgrades will be required and integrated into a new Operation Control Center.

**Fire/life/safety issues**

- A signal system has been developed and operating rules established that would maintain vehicle separation between trains and buses in the transit tunnel. A ventilation analysis is currently underway to determine any required changes to the existing ventilation system. A modified deluge system has been designed, but final design will be dependent upon the findings from the hazard analysis.

**Costs**

- The retrofit of the DSTT for rail use only is estimated at $25 million (YOE). The additional cost to retrofit the tunnel for joint operations is estimated at $43 million and covers such items as trackwork, overhead contact system (for both rail and bus), communications and signal systems, emergency ventilation system and the fire suppression system.